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PURIFICATION OF LABORATORY CHEMICALS
FIFTH EDITION

Wilfred L.F. Armarego • Christina L.L. Chai
PURIFICATION
OF
LABORATORY CHEMICALS

Fifth Edition
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Preface to the Fifth Edition

THE DEMAND for Purification of Laboratory Chemicals has not abated since the publication of the fourth edition as evidenced by the number of printings and the sales. The request by the Editor for a fifth edition offered an opportunity to increase the usefulness of this book for laboratory purposes. It is with deep regret that mention should be made that Dr Douglas D. Perrin had passed away soon after the fourth edition was published. His input in the first three editions was considerable and his presence has been greatly missed. A fresh, new and young outlook was required in order to increase the utility of this book and it is with great pleasure that Dr Christina L.L. Chai, a Reader in Chemistry and leader of a research group in organic and bio-organic chemistry, has agreed to coauthor this edition. The new features of the fifth edition have been detailed below.

Chapters 1 and 2 have been reorganised and updated in line with recent developments. A new chapter on the 'Future of Purification' has been added. It outlines developments in syntheses on solid supports, combinatorial chemistry as well as the use of ionic liquids for chemical reactions and reactions in fluororous media. These technologies are becoming increasingly useful and popular so much so that many future commercially available substances will most probably be prepared using these procedures. Consequently, a knowledge of their basic principles will be helpful in many purification methods of the future.

Chapters 4, 5 and 6 form the bulk of the book. The number of entries has been increased to include the purification of many recent commercially available reagents that have become more and more popular in the syntheses of organic, inorganic and bio-organic compounds. Several purification procedures for commonly used liquids, e.g. solvents, had been entered with excessive thoroughness, but in many cases the laboratory worker only requires a simple, rapid but effective purification procedure for immediate use. In such cases a Rapid purification procedure has been inserted at the end of the respective entry, and should be satisfactory for most purposes. With the increased use of solid phase synthesis, even for small molecules, and the use of reagents on solid support (e.g. on polystyrene) for reactions in liquid media, compounds on solid support have become increasingly commercially available. These have been inserted at the end of the respective entry and have been listed in the General Index together with the above rapid purification entries.

A large number of substances are ionisable in aqueous solutions and a knowledge of their ionisation constants, stated as pK (pKa) values, can be of importance not only in their purification but also in their reactivity. Literature values of the pKs have been inserted for ionisable substances, and where values could not be found they were estimated (pK\text{est}). The estimates are usually so close to the true values as not to affect the purification process or the reactivity seriously. The book will thus be a good compilation of pK values for ionisable substances.

Almost all the entries in Chapters 4, 5 and 6 have CAS (Chemical Abstract Service) Registry Numbers to identify them, and these have been entered for each substance. Unlike chemical names which may have more than one synonymous name, there is only one CAS Registry Number for each substance (with only a few exceptions, e.g. where a substance may have another number before purification, or before determination of absolute configuration). To simplify the method for locating the purification of a substance, a CAS Registry Number Index with the respective page numbers has been included after the General Index at the end of the book. This will also provide the reader with a rapid way to see if the purification of a particular one.
substance has been reported in the book. The brief General Index includes page references to procedures and equipment, page references to abbreviations of compounds, e.g. TRIS, as well as the names of substances for which a Registry Number was not found.

Website references for distributors of substances or/and of equipment have been included in the text. However, since these may be changed in the future we must rely on the suppliers to inform users of their change in website references.

We wish to thank readers who have provided advice, constructive criticism and new information for inclusion in this book. We should be grateful to our readers for any further comments, suggestions, amendments and criticisms which could, perhaps, be inserted in a second printing of this edition. In particular, we thank Professor Ken-chi Sugiura (Graduate School of Science, Tokyo Metropolitan University, Japan) who has provided us with information on the purification of several organic compounds from his own experiences, and Joe Papa BS MS (EXAXOL in Clearwater, Florida, USA) who has provided us not only with his experiences in the purification of many inorganic substances in this book, but also gave us his analytical results on the amounts of other metal impurities at various stages of purification of several salts. We thank them graciously for permission to include their reports in this work. We express our gratitude to Dr William B. Cowden for his generous advice on computer hardware and software over many years and for providing an Apple LaserWriter (16/600PS) which we used to produce the master copy of this book. We also extend our sincere thanks to Dr Bart Eschler for advice on computer hardware and software and for assistance in setting up the computers (iMac and eMac) used to produce this book.

We thank Dr Pauline M. Armarego for assistance in the painstaking task of entering data into respective files, for many hours of proofreading, correcting typographical errors and checking CAS Registry Numbers against their respective entries.

One of us (W.L.F.A) owes a debt of gratitude to Dr Desmond (Des) J. Brown of the Research School of Chemistry, ANU, for unfailing support and advice over several decades and for providing data that was difficult to acquire not only for this edition but also for the previous four editions of this book.

One of us (C.L.L.C) would specially like to thank her many research students (past and present) for their unwavering support, friendship and loyalty, which enabled her to achieve what she now has. She wishes also to thank her family for their love, and would particularly like to dedicate her contribution towards this book to the memory of her brother Andrew who had said that he should have been a scientist.

We thank Mrs Joan Smith, librarian of the Research School of Chemistry, ANU, for her generous help in many library matters which have made the tedious task of checking references more enduring.

W.L.F. Armarego & C.L.L. Chai
November 2002

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Preface to the First Edition

WE BELIEVE that a need exists for a book to help the chemist or biochemist who wishes to purify the reagents she or he uses. This need is emphasised by the previous lack of any satisfactory central source of references dealing with individual substances. Such a lack must undoubtedly have been a great deterrent to many busy research workers who have been left to decide whether to purify at all, to improvise possible methods, or to take a chance on finding, somewhere in the chemical literature, methods used by some previous investigators.

Although commercially available laboratory chemicals are usually satisfactory, as supplied, for most purposes in scientific and technological work, it is also true that for many applications further purification is essential.

With this thought in mind, the present volume sets out, firstly, to tabulate methods, taken from the literature, for purifying some thousands of individual commercially available chemicals. To help in applying this information, two chapters describe the more common processes currently used for purification in chemical laboratories and give fuller details of new methods which appear likely to find increasing application for the same purpose. Finally, for dealing with substances not separately listed, a chapter is included setting out the usual methods for purifying specific classes of compounds.

To keep this book to a convenient size, and bearing in mind that its most likely users will be laboratory-trained, we have omitted manipulative details with which they can be assumed to be familiar, and also detailed theoretical discussion. Both are readily available elsewhere, for example in Vogel's very useful book *Practical Organic Chemistry* (Longmans, London, 3rd ed., 1956), or Fieser's *Experiments in Organic Chemistry* (Heath, Boston, 3rd ed, 1957).

For the same reason, only limited mention is made of the kinds of impurities likely to be present, and of the tests for detecting them. In many cases, this information can be obtained readily from existing monographs.

By its nature, the present treatment is not exhaustive, nor do we claim that any of the methods taken from the literature are the best possible. Nevertheless, we feel that the information contained in this book is likely to be helpful to a wide range of laboratory workers, including physical and inorganic chemists, research students, biochemists, and biologists. We hope that it will also be of use, although perhaps to only a limited extent, to experienced organic chemists.

We are grateful to Professor A. Albert and Dr D.J. Brown for helpful comments on the manuscript.

D.D.P., W.L.F.A. & D.R.P.
1966

Preface to the Second Edition

SINCE the publication of the first edition of this book there have been major advances in purification procedures. Sensitive methods have been developed for the detection and elimination of progressively lower levels of impurities. Increasingly stringent requirements for reagent purity have gone hand-in-hand with developments in semiconductor technology, in the preparation of special alloys and in the isolation of highly biologically active substances. The need to eliminate trace impurities at the micro- and nanogram levels has placed greater emphasis on ultrapurification technique. To meet these demands the range of purities of laboratory chemicals has become correspondingly extended. Purification of individual chemicals thus depends more and more critically on the answers to two questions - Purification from what, and to what permissible level of contamination. Where these questions can be specifically answered, suitable methods of purification can usually be devised.

Several periodicals devoted to ultrapurification and separations have been started. These include "Progress in Separation and Purification" Ed. (vol. 1) E.S. Perry, Wiley-Interscience, New York, vols. 1-4, 1968-1971, and *Separation and Purification Methods* Ed. E.S.Perry and C.J. van Oss. Marcel Dekker, New York, vol. 1-, 1973-. Nevertheless, there still remains a broad area in which a general improvement in the level of purity of many compounds can be achieved by applying more or less conventional procedures. The need for a convenient source of information on methods of purifying available laboratory chemicals was indicated by the continuing demand for copies of this book even though it had been out of print for several years.

We have sought to revise and update this volume, deleting sections that have become more familiar or less important, and incorporating more topical material. The number of compounds in Chapters 3 and 4 have been increased appreciably. Also, further details in purification and physical constants are given for many compounds that were listed in the first edition.

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We take this opportunity to thank users of the first edition who pointed out errors and omissions, or otherwise suggested improvements or additional material that should be included. We are indebted to Mrs S. Schenk who emerged from retirement to type this manuscript.

D.D.P., W.L.F.A. & D.R.P.
1980

Preface to the Third Edition

THE CONTINUING demand for this monograph and the publisher’s request that we prepare a new edition, are an indication that Purification of Laboratory Chemicals fills a gap in many chemists’ reference libraries and laboratory shelves. The present volume is an updated edition which contains significantly more detail than the previous editions, as well as an increase in the number of individual entries and a new chapter.

Additions have been made to Chapters 1 and 2 in order to include more recent developments in techniques (e.g. Schlenk-type, cf. p. 10), and chromatographic methods and materials. Chapter 3 still remains the core of the book, and lists in alphabetical order relevant information on ca 4000 organic compounds. Chapter 4 gives a smaller listing of ca 750 inorganic and metal-organic substances, and makes a total increase of ca 13% of individual entries in these two chapters. Some additions have also been made to Chapter 5.

We are currently witnessing a major development in the use of physical methods for purifying large molecules and macromolecules, especially of biological origin. Considerable developments in molecular biology are apparent in techniques for the isolation and purification of key biochemicals and substances of high molecular weight. In many cases something approaching homogeneity has been achieved, as evidenced by electrophoresis, immunological and other independent criteria. We have consequently included a new section, Chapter 6, where we list upwards of 100 biological substances to illustrate their current methods of purification. In this chapter the details have been kept to a minimum, but the relevant references have been included.

The lists of individual entries in Chapters 3 and 4 range in length from single line entries to ca one page or more for solvents such as acetonitrile, benzene, ethanol and methanol. Some entries include information such as likely contaminants and storage conditions. More data referring to physical properties have been inserted for most entries [i.e. melting and boiling points, refractive indexes, densities, specific optical rotations (where applicable) and UV absorption data]. Inclusion of molecular weights should be useful when deciding on the quantities of reagents needed to carry out relevant synthetic reactions, or preparing analytical solutions. The Chemical Abstracts registry numbers have also been inserted for almost all entries, and should assist in the precise identification of the substances.

In the past ten years laboratory workers have become increasingly conscious of safety in the laboratory environment. We have therefore in three places in Chapter 1 (pp. 3 and 33, and bibliography p. 52) stressed more strongly the importance of safety in the laboratory. Also, where possible, in Chapters 3 and 4 we draw attention to the dangers involved with the manipulation of some hazardous substances.

The world wide facilities for retrieving chemical information provided by the Chemical Abstract Service (CAS on-line) have made it a relatively easy matter to obtain CAS registry numbers of substances, and most of the numbers in this monograph were obtained via CAS on-line. We should point out that two other available useful files are CSCHCM and CSCORP which provide, respectively, information on chemicals (and chemical products) and addresses and telephone numbers of the main branch offices of chemical suppliers.

The present edition has been produced on an IBM PC and a Laser Jet printer using the Microsoft Word (4.0) word-processing program with a set stylesheet. This has allowed the use of a variety of fonts and font sizes which has made the presentation more attractive than in the previous edition. Also, by altering the format and increasing slightly the sizes of the pages, the length of the monograph has been reduced from 568 to 391 pages. The reduction in the number of pages has been achieved in spite of the increase of ca 15% of total text.

We extend our gratitude to the readers whose suggestions have helped to improve the monograph, and to those who have told us of their experiences with the purifications stated in the previous editions, and in particular with the hazards that they have encountered. We are deeply indebted to Dr M.D. Fenn for the several hours that he has spent on the terminal to provide us with a large number of CAS registry numbers.

This monograph could not have been produced without the expert assistance of Mr David Clarke who has spent many hours to load the necessary fonts in the computer, and for advising one of the authors (W.L.F.A.) on how to use them together with the idiosyncrasies of Microsoft Word.

D.D.P. & W.L.F.A.
1988
Preface to the Fourth Edition

THE AIMS of the first three editions, to provide purification procedures of commercially available chemicals and biochemicals from published literature data, are continued in this fourth edition. Since the third edition in 1988 the number of new chemicals and biochemicals which have been added to most chemical and biochemical catalogues have increased enormously. Accordingly there is a need to increase the number of entries with more recent useful reagents and chemical and biochemical intermediates. With this in mind, together with the need to reorganize and update general purification procedures, particularly in the area of biological macromolecules, as well as the time lapse since the previous publication, this fourth edition of Purification of Laboratory Chemicals has been produced. Chapter 1 has been reorganised with some updating, and by using a smaller font it was kept to a reasonable number of pages. Chapters 2 and 5 were similarly altered and have been combined into one chapter. Eight hundred and three hundred and fifty entries have been added to Chapters 3 (25% increase) and 4 (44% increase) respectively, and four hundred entries (310% increase) were added to Chapter 5 (Chapter 6 in the Third Edition), making a total of 5700 entries; all resulting in an increase from 391 to 529 pages, i.e. by ca 35%.

Many references to the original literature have been included remembering that some of the best references happened to be in the older literature. Every effort has been made to provide the best references but this may not have been achieved in all cases. Standard abbreviations, listed on page I, have been used throughout this edition to optimise space, except where no space advantage was achieved, in which cases the complete words have been written down to improve the flow of the sentences.

With the increasing facilities for information exchange, chemical, biochemical and equipment suppliers are making their catalogue information available on the Internet, e.g. Aldrich-Fluka-Sigma catalogue information is available on the World Wide Web by using the address http://www.sigma.sial.com, and GIBCO BRL catalogue information from http://www.lifetech.com, as well as on CD-ROMS which are regularly updated. Facility for enquiring about, ordering and paying for items is available via the Internet. CAS on-line can be accessed on the Internet, and CAS data is available now on CD-ROM. Also biosafety bill boards can similarly be obtained by sending SUBSCRIBE SAFETY John Doe at the address "listserv@uvnmuvm.uvm.edu", SUBSCRIBE BIOSAFETY at the address "listserv@mitvma.mit.edu", and SUBSCRIBE RADSAF at the address "listserv@romulus.chohs.uiuc.edu"; and the Occupational, Health and Safety information (Australia) is available at the address "http://www.worksafe.gov.au/-wsaI". Sigma-Aldrich provide Material Safety data sheets on CD-ROMs.

It is with much sadness that Dr Douglas D. Perrin was unable to participate in the preparation of the present edition due to illness. His contributions towards the previous editions have been substantial, and his drive and tenacity have been greatly missed.

The Third Edition was prepared on an IBM-PC and the previous IBM files were converted into Macintosh files. These have now been reformatted on a Macintosh LC575 computer and all further data to complete the Fourth Edition were added to these files. The text was printed with a Hewlett-Packard 4MV -600dpi Laser Jet printer which gives a clearer resolution.

I thank my wife Dr Pauline M. Armarego, also an organic chemist, for the arduous and painstaking task of entering the new data into the respective files, and for the numerous hours of proofreading as well as the corrections of typographic errors in the files. I should be grateful to my readers for any comments, suggestions, amendments and criticisms which could, perhaps, be inserted in the second printing of this edition.

W.L.F. Armarego
30 June 1996
INTRODUCTION

Purity is a matter of degree. Other than adventitious contaminants such as dust, paper fibres, wax, cork, etc., that may have been incorporated into the sample during manufacture, all commercially available chemical substances are in some measure impure. Any amounts of unreacted starting material, intermediates, by-products, isomers and related compounds may be present depending on the synthetic or isolation procedures used for preparing the substances. Inorganic reagents may deteriorate because of defective packaging (glued liners affected by sulfuric acid, zinc extracted from white rubber stoppers by ammonia), corrosion or prolonged storage. Organic molecules may undergo changes on storage. In extreme cases the container may be incorrectly labelled or, where compositions are given, they may be misleading or inaccurate for the proposed use. Where any doubt exists it is usual to check for impurities by appropriate spot tests, or by recourse to tables of physical or spectral properties such as the extensive infrared and NMR libraries published by the Sigma Aldrich Chemical Co.

The important question, then, is not whether a substance is pure but whether a given sample is sufficiently pure for some intended purpose. That is, are the contaminants likely to interfere in the process or measurement that is to be studied. By suitable manipulation it is often possible to reduce levels of impurities to acceptable limits, but absolute purity is an ideal which, no matter how closely approached, can never be attained. A negative physical or chemical test indicates only that the amount of an impurity in a substance lies below a certain sensitivity level; no test can demonstrate that a specified impurity is entirely absent.

When setting out to purify a laboratory chemical, it is desirable that the starting material is of the best grade commercially available. Particularly among organic solvents there is a range of qualities varying from laboratory chemical to spectroscopic and chromatographic grades. Many of these are suitable for use as received. With many of the more common reagents it is possible to obtain from the current literature some indications of likely impurities, their probable concentrations and methods for detecting them. However, in many cases complete analyses are not given so that significant concentrations of unspecified impurities may be present.

THE QUESTION OF PURITY

Solvents and substances that are specified as pure for a particular purpose may, in fact, be quite impure for other uses. Absolute ethanol may contain traces of benzene, which makes it unsuitable for ultraviolet spectroscopy, or plasticizers which make it unsuitable for use in solvent extraction.

Irrespective of the grade of material to be purified, it is essential that some criteria exist for assessing the degree of purity of the final product. The more common of these include:

1. Examination of physical properties such as:
   (a) Melting point, freezing point, boiling point, and the freezing curve (i.e. the variation, with time, in the freezing point of a substance that is being slowly and continuously frozen).
   (b) Density.
   (c) Refractive index at a specified temperature and wavelength. The sodium D line at 589.26 nm (weighted mean of D1 and D2 lines) is the usual standard of wavelength but results from other wavelengths can often be interpolated from a plot of refractive index versus 1/(wavelength)^2.
(d) Specific conductivity. (This can be used to detect, for example, water, salts, inorganic and organic acids and bases, in non-electrolytes).
(e) Optical rotation, optical rotatory dispersion and circular dichroism.

2. Empirical analysis, for C, H, N, ash, etc.

3. Chemical tests for particular types of impurities, e.g. for peroxides in aliphatic ethers (with acidified KI), or for water in solvents (quantitatively by the Karl Fischer method, see Fieser and Fieser, Reagents for Organic Synthesis J. Wiley & Sons, NY, Vol 1 pp. 353, 528, 1967, Library of Congress Catalog Card No 66-27894).

4. Physical tests for particular types of impurities:
   (a) Emission and atomic absorption spectroscopy for detecting organic impurities and determining metal ions.
   (b) Chromatography, including paper, thin layer, liquid (high, medium and normal pressure) and vapour phase.
   (c) Electron spin resonance for detecting free radicals.
   (d) X-ray spectroscopy.
   (e) Mass spectroscopy.
   (f) Fluorimetry.

5. Examination of spectroscopic properties
   (a) Nuclear Magnetic Resonance (1H, 13C, 31p, 19F NMR etc)
   (b) Infrared spectroscopy (IR)
   (c) Ultraviolet spectroscopy (UV)
   (d) Mass spectroscopy [electron ionisation (EI), electron ionisation (CI), electrospray ionisation (ESI), fast atom bombardment (FAB), matrix-associated laser desorption ionisation (MALDI), etc]

6. Electrochemical methods (see Chapter 6 for macromolecules).

7. Nuclear methods which include a variety of radioactive elements as in organic reagents, complexes or salts.

A substance is usually taken to be of an acceptable purity when the measured property is unchanged by further treatment (especially if it agrees with a recorded value). In general, at least two different methods, such as recrystallisation and distillation, should be used in order to ensure maximum purity. Crystallisation may be repeated (from the same solvent or better from different solvents) until the substance has a constant melting point or absorption spectrum, and until it distils repeatedly within a narrow, specified temperature range.

With liquids, the refractive index at a specified temperature and wavelength is a sensitive test of purity. Note however that this is sensitive to dissolved gases such as O2, N2 or CO2. Under favourable conditions, freezing curve studies are sensitive to impurity levels of as little as 0.001 moles per cent. Analogous fusion curves or heat capacity measurements can be up to ten times as sensitive as this. With these exceptions, most of the above methods are rather insensitive, especially if the impurities and the substances in which they occur are chemically similar. In some cases, even an impurity comprising many parts per million of a sample may escape detection.

The common methods of purification, discussed below, comprise distillation (including fractional distillation, distillation under reduced pressure, sublimation and steam distillation), crystallisation, extraction, chromatographic and other methods. In some cases, volatile and other impurities can be removed simply by heating. Impurities can also sometimes be eliminated by the formation of derivatives from which the purified material is regenerated (see Chapter 2).

SOURCES OF IMPURITIES
Some of the more obvious sources of contamination of solvents arise from storage in metal drums and plastic containers, and from contact with grease and screw caps. Many solvents contain water. Others have traces of acidic materials such as hydrochloric acid in chloroform. In both cases this leads to corrosion of the drum and contamination of the solvent by traces of metal ions, especially Fe^{3+}. Grease, for example on stopcocks of separating funnels and other apparatus, e.g. greased ground joints, is also likely to contaminate solvents during extractions and chemical manipulation.
A much more general source of contamination that has not received the consideration it merits comes from the use of plastics for tubing and containers. Plasticisers can readily be extracted by organic solvents from PVC and other plastics, so that most solvents, irrespective of their grade (including spectrograde and ultrapure) have been reported to contain 0.1 to 5 ppm of plasticiser [de Zeeuw, Jonkman and van Mansvelt Anal Biochem 67 339 1975]. Where large quantities of solvent are used for extraction (particularly of small amounts of compounds), followed by evaporation, this can introduce significant amounts of impurity, even exceeding the weight of the genuine extract and giving rise to spurious peaks in gas chromatography (for example of fatty acid methyl esters [Pascaud, Anal Biochem 18 570 1967]). Likely contaminants are di(2-ethylhexyl) phthalate and dibutyl phthalate, but upwards of 20 different phthalate esters are listed as plasticisers as well as adipates, azelates, phosphates, epoxides, polyesters and various heterocyclic compounds. These plasticisers would enter the solvent during passage through plastic tubing or from storage in containers or from plastic coatings used in cap liners for bottles. Such contamination could arise at any point in the manufacture or distribution of a solvent. The problem with cap liners is avoidable by using corks wrapped in aluminium foil, although even in this case care should be taken because aluminium foil can dissolve in some liquids e.g. benzylamine and propionic acid.

Solutions in contact with polyvinyl chloride can become contaminated with trace amounts of lead, titanium, tin, zinc, iron, magnesium or cadmium from additives used in the manufacture and moulding of PVC. N-Phenyl-2-naphthylamine is a contaminant of solvents and biological materials that have been in contact with black rubber or neoprene (in which it is used as an antioxidant). Although it was only an artefact of the separation procedure it has been isolated as an apparent component of vitamin K preparations, extracts of plant lipids, algae, livers, butter, eye tissue and kidney tissue [Brown Chem Br 3 524 1967]. Most of the above impurities can be removed by prior distillation of the solvent, but care should be taken to avoid plastic or black rubber as much as possible.

**PRACTICES TO AVOID IMPURITIES**

**Cleaning practices**

Laboratory glassware and Teflon equipment can be cleaned satisfactorily for most purposes by careful immersion into a solution of sodium dichromate in concentrated sulfuric acid, followed by draining, and rinsing copiously with distilled water. This is an exothermic reaction and should be carried out very cautiously in an efficient fume cupboard. [To prepare the chromic acid bath, dissolve 5 g of sodium dichromate (CARE: cancer suspect agent) in 5 mL of water. The dichromate solution is then cooled and stirred while 100 mL of concentrated sulfuric acid is added slowly. Store in a glass bottle.] Where traces of chromium (adsorbed on the glass) must be avoided, a 1:1 mixture of concentrated sulfuric and nitric acid is a useful alternative. (Use in a fume hood to remove vapour and with adequate face protection.) Acid washing is also suitable for polyethylene ware but prolonged contact (some weeks) leads to severe deterioration of the plastic. Alternatively an alcoholic solution of sodium hydroxide (alkaline base bath) can be used. This strongly corrosive solution (CAUTION: Alkali causes serious burns) can be made by dissolving 120 g of NaOH in 120 mL water, followed by dilution to 1 L with 95% ethanol. This solution is conveniently stored in suitable alkaline resistant containers (e.g. Nalgene heavy duty rectangular tanks) with lids. Glassware can be soaked overnight in the base bath and rinsed thoroughly after soaking. For much glassware, washing with hot detergent solution, using tap water, followed by rinsing with distilled water and acetone, and heating to 200-300° overnight, is adequate. (Volumetric apparatus should not be heated: after washing it is rinsed with acetone, then hexane, and air-dried. Prior to use, equipment can be rinsed with acetone, then with petroleum ether or hexane, to remove the last traces of contaminants.) Teflon equipment should be soaked, first in acetone, then in petroleum ether or hexane for ten minutes prior to use. For trace metal analyses, prolonged soaking of equipment in 1 M nitric acid may be needed to remove adsorbed metal ions.

Soxhlet thimbles and filter papers may contain traces of lipid-like materials. For manipulations with highly pure materials, as in trace-pesticide analysis, thimbles and filter papers should be thoroughly extracted with hexane before use.

Trace impurities in silica gel for TLC can be removed by heating at 300° for 16 h or by Soxhlet extraction for 3 h with distilled chloroform, followed by 4 h extraction with distilled hexane.

**Silylation of glassware and plasticware**

Silylation of apparatus makes it repellent to water and hydrophilic materials. It minimises loss of solute by adsorption onto the walls of the container. The glassware is placed in a desiccator containing dichloromethyl silane (1 mL) in a small beaker and evacuated for 5 min. The vacuum is turned off and air is introduced into the desiccator which allows the silylating agent to coat the glassware uniformly. The desiccator is then evacuated, closed and set aside for 2 h. The glassware is removed from the desiccator and baked at 180° for 2 h before use.
Plasticware is treated similarly except that it is rinsed well with water before use instead of baking. Note that dichloromethyl silane is highly TOXIC and VOLATILE, and the whole operation should be carried out in an efficient fume cupboard.

An alternative procedure used for large apparatus is to rinse the apparatus with a 5% solution of dichloromethyl silane in chloroform, followed by several rinses with water before baking the apparatus at 180°/2h (for glass) or drying in air (for plasticware).

Plus One REPEL-SILANE ES (a solution of 2% w/v of dichloromethyl silane in octamethyl cyclooctasilane) is used to inhibit the sticking of polyacrylamide gels, agarose gels and nucleic acids to glass surfaces and is available commercially (Amersham Biosciences).

SAFETY PRECAUTIONS ASSOCIATED WITH THE PURIFICATION OF LABORATORY CHEMICALS

Although most of the manipulations involved in purifying laboratory chemicals are inherently safe, care is necessary if hazards are to be avoided in the chemical laboratory. In particular there are dangers inherent in the inhalation of vapours and absorption of liquids and low melting solids through the skin. In addition to the toxicity of solvents there is also the risk of their flammability and the possibility of eye damage. Chemicals, particularly in admixture, may be explosive. Compounds may be carcinogenic or otherwise deleterious to health. Present day chemical catalogues specifically indicate the particular dangerous properties of the individual chemicals they list and these should be consulted whenever the use of commercially available chemicals is contemplated. Radioisotopic labelled compounds pose special problems of human exposure and of disposal of laboratory waste. Hazardous purchased chemicals are accompanied by detailed MSDS (Material Safety Data Sheets), which contain information regarding their toxicity, safety handling procedures and the necessary precautions to be taken. These should be read carefully and filed for future reference. In addition, chemical management systems such as ChemWatch which include information on hazards, handling and storage are commercially available. There are a number of websites which provide selected safety information: they include the Sigma-Aldrich website (www.sigmaaldrich.com) and other chemical websites e.g. www.ilpi.com/msds).

The most common hazards are:

1. Explosions due to the presence of peroxides formed by aerial oxidation of ethers and tetrahydrofuran, decahydronaphthalene, acrylonitrile, styrene and related compounds.
2. Compounds with low flash points (below room temperature). Examples are acetaldehyde, acetone, acetonitrile, benzene, carbon disulfide, cyclohexane, diethyl ether, ethyl acetate and n-hexane.
3. Contact of oxidising agents (KMnO₄, HClO₄, chromic acid) with organic liquids.
4. Toxic reactions with tissues.

The laboratory should at least be well ventilated and safety glasses should be worn, particularly during distillation and manipulations carried out under reduced pressure or elevated temperatures. With this in mind we have endeavoured to warn users of this book whenever greater than usual care is needed in handling chemicals. As a general rule, however, all chemicals which users are unfamiliar with should be treated with extreme care and assumed to be highly flammable and toxic. The safety of others in a laboratory should always be foremost in mind, with ample warning whenever a potentially hazardous operation is in progress. Also, unwanted solutions or solvents should never be disposed of via the laboratory sink. The operator should be aware of the usual means for disposal of chemicals in her/his laboratories and she/he should remove unwanted chemicals accordingly. Organic liquids for disposal should be temporarily stored, as is practically possible, in respective containers. Avoid placing all organic liquids in the same container particularly if they contain small amounts of reagents which could react with each other. Halogenated waste solvents should be kept separate from other organic liquids.

SOME HAZARDS OF CHEMICAL MANIPULATION IN PURIFICATION AND RECOVERY OF RESIDUES
Performing chemical manipulations calls for some practical knowledge if danger is to be avoided. However, with care, hazards can be kept to an acceptable minimum. A good general approach is to consider every operation as potentially perilous and then to adjust one's attitude as the operation proceeds. A few of the most common dangers are set out below. For a larger coverage of the following sections, and of the literature, the bibliography at the end of this chapter should be consulted.
**Perchlorates and perchloric acid.** At 160° perchloric acid is an exceedingly strong oxidising acid and a strong dehydrating agent. Organic perchlorates, such as methyl and ethyl perchlorates, are unstable and are violently explosive compounds. A number of heavy-metal perchlorates are extremely prone to explode. The use of anhydrous magnesium perchlorate, *Anhydrite, Dehydrite*, as a drying agent for organic vapours is not recommended. Desiccators which contain this drying agent should be adequately shielded at all times and kept in a cool place, i.e. never on a window sill where sunlight can fall on it.

No attempt should be made to purify perchlorates, except for ammonium, alkali metal and alkaline earth salts which, in water or aqueous alcoholic solutions are insensitive to heat or shock. Note that perchlorates react relatively slowly in aqueous organic solvents, but as the water is removed there is an increased possibility of an explosion. Perchlorates, often used in non-aqueous solvents, are explosive in the presence of even small amounts of organic compounds when heated. Hence stringent care should be taken when purifying perchlorates, and direct flame and infrared lamps should be avoided. Tetra-alkylammonium perchlorates should be dried below 50° under vacuum (and protection). Only very small amounts of such materials should be prepared, and stored, at any one time.

**Peroxides.** These are formed by aerial oxidation or by autoxidation of a wide range of organic compounds, including diethyl ether, allyl ethyl ether, allyl phenyl ether, dibenzyl ether, benzyl butyl ether, *n*-butyl ether, *iso*-butyl ether, t-butyl ether, dioxane, tetrahydrofuran, olefins, and aromatic and saturated aliphatic hydrocarbons. They accumulate during distillation and can detonate violently on evaporation or distillation when their concentration becomes high. If peroxides are likely to be present materials should be tested for peroxides before distillation (for tests see entry under “Ethers”, in Chapter 2). Also, distillation should be discontinued when at least one quarter of the residue is left in the distilling flask.

**Heavy-metal-containing-explosives.** Ammoniacal silver nitrate, on storage or treatment, will eventually deposit the highly explosive silver nitride "fulminating silver". Silver nitrate and ethanol may give silver fulminate (see Chapter 5), and in contact with azides or hydrazine and hydrazides may form silver azide. Mercury can also form such compounds. Similarly, ammonia or ammonium ions can react with gold salts to form "fulminating gold". Metal fulminates of cadmium, copper, mercury and thallium are powerfully explosive, and some are detonators [Luchs, *Photog Sci Eng* 10 334 1966]. Heavy metal containing solutions, particularly when organic material is present should be treated with great respect and precautions towards possible explosion should be taken.

**Strong acids.** In addition to perchloric acid (see above), extra care should be taken when using strong mineral acids. Although the effects of concentrated sulfuric acid are well known these cannot be stressed strongly enough. Contact with tissues will leave irreparable damage. Always dilute the concentrated acid by carefully adding the acid down the side of the flask which contains water, and the process should be carried out under cooling. This solution is not safe to handle until the acid has been thoroughly mixed with the water. **Protective face, and body coverage should be used at all times.** Fuming sulfuric acid and chlorosulfonic acid are even more dangerous than concentrated sulfuric acid and adequate precautions should be taken. Chromic acid cleaning mixture contains strong sulfuric acid and should be treated in the same way; and in addition the mixture is potentially carcinogenic. Concentrated and fuming nitric acids are also dangerous because of their severe deleterious effects on tissues.

**Reactive halides and anhydrides.** Substances like acid chlorides, low molecular weight anhydrides and some inorganic halides (e.g. *PCl*₃) can be highly toxic and lachrymatory affecting mucous membranes and lung tissues. **Utmest care should be taken when working with these materials.** **Work should be carried out in a very efficient fume cupboard.**

**Solvents.** The flammability of low-boiling organic liquids cannot be emphasised strongly enough. These invariably have very low flash points and can ignite spontaneously. Special precautions against explosive flammability should be taken when recovering such liquids. **Care should be taken with small volumes (ca 250mL) as well as large volumes (> 1L), and the location of all the fire extinguishers, and fire blankets, in the immediate vicinity of the apparatus should be checked. The fire extinguisher should be operational.** The following flammable liquids (in alphabetical order) are common fire hazards in the laboratory: acetaldehyde, acetone, acrylonitrile, acetonitrile, benzene, carbon disulfide, cyclohexane, diethyl ether, ethyl acetate, hexane, low-boiling petroleum ether, tetrahydrofuran and toluene. Toluene should always be used in place of benzene wherever possible due to the potential carcinogenic effects of the liquid and vapour of the latter.

The drying of flammable solvents with sodium or potassium metal and metal hydrides poses serious potential fire hazards and adequate precautions should be stressed.
Salts. In addition to the dangers of perchlorate salts, other salts such as nitrates, azides and diazo salts can be hazardous and due care should be taken when these are dried. Large quantities should never be prepared or stored for long periods.

SAFETY DISCLAIMER
Experimental chemistry is a very dangerous occupation and extreme care and adequate safety precautions should be taken at all times. Although we have stated the safety measures that have to be taken under specific entries these are by no means exhaustive and some may have been unknowingly or accidentally omitted. The experimenter without prior knowledge or experience must seek further safety advice on reagents and procedures from experts in the field before undertaking the purification of any material. We take no responsibility whatsoever if any mishaps occur when using any of the procedures described in this book.

METHODS OF PURIFICATION OF REAGENTS AND SOLVENTS

Many methods exist for the purification of reagents and solvents. A number of these methods are routinely used in synthetic as well as analytical chemistry and biochemistry. These techniques, outlined below, will be discussed in greater detail in the respective sections in this Chapter. It is important to note that more than one method of purification may need to be implemented in order to obtain compounds of highest purity.

Common methods of purification are:
(a) Solvent Extraction and Distribution
(b) Distillation
(c) Recrystallisation
(d) Sublimation
(e) Chromatography

For substances contaminated with water or solvents, drying with appropriate absorbents and desiccants may be sufficient.

SOLVENT EXTRACTION AND DISTRIBUTION

Extraction of a substance from suspension or solution into another solvent can sometimes be used as a purification process. Thus, organic substances can often be separated from inorganic impurities by shaking an aqueous solution or suspension with suitable immiscible solvents such as benzene, carbon tetrachloride, chloroform, diethyl ether, disopropyl ether or petroleum ether. After several such extractions the combined organic phase is dried and the solvent is evaporated. Grease from the glass taps of conventional separating funnels is invariably soluble in the solvents used. Contamination with grease can be very troublesome particularly when the amounts of material to be extracted are very small. Instead, the glass taps should be lubricated with the extraction solvent; or better, the taps of the extraction funnels should be made of the more expensive material Teflon. Immiscible solvents suitable for extractions are given in Table 1. Addition of electrolytes (such as ammonium sulfate, calcium chloride or sodium chloride) to the aqueous phase helps to ensure that the organic layer separates cleanly and also decreases the extent of extraction into the latter. Emulsions can also be broken up by filtration (with suction) through Celite, or by adding a little octyl alcohol or some other paraffinic alcohol. The main factor in selecting a suitable immiscible solvent is to find one in which the material to be extracted is readily soluble, whereas the substance from which it is being extracted is not. The same considerations apply irrespective of whether it is the substance being purified, or one of its contaminants, that is taken into the new phase. (The second of these processes is described as washing.)

Common examples of washing with aqueous solutions include the following:
- Removal of acids from water-immiscible solvents by washing with aqueous alkali, sodium carbonate or sodium bicarbonate.
- Removal of phenols from similar solutions by washing with aqueous alkali.
- Removal of organic bases by washing with dilute hydrochloric or sulfuric acids.
- Removal of unsaturated hydrocarbons, of alcohols and of ethers from saturated hydrocarbons or alkyl halides by washing with cold concentrated sulfuric acid.

This process can also be applied to purification of the substance if it is an acid, a phenol or a base, by extracting into the appropriate aqueous solution to form the salt which, after washing with pure solvent, is again converted to
the free species and re-extracted. Paraffin hydrocarbons can be purified by extracting them with phenol (in which aromatic hydrocarbons are highly soluble) prior to fractional distillation. For extraction of solid materials with a solvent, a Soxhlet extractor is commonly used. This technique is applied, for example, in the alcohol extraction of dyes to free them from insoluble contaminants such as sodium chloride or sodium sulfate. Acids, bases and amphoteric substances can be purified by taking advantage of their ionisation constants.

Ionisation constants and pK.

When substances ionise their neutral species produce positive and negative species. The ionisation constants are those constant values (equilibrium constants) for the equilibria between the charged species and the neutral species, or species with a larger number of charges (e.g. between mono and dications). These ionisation constants are species [Albert and Serjeant

The advantage of using pK values (instead of K values) is that theory (and practice) states that the pK values of acids, bases and amphoteric substances can be purified by taking advantage of their ionisation constants.

Aniline will be used as a second example. It has a pKZ5 of 4.60 at 25°C in H2O. If it is placed in aqueous solution at pH 1.60 it will exist almost completely (99.9%) as the anilinium cation. This solution can then be extracted with solvents e.g. diethyl ether leaving almost all the acetic acid in the form of AcO- in the aqueous solution. If then the pH of the solution is then adjusted to 7.60 whereby aniline will exist as the free base (99.9%) and can be extracted into diethyl ether in order to give purer aniline.

See Table 2 for the pH values of selected buffers.

A knowledge of the pH allows the adjustment of the pH without the need of large excesses of acids or base. In the case of inorganic compounds a knowledge of the pK is useful for adjusting the ionic species for making metal complexes which could be masked or extracted into organic solvents [Perrin and Dempsey Buffers for pH and Metal Ion Control, Chapman & Hall, New York, London, 1974, ISBN 0412117002], or for obtaining specific anionic species in solution e.g. H2PO4-, HPO42- or PO43-.

All the pK values in this book are pKa values, the acidic pK, i.e. dissociation of H+ from an acid (AH) or from a conjugate base (BH+). Occasionally pKb values are reported in the literature but these can be converted using the equation: pKa + pKb = 14. For strong acids e.g. sulfuric acid, and strong bases, e.g. sodium hydroxide, the pK values lie beyond the 1 to 11 scale and have to be measured in strong acidic and basic media. In these cases appropriate scales e.g. the H0 (for acids) and H- (for bases) have been used [see Katritzky and Waring J Chem Soc 1540 (1962)]. These values will be less than 1 (and negative) for acids and >11 for bases. They are rough guides to the strengths of acids and bases. Errors in the stated pK and pKb values can be judged from the numerical values given. Thus pK values of 4.55, 4.5 and 4 mean that the respective errors are better than 0.05, ± 0.3 and ± 0.5. Values taken from the literature are written as pK, and all the values that were estimated because they were not found in the literature are written as pKEst.

pK and Temperature.
The temperatures at which the literature measurements were made are given as superscripts, e.g. pK25. Where no temperature is given, it is assumed that the measurements were carried out at room temperature, e.g. 15–25°C. No temperature is given for estimated values (pKEst) and these have been calculated from data at room temperature. The variation of pK with temperature is given by the equation:

\[ \frac{d(pK)}{dT} = \frac{pK + 0.052DS^0}{T} \]

where T is in degrees Kelvin and DS^0 is in Joules deg^-1 mol^-1. The -d(pK)/dT in the range of temperatures between 5 to 70°C is generally small (e.g. between ~0.0024 and ~0.04), and for chemical purification purposes is not a seriously deterring factor. It does however, vary with the compound under study because DS^0 varies from compound to compound. The following are examples of the effect of temperature on pK values on pK values: for imidazole the pK values are 7.57 (0°C), 7.33 (10°C), 7.10 (20°C), 6.99 (25°C), 6.89 (30°C), 6.58 (40°C) and 6.49 (50°C), and for 3,5-dinitrobenzoic acid they are 2.60 (10°C), 2.73 (20°C), 2.85 (30°C), 2.96 (40°C) and 3.07 (40°C), and for N-acetyl-Dalanine they are 4.4788 (5°C), 4.4652 (10°C), 4.4564 (15°C), 4.4488 (20°C), 4.4452 (25°C), 4.4444 (30°C), 4.4434 (35°C) and 4.4412 (40°C).

pK and solvent.
All stated pK values in this book are for data in dilute aqueous solutions unless otherwise stated, although the dielectric constants, ionic strengths of the solutions and the method of measurement, e.g. potentiometric, spectrophotometric etc, are not given. Estimated values are also for dilute aqueous solutions whether or not the material is soluble enough in water. Generally the more dilute the solution the closer is the pK to the real thermodynamic value. The pK in mixed aqueous solvents can vary considerably with the relative concentrations and with the nature of the solvents. For example the pK25 values for N-benzylpenicillin are 2.76 and 4.84 in H2O and H2O/EtOH (20:80) respectively; the pK25 values for (-)-ephedrine are 9.58 and 8.84 in H2O and H2O/MeOCH2CH2OH (20:80) respectively and for cycloopenylamine the pK25 values are 10.65 and 4.05 in H2O and H2O/EtOH (50:50) respectively. pK values in acetic acid or aqueous acetic acid are generally lower than in H2O.
The dielectric constant of the medium affects the equilibria where charges are generated in the dissociations e.g. AH ⇌ A^- + H^+ and therefore affects the pK values. However, its effect on dissociations where there are no changes in total charge such as BH^+ ⇌ B + H^+ is considerably less, with a slight decrease in pK with decreasing dielectric constant.

DISTILLATION
One of the most widely applicable and most commonly used methods of purification of liquids or low melting solids (especially of organic chemicals) is fractional distillation at atmospheric, or some lower, pressure. Almost without exception, this method can be assumed to be suitable for all organic liquids and most of the low-melting organic solids. For this reason it has been possible in Chapter 4 to omit many procedures for purification of organic chemicals when only a simple fractional distillation is involved - the suitability of such a procedure is implied from the boiling point.
The boiling point of a liquid varies with the 'atmospheric' pressure to which it is exposed. A liquid boils when its vapour pressure is the same as the external pressure on its surface, its normal boiling point being the temperature at which its vapour pressure is equal to that of a standard atmosphere (760mm Hg). Lowering the external pressure lowers the boiling point. For most substances, boiling point and vapour pressure are related by an equation of the form,

\[ \log p = A + B/(t + 273) \]
where \( p \) is the pressure, \( t \) is in °C, and \( A \) and \( B \) are constants. Hence, if the boiling points at two different pressures are known the boiling point at another pressure can be calculated from a simple plot of \( \log p \) versus \( 1/(t + 273) \). For organic molecules that are not strongly associated, this equation can be written in the form,

\[
\log p = 8.586 - 5.703 \left( \frac{T}{t + 273} \right)
\]

where \( T \) is the boiling point in °C at 760mm Hg. Tables 3A and 3B give computed boiling points over a range of pressures. Some examples illustrate its application. Ethyl acetoacetate, \( b \) 180° (with decomposition) at 760mm Hg has a predicted \( b \) of 79° at 16mm; the experimental value is 78°. Similarly 2,4-diaminotoluene, \( b \) 292° at 760mm, has a predicted \( b \) of 147° at 8mm; the experimental value is 148-150°. For self-associated molecules the predicted \( b \) are lower than the experimental values. Thus, glycerol, \( b \) 290° at 760mm, has a predicted \( b \) of 146° at 8mm: the experimental value is 182°.

Similarly an estimate of the boiling points of liquids at reduced pressure can be obtained using a nomogram (see Figure 1).

For pressures near 760mm, the change in boiling point is given approximately by,

\[
\Delta T = a(760 - p)(t + 273)
\]

where \( a = 0.00012 \) for most substances, but \( a = 0.00010 \) for water, alcohols, carboxylic acids and other associated liquids, and \( a = 0.00014 \) for very low-boiling substances such as nitrogen or ammonia [Crafts Chem Ber 20 709 1887]. When all the impurities are non-volatile, simple distillation is adequate purification. The observed boiling point remains almost constant and approximately equal to that of the pure material. Usually, however, some of the impurities are appreciably volatile, so that the boiling point progressively rises during the distillation because of the progressive enrichment of the higher-boiling components in the distillation flask. In such cases, separation is effected by fractional distillation using an efficient column.

**Techniques.**

The distillation apparatus consists basically of a distillation flask, usually fitted with a vertical fractionating column (which may be empty or packed with suitable materials such as glass helices or stainless-steel wool) to which is attached a condenser leading to a receiving flask. The bulb of a thermometer projects into the vapour phase just below the region where the condenser joins the column. The distilling flask is heated so that its contents are steadily vaporised by boiling. The vapour passes up into the column where, initially, it condenses and runs back into the flask. The resulting heat transfer gradually warms the column so that there is a progressive movement of the vapour phase-liquid boundary up the column, with increasing enrichment of the more volatile component. Because of this fractionation, the vapour finally passing into the condenser (where it condenses and flows into the receiver) is commonly that of the lowest-boiling components in the system. The conditions apply until all of the low-boiling material has been distilled, whereupon distillation ceases until the column temperature is high enough to permit the next component to distil. This usually results in a temporary fall in the temperature indicated by the thermometer.

**Distillation of liquid mixtures.**

The principles involved in fractional distillation of liquid mixtures are complex but can be seen by considering a system which approximately obeys Raoult's law. (This law states that the vapour pressure of a solution at any given temperature is the sum of the vapour pressures of each component multiplied by its mole fraction in the solution.) If two substances, \( A \) and \( B \), having vapour pressures of 600mm Hg and 360mm Hg, respectively, were mixed in a molar ratio of 2:1 (i.e. 0.666:0.333 mole ratio), the mixture would have (ideally) a vapour pressure of 520mm Hg (i.e. 600 x 0.666 + 360 x 0.333, or 399.6 + 119.88 mm Hg) and the vapour phase would contain 77% (399.6 x 100/520) of \( A \) and 23% (119.88 x 100/520) of \( B \). If this phase was now condensed, the new liquid phase would, therefore, be richer in the volatile component \( A \). Similarly, the vapour in equilibrium with this phase is still further enriched in \( A \). Each such liquid-vapour equilibrium constitutes a "theoretical plate". The efficiency of a fractionating column is commonly expressed as the number of such plates to which it corresponds in operation. Alternatively, this information may be given in the form of the height equivalent to a theoretical plate, or HETP. The number of theoretical plates and equilibria between liquids and vapours are affected by the factors listed to achieve maximum separation by fractional distillation in the section below on techniques.

In most cases, systems deviate to a greater or lesser extent from Raoult's law, and vapour pressures may be greater or less than the values calculated. In extreme cases (e.g. azeotropes), vapour pressure-composition curves pass through maxima or minima, so that attempts at fractional distillation lead finally to the separation of a constant-boiling (azeotropic) mixture and one (but not both) of the pure species if either of the latter is present in excess.
Elevation of the boiling point by dissolved solids. Organic substances dissolved in organic solvents cause a rise in boiling point which is proportional to the concentration of the substance, and the extent of rise in temperature is characteristic of the solvent. The following equation applies for dilute solutions and non-associating substances:

\[
\frac{M \cdot D_t}{c} = K
\]

Where \( M \) is the molecular weight of the solute, \( D_t \) is the elevation of boiling point in °C, \( c \) is the concentration of solute in grams for 1000gm of solvent, and \( K \) is the Ebullioscopic Constant (molecular elevation of the boiling point) for the solvent. \( K \) is a fixed property (constant) for the particular solvent. This has been very useful for the determination of the molecular weights of organic substances in solution.

The efficiency of a distillation apparatus used for purification of liquids depends on the difference in boiling points of the pure material and its impurities. For example, if two components of an ideal mixture have vapour pressures in the ratio 2:1, it would be necessary to have a still with an efficiency of at least seven plates (giving an enrichment of \( 2^7 = 128 \)) if the concentration of the higher-boiling component in the distillate was to be reduced to less than 1% of its initial value. For a vapour pressure ratio of 5:1, three plates would achieve as much separation.

In a fractional distillation, it is usual to reject the initial and final fractions, which are likely to be richer in the lower-boiling and higher-boiling impurities respectively. The centre fraction can be further purified by repeated fractional distillation.

To achieve maximum separation by fractional distillation:

1. The column must be flooded initially to wet the packing. For this reason it is customary to operate a still at reflux for some time before beginning the distillation.

2. The reflux ratio should be high (i.e. the ratio of drops of liquid which return to the distilling flask and the drops which distil over), so that the distillation proceeds slowly and with minimum disturbance of the equilibria in the column.

3. The hold-up of the column should not exceed one-tenth of the volume of any one component to be separated.

4. Heat loss from the column should be prevented but, if the column is heated to offset this, its temperature must not exceed that of the distillate in the column.

5. Heat input to the still-pot should remain constant.

6. For distillation under reduced pressure there must be careful control of the pressure to avoid flooding or cessation of reflux.

Types of distillation

The distilling flask. To minimise superheating of the liquid (due to the absence of minute air bubbles or other suitable nuclei for forming bubbles of vapour), and to prevent bumping, one or more of the following precautions should be taken:

(a) The flask is heated uniformly over a large part of its surface, either by using an electrical heating mantle or, by partial immersion in a bath above the boiling point of the liquid to be distilled.

(b) Before heating begins, small pieces of unglazed fireclay or porcelain (porous pot, boiling chips), pumice, diatomaceous earth, or platinum wire are added to the flask. These act as sources of air bubbles.

(c) The flask may contain glass siphons or boiling tubes. The former are inverted J-shaped tubes, the end of the shorter arm being just above the surface of the liquid. The latter comprise long capillary tubes sealed above the lower end.

(d) A steady slow stream of inert gas (e.g. \( \text{N}_2 \), \( \text{Ar} \) or \( \text{He} \)) is passed through the liquid.

(e) The liquid in the flask is stirred mechanically. This is especially necessary when suspended insoluble material is present.

For simple distillations a Claisen flask is often used. This flask is, essentially, a round-bottomed flask to the neck of which is joined another neck carrying a side arm. This second neck is sometimes extended so as to form a
Vigreux column [a glass tube in which have been made a number of pairs of indentations which almost touch each other and which slope slightly downwards. The pairs of indentations are arranged to form a spiral of glass inside the tube].

For heating baths, see Table 4. For distillation apparatus on a micro or semi-micro scale see Aldrich and other glassware catalogues. Alternatively, some useful websites for suppliers of laboratory glassware are www.wheatonsci.com, www.sigmaaldrich.com and www.kimble-kontes.com.

**Types of columns and packings.** A slow distillation rate is necessary to ensure that equilibrium conditions operate and also that the vapour does not become superheated so that the temperature rises above the boiling point. Efficiency is improved if the column is heat insulated (either by vacuum jacketing or by lagging) and, if necessary, heated to just below the boiling point of the most volatile component. Efficiency of separation also improves with increase in the heat of vaporisation of the liquids concerned (because fractionation depends on heat equilibration at multiple liquid-gas boundaries). Water and alcohols are more easily purified by distillation for this reason.

Columns used in distillation vary in their shapes and types of packing. Packed columns are intended to give efficient separation by maintaining a large surface of contact between liquid and vapour. Efficiency of separation is further increased by operation under conditions approaching total reflux, i.e. under a high reflux ratio. However, great care must be taken to avoid flooding of the column during distillation. The minimum number of theoretical plates for satisfactory separation of two liquids differing in boiling point by \( \Delta t \) is approximately \( \left( \frac{273 + t}{31t} \right) \), where \( t \) is the average boiling point in °C.

The packing of a column greatly increases the surface of liquid films in contact with the vapour phase, thereby increasing the efficiency of the column, but reducing its capacity (the quantities of vapour and liquid able to flow in opposite directions in a column without causing flooding). Material for packing should be of uniform size, symmetrical shape, and have a unit diameter less than one eighth that of the column. (Rectification efficiency increases sharply as the size of the packing is reduced but so, also, does the hold-up in the column.) It should also be capable of uniform, reproducible packing.

The usual packings are:

(a) Rings. These may be hollow glass or porcelain (Raschig rings), of stainless steel gauze (Dixon rings), or hollow rings with a central partition (Lessing rings) which may be of porcelain, aluminium, copper or nickel.

(b) Helices. These may be of metal or glass (Fenske rings), the latter being used where resistance to chemical attack is important (e.g. in distilling acids, organic halides, some sulfur compounds, and phenols). Metal single-turn helices are available in aluminium, nickel or stainless steel. Glass helices are less efficient, because they cannot be tamped to ensure uniform packing.

(c) Balls or beads. These are usually made of glass.

**Condensers.** Some of the more commonly used condensers are:

Air condenser. A glass tube such as the inner part of a Liebig condenser (see below). Used for liquids with boiling points above 90°. Can be of any length.

Coil condenser. An open tube, into which is sealed a glass coil or spiral through which water circulates. The tube is sometimes also surrounded by an outer cooling jacket. A double coil condenser has two inner coils with circulating water.

Double surface condenser. A tube in which the vapour is condensed between an outer and inner water-cooled jacket after impinging on the latter. Very useful for liquids boiling below 40°.

Friedrichs condenser. A "cold-finger" type of condenser sealed into a glass jacket open at the bottom and near the top. The cold finger is formed into glass screw threads.

Liebig condenser. An inner glass tube surrounded by a glass jacket through which water is circulated.

**Vacuum distillation.** This expression is commonly used to denote a distillation under reduced pressure lower than that of the normal atmosphere. Because the boiling point of a substance depends on the pressure, it is often possible by sufficiently lowering the pressure to distil materials at a temperature low enough to avoid partial or complete decomposition, even if they are unstable when boiled at atmospheric pressure.

Sensitive or high-boiling liquids should invariably be distilled or fractionally distilled under reduced pressure. The apparatus is essentially as described for distillation except that ground joints connecting the different parts of the apparatus should be air tight by using grease, or better Teflon sleeves. For low, moderately high, and very high temperatures Apiezon L, M and T greases respectively, are very satisfactory. Alternatively, it is often preferable to avoid grease and to use thin Teflon sleeves in the joints. The distilling flask must be supplied with a capillary
bleed (which allows a fine stream of air, nitrogen or argon into the flask), and the receiver should be of the fraction collector type. When distilling under vacuum it is very important to place a loose packing of glass wool above the liquid to buffer sudden boiling of the liquid. The flask should be not more than two-thirds full of liquid. The vacuum must have attained a steady state, i.e. the liquid has been completely degassed, before the heat source is applied, and the temperature of the heat source must be raised very slowly until boiling is achieved.

If the pump is a filter pump off a high-pressure water supply, its performance will be limited by the temperature of the water because the vapour pressure of water at 10°C, 15°C, 20°C and 25°C is 9.2, 12.8, 17.5 and 23.8 mm Hg respectively. The pressure can be measured with an ordinary manometer. For vacuums in the range 10⁻² mm Hg to 10 mm Hg, rotary mechanical pumps (oil pumps) are used and the pressure can be measured with a Vacustat McLeod type gauge. If still higher vacuums are required, for example for high vacuum sublimations, a mercury diffusion pump is suitable. Such a pump can provide a vacuum up to 10⁻⁶ mm Hg. For better efficiencies, the pump can be backed up by a mechanical pump. In all cases, the mercury pump is connected to the distillation apparatus through several traps to remove mercury vapours. These traps may operate by chemical action, for example the use of sodium hydroxide pellets to react with acids, or by condensation, in which case empty tubes cooled in solid carbon dioxide-ethanol or liquid nitrogen (contained in wide-mouthed Dewar flasks) are used.

Special oil or mercury traps are available commercially and a liquid-nitrogen (b -209.9°C) trap is the most satisfactory one to use between these and the apparatus. It has an advantage over liquid air or oxygen in that it is non-explosive if it becomes contaminated with organic matter. Air should not be sucked through the apparatus before starting a distillation because this will cause liquid oxygen (b -183°C) to condense in the liquid nitrogen trap and this is potentially explosive (especially in mixtures with organic materials). Due to the potential lethal consequences of liquid oxygen/organic material mixtures, care must be exercised when handling liquid nitrogen. Hence, it is advisable to degas the system for a short period before the trap is immersed into the liquid nitrogen (which is kept in a Dewar flask).

**Spinband distillation.** Factors which limit the performance of distillation columns include the tendency to flood (which occurs when the returning liquid blocks the pathway taken by the vapour through the column) and the increased hold-up (which decreases the attainable efficiency) in the column that should, theoretically, be highly efficient. To overcome these difficulties, especially for distillation under high vacuum of heat sensitive or high-boiling highly viscous fluids, spinband columns are commercially available. In such units, the distillation columns contain a rapidly rotating, motor-driven, spiral band, which may be of polymer-coated metal, stainless steel or platinum. The rapid rotation of the band in contact with the walls of the still gives intimate mixing of descending liquid and ascending vapour while the screw-like motion of the band drives the liquid towards the still-pot, helping to reduce hold-up. There is very little pressure drop in such a system, and very high throughputs are possible, with high efficiency. For example, a 765-mm long 10-mm diameter commercial spinband column is reported to have an efficiency of 28 plates and a pressure drop of 0.2 mm Hg for a throughput of 330 mL/h. The columns may be either vacuum jacketed or heated externally. The stills can be operated down to 10⁻⁵ mm Hg. The principle, which was first used commercially in the Podbielniak Centrifugal Superfractionator, has also been embodied in descending-film molecular distillation apparatus.

**Steam distillation.** When two immiscible liquids distil, the sum of their (independent) partial pressures is equal to the atmospheric pressure. Hence in steam distillation, the distillate has the composition

\[
\frac{\text{Moles of substance}}{\text{Moles of water}} = \frac{P_{\text{substance}}}{P_{\text{water}}} = 760 - P_{\text{water}}
\]

where the \(P\)’s are vapour pressures (in mm Hg) in the boiling mixture.

The customary technique consists of heating the substance and water in a flask (to boiling), usually with the passage of steam, followed by condensation and separation of the aqueous and non-aqueous phases in the distillate. Its advantages are those of selectivity (because only some water-insoluble substances, such as naphthalene, nitrobenzene, phenol and aniline are volatile in steam) and of ability to distil certain high-boiling substances well below their boiling point. It also facilitates the recovery of a non-steam-volatile solid at a relatively low temperature from a high-boiling solvent such as nitrobenzene. The efficiency of steam distillation is increased if superheated steam is used (because the vapour pressure of the organic component is increased relative to water). In this case the flask containing the material is heated (without water) in an oil bath and the steam passing through it is superheated by prior passage through a suitable heating device (such as a copper coil heated electrically or an oil bath).
Azeotropic distillation. In some cases two or more liquids form constant-boiling mixtures, or azeotropes. Azeotropic mixtures are most likely to be found with components which readily form hydrogen bonds or are otherwise highly associated, especially when the components are dissimilar, for example an alcohol and an aromatic hydrocarbon, but have similar boiling points.

Examples where the boiling point of the distillate is a minimum (less than either pure component) include:
- **Water** with ethanol, n-propanol and isopropanol, tert-butanol, propionic acid, butyric acid, pyridine,
- **methanol** with methyl iodide, methyl acetate, chloroform,
- **ethanol** with ethyl iodide, ethyl acetate, chloroform, benzene, toluene, methyl ethyl ketone,
- **benzene** with cyclohexane,
- **acetic acid** with toluene.

Although less common, azeotropic mixtures are known which have higher boiling points than their components. These include water with most of the mineral acids (hydrofluoric, hydrochloric, hydrobromic, perchloric, nitric and sulfuric) and formic acid. Other examples are acetic acid-pyridine, acetone-chloroform, aniline-phenol, and chloroform-methyl acetate.

The following azeotropes are important commercially for drying ethanol:

- ethanol 95.5% (by weight) - water 4.5% b 78.1°
- ethanol 32.4% - benzene 67.6% b 68.2°
- ethanol 18.5% - benzene 74.1% - water 7.4% b 64.9°

Materials are sometimes added to form an azeotropic mixture with the substance to be purified. Because the azeotrope boils at a different temperature, this facilitates separation from substances distilling in the same range as the pure material. (Conversely, the impurity might form the azeotrope and be removed in this way). This method is often convenient, especially where the impurities are isomers or are otherwise closely related to the desired substance. Formation of low-boiling azeotropes also facilitates distillation.

One or more of the following methods can generally be used for separating the components of an azeotropic mixture:

1. By using a chemical method to remove most of one species prior to distillation. (For example, water can be removed by suitable drying agents; aromatic and unsaturated hydrocarbons can be removed by sulfonation).
2. By redistillation with an additional substance which can form a ternary azeotropic mixture (as in ethanol-water-benzene example given above).
3. By selective adsorption of one of the components. (For example, of water on to silica gel or molecular sieves, or of unsaturated hydrocarbons onto alumina).
4. By fractional crystallisation of the mixture, either by direct freezing or by dissolving in a suitable solvent.

**Kugelrohr distillation.** The apparatus (Büchi, see www.buchi.com) is made up of small glass bulbs (ca 4-5cm diameter) which are joined together via Quickfit joints at each pole of the bulbs. The liquid (or low melting solid) to be purified is placed in the first bulb of a series of bulbs joined end to end, and the system can be evacuated. The first bulb is heated in a furnace at a high temperature whereby most of the material distils into the second bulb (which is outside of the furnace). The second bulb is then moved into the furnace and the furnace temperature is reduced by ca 5° whereby the liquid in the second bulb distils into the third bulb (at this stage the first bulb is now out at the back of the furnace and the third and subsequent bulbs are outside the front of the furnace). The furnace temperature is lowered by a further ca 5° and the third bulb is moved into the furnace. The lower boiling material will distil into the fourth bulb. The process is continued until no more material distils into the subsequent bulb. The vacuum (if applied) and the furnace are removed, the bulbs are separated and the various fractions of distillates are collected from the individual bulbs. For volatile liquids, it may be necessary to cool the receiving bulb with solid CO₂ held in a suitable container (Kügelrohr distillation apparatus with an integrated cooling system is available). This procedure is used for preliminary purification and the distillates are then redistilled or recrystallised.

**Isopiestic or isothermal distillation.** This technique can be useful for the preparation of metal-free solutions of volatile acids and bases for use in trace metal studies. The procedure involves placing two beakers, one of distilled water and the other of a solution of the material to be purified, in a desiccator. The desiccator is sealed and left to stand at room temperature for several days. The volatile components distribute themselves between the two beakers whereas the non-volatile contaminants remain in the original beaker. This technique has afforded metal-free pure solutions of ammonia, hydrochloric acid and hydrogen fluoride.
**RECRYSTALLISATION Techniques**

The most commonly used procedure for the purification of a solid material by recrystallisation from a solution involves the following steps:

(a) The impure material is dissolved in a suitable solvent, by shaking or vigorous stirring, at or near the boiling point, to form a near-saturated solution.

(b) The hot solution is filtered to remove any insoluble particles. To prevent crystallisation during this filtration, a heated filter funnel can be used or the solution can be diluted with more of the solvent.

(c) The solution is then allowed to cool so that the dissolved substance crystallises out.

(d) The crystals are separated from the mother liquor, either by centrifuging or by filtering, under suction, through a sintered glass, a Hirsch or a Büchner, funnel. Usually, centrifugation is preferred because of the greater ease and efficiency of separating crystals and mother liquor, and also because of the saving of time and effort, particularly when very small crystals are formed or when there is entrainment of solvent.

(e) The crystals are washed free from mother liquor with a little fresh cold solvent, then dried.

If the solution contains extraneous coloured material likely to contaminate the crystals, this can often be removed by adding some activated charcoal (decolorising carbon) to the hot, but not boiling, solution which is then shaken frequently for several minutes before being filtered. (The large active surface of the carbon makes it a good adsorbent for this purpose.) In general, the cooling and crystallisation steps should be rapid so as to give small crystals which occlude less of the mother liquor. This is usually satisfactory with inorganic material, so that commonly the filtrate is cooled in an ice-water bath while being vigorously stirred. In many cases, however, organic molecules crystallise much more slowly, so that the filtrate must be set aside to cool to room temperature or left in the refrigerator. It is often desirable to subject material that is very impure to preliminary purification, such as steam distillation, Soxhlet extraction, or sublimation, before recrystallising it. A greater degree of purity is also to be expected if the crystallisation process is repeated several times, especially if different solvents are used. The advantage of several crystallisations from different solvents lies in the fact that the material sought, and its impurities, are unlikely to have similar solubilities as solvents and temperatures are varied.

For the final separation of solid material, sintered-glass discs are preferable to filter paper. Sintered glass is unaffected by strongly acid solutions or by oxidising agents. Also, with filter paper, cellulose fibres are likely to become included in the sample. The sintered-glass discs or funnels can be readily cleaned by washing in freshly prepared *chronic acid cleaning mixture*. This mixture is made by adding 100mL of concentrated sulfuric acid slowly with stirring to a solution of 5g of sodium dichromate (CARE: cancer suspect) in 5mL of water. (The mixture warms to about 70º, see p 3).

For materials with very low melting points it is sometimes convenient to use dilute solutions in acetone, methanol, pentane, diethyl ether or CHCl₃-CCl₄. The solutions are cooled to -78º in a dry-ice/acetone bath, to give a slurry which is filtered off through a precooled Büchner funnel. Experimental details, as applied to the purification of nitromethane, are given by Parrett and Sun [*J Chem Educ* 54 448 1977].

Where substances vary little in solubility with temperature, *isothermal crystallisation* may sometimes be employed. This usually takes the form of a partial evaporation of a saturated solution at room temperature by leaving it under reduced pressure in a desiccator. However, in rare cases, crystallisation is not a satisfactory method of purification, especially if the impurity forms crystals that are isomorphous with the material being purified. In fact, the impurity content may even be greater in such recrystallised material. For this reason, it still remains necessary to test for impurities and to remove or adequately lower their concentrations by suitable chemical manipulation prior to recrystallisation.

**Filtration.** Filtration removes particulate impurities rapidly from liquids and is also used to collect insoluble or crystalline solids which separate or crystallise from solution. The usual technique is to pass the solution, cold or hot, through a fluted filter paper in a conical glass funnel.

If a solution is hot and needs to be filtered rapidly a Büchner funnel and flask are used and filtration is performed under a slight vacuum (water pump), the filter medium being a circular cellulose filter paper wet with solvent. If filtration is slow, even under high vacuum, a pile of about twenty filter papers, wet as before, are placed in the Büchner funnel and, as the flow of solution slows down, the upper layers of the filter paper are progressively removed. Alternatively, a filter aid, e.g. Celite, Florisil or Hyflo-supercel, is placed on top of a filter paper in the funnel. When the flow of the solution (under suction) slows down, the upper surface of the filter aid is scratched gently. Filter papers with various pore sizes are available covering a range of filtration rates. Hardened filter papers are slow filtering but they can withstand acidic and alkaline solutions without appreciable hydrolysis of the
Freeing a solution from extremely small particles [e.g. for optical rotatory dispersion (ORD) or circular dichroism (CD) measurements] requires filters with very small pore size. Commercially available (Millipore, Gelman, Nucleopore) filters other than cellulose or glass include nylon, Teflon, and polyvinyl chloride, and the pore diameter may be as small as 0.01 micron (see Table 6). Special containers are used to hold the filters, through which the solution is pressed by applying pressure, e.g. from a syringe. Some of these filters can be used to clear strong sulfuric acid solutions.

As an alternative to the Büchner funnel for collecting crystalline solids, a funnel with a sintered glass-plate under suction may be used. Sintered-glass funnels with various porosities are commercially available and can be easily cleaned with warm chromic or nitric acid (see above).

When the solid particles are too fine to be collected on a filter funnel because filtration is extremely slow, separation by centrifugation should be used. Bench type centrifuges are most convenient for this purpose. The solid is placed in the centrifuge tube, the tubes containing the solutions on opposite sides of the rotor should be balanced accurately (at least within 0.05 to 0.1g), and the solutions are spun at maximum speed for as long as it takes to settle the solid (usually ca 3-5 minutes). The solid is washed with cold solvent by centrifugation, and finally twice with a pure volatile solvent in which the solid is insoluble, also by centrifugation. After decanting the supernatant, the residue is dried in a vacuum, at elevated temperatures if necessary. In order to avoid “spitting” and contamination with dust while the solid in the centrifuge tube is dried, the mouth of the tube is covered with aluminium foil and held fast with a tight rubber band near the lip. The flat surface of the aluminium foil is then perforated in several places with a pin and the tube and contents are dried in a vacuum desiccator over a desiccant.

The following generalisations provide a rough guide to the selection of a suitable solvent:

1. The material is much more soluble at higher temperatures than it is at room temperature or below.
2. Well-formed (but not large) crystals are produced.
3. Impurities are either very soluble or only sparingly soluble.
4. The solvent must be readily removed from the purified material.
5. There must be no reaction between the solvent and the substance being purified.
6. The solvent must not be inconveniently volatile or too highly flammable. (These are reasons why diethyl ether and carbon disulfide are not commonly used in this way.)

The best solvents for recrystallisation have the following properties:

(a) The material is much more soluble at higher temperatures than it is at room temperature or below.
(b) Well-formed (but not large) crystals are produced.
(c) Impurities are either very soluble or only sparingly soluble.
(d) The solvent must be readily removed from the purified material.
(e) There must be no reaction between the solvent and the substance being purified.
(f) The solvent must not be inconveniently volatile or too highly flammable. (These are reasons why diethyl ether and carbon disulfide are not commonly used in this way.)

The following generalisations provide a rough guide to the selection of a suitable solvent:

(a) Substances usually dissolve best in solvents to which they are most closely related in chemical and physical characteristics. Thus, hydroxylic compounds are likely to be most soluble in water, methanol, ethanol, acetic acid or acetone. Similarly, petroleum ether might be used with water-insoluble substances. However, if the resemblance is too close, solubilities may become excessive.
(b) Higher members of homologous series approximate more and more closely to their parent hydrocarbon.
(c) Polar substances are more soluble in polar, than in non-polar, solvents.

Although Chapters 4, 5 and 6 provide details of the solvents used for recrystallising a large portion of commercially available laboratory chemicals, they cannot hope to be exhaustive, nor need they necessarily be the best choice. In other cases where it is desirable to use this process, it is necessary to establish whether a given solvent is suitable. This is usually done by taking only a small amount of material in a small test-tube and adding enough solvent to cover it. If it dissolves readily in the cold or on gentle warming, the solvent is unsuitable. Conversely, if it remains insoluble when the solvent is heated to boiling (adding more solvent if necessary), the solvent is again unsuitable. If the material dissolves in the hot solvent but does not crystallise readily within several minutes of cooling in an ice-salt mixture, another solvent should be tried.

Petroleum ethers are commercially available fractions of refined petroleum and are sold in fractions with about 20° boiling ranges. This ensures that little of the hydrocarbon ingredients boiling below the range is lost during standing or boiling when recrystallising a substance. Petroleum ethers with boiling ranges (at 760mm pressure) of 35—60°, 40—60°, 60—80°, 80—100°, and 100—120° are generally free from unsaturated and aromatic hydrocarbons. The lowest boiling petroleum ether commercially available has b 30—40°/760mm and is mostly n-pentane. The purer spectroscopic grades are almost completely free from olefinic and aromatic hydrocarbons. Petroleum spirit (which is sometimes used synonymously with petroleum ether or light
petroleum) is usually less refined petroleum, and ligroin is used for fractions boiling above 100°C. The lower boiling fractions consist of mixtures of n-pentane (b 36.0°C), n-hexane (b 68.5°C) and n-heptane (b 98°C), and some of their isomers in varying proportions. For purification of petroleum ether b 35-60°C see p. 324.

Solvents commonly used for recrystallisation, and their boiling points, are given in Table 7. For comments on the toxicity and use of benzene see the first pages of Chapters 4, 5 and 6.

**Mixed Solvents.** Where a substance is too soluble in one solvent and too insoluble in another, for either to be used for recrystallisation, it is often possible (provided they are miscible) to use them as a mixed solvent. (In general, however, it is preferable to use a single solvent if this is practicable.) Table 8 contains many of the common pairs of miscible solvents.

The technique of recrystallisation from mixed solvents is as follows:

The material is dissolved in the solvent in which it is the more soluble, then the other solvent (heated to near boiling) is added cautiously to the hot solution until a slight turbidity persists or crystallisation begins. This is cleared by adding several drops of the first solvent, and the solution is allowed to cool and crystallise in the usual way.

A variation of this procedure is simply to precipitate the material in a microcrystalline form from solution in one solvent at room temperature, by adding a little more of the second solvent, filtering off the crystals, adding a little more of the second solvent and repeating the process. This ensures, at least in the first or last precipitation, a material which contains as little as possible of the impurities, which may also be precipitated in this way. With salts, the first solvent is commonly water, and the second solvent is alcohol or acetone.

**Recrystallisation from the melt.** A crystalline solid melts when its temperature is raised sufficiently for the thermal agitation of its molecules or ions to overcome the restraints imposed by the crystal lattice. Usually, impurities weaken crystal structures, and hence lower the melting points of solids (or the freezing points of liquids). If an impure material is melted and cooled slowly (with the addition, if necessary, of a trace of solid material near the freezing point to avoid supercooling), the first crystals that form will usually contain less of the impurity, so that fractional solidification by partial freezing can be used as a purification process for solids with melting points lying in a convenient temperature range (or for more readily frozen liquids). Some examples of cooling baths that are useful in recrystallisation are summarised in Table 9. In some cases, impurities form higher melting eutectics with substances to be purified, so that the first material to solidify is less pure than the melt. For this reason, it is often desirable to discard the first crystals and also the final portions of the melt.

Substances having similar boiling points often differ much more in melting points, so that fractional solidification can offer real advantages, especially where ultrapurity is sought. For further information on this method of recrystallisation, consult the earlier editions of this book as well as references by Schwab and Wichers (J Res Nat Bur Stand. 25 747 1940). This method works best if the material is already nearly pure, and hence tends to be a final purification step.

**Zone refining.** Zone refining (or zone melting) is a particular development for fractional solidification and is applicable to all crystalline substances that show differences in the concentrations of impurities in liquid and solid states at solidification. The apparatus used in this technique consists essentially of a device in which the crystalline solid to be purified is placed in a glass tube (set vertically) which is made to move slowly upwards while it passes through a fixed coil (one or two turns) of heated wire. A narrow zone of molten crystals is formed when the tube is close to the heated coil. As the zone moves away from the coil the liquid crystallises, and a fresh molten zone is formed below it at the coil position. The machine can be set to recycle repeatedly. At its advancing side, the zone has a melting interface with the impure material whereas on the upper surface of the zone there is a constantly growing face of higher-melting, resolidified material. This leads to a progressive increase in impurity in the liquid phase which, at the end of the run, is discarded from the bottom of the tube. Also, because of the progressive increase in impurity in the liquid phase, the resolidified material contains correspondingly more of the impurities. For this reason, it is usually necessary to make several zone-melting runs before a sample is satisfactorily purified. This is also why the method works most successfully if the material is already fairly pure. In all these operations the zone must travel slowly enough to enable impurities to diffuse or be convected away from the area where resolidification is occurring.

The technique finds commercial application in the production of metals of extremely high purity (impurities down to 10-9 ppm), in purifying refractory oxides, and in purifying organic compounds, using commercially available equipment. Criteria for indicating that definite purification is achieved include elevation of melting point, removal of colour, fluorescence or smell, and a lowering of electrical conductivity. Difficulties likely to be found with organic compounds, especially those of low melting points and low rates of crystallisation, are supercooling and, because of surface tension and contraction, the tendency of the molten zone to seep back into the recrystallised areas. The method is likely to be useful in cases where fractional distillation is not practicable, either because of

**SUBLIMATION**

Sublimation differs from ordinary distillation because the vapour condenses to a solid instead of a liquid. Usually, the pressure in the heated system is diminished by pumping, and the vapour is condensed (after travelling a relatively short distance) onto a cold finger or some other cooled surface. This technique, which is applicable to many organic solids, can also be used with inorganic solids such as aluminium chloride, ammonium chloride, arsenious oxide and iodine. In some cases, passage of a stream of inert gas over the heated substance secures adequate vaporisation. This procedure has the added advantage of removing occluded solvent used in recrystallising the solid.

**CHROMATOGRAPHY**

Chromatography is often used with advantage for the purification of small amounts of complex organic mixtures. Chromatography techniques all rely on the differential distribution of the various components in a mixture between the mobile phase and the stationary phase. The mobile phase can either be a gas or a liquid whereas the stationary phase can either be a solid or a liquid.

The major chromatographic techniques can also be categorised according to the nature of the mobile phase used - vapour phase chromatography for when a gas is the mobile phase and liquid chromatography for when a liquid is the mobile phase.

A very useful catalog for chromatographic products and information relating to chromatography (from gas chromatography to biochromatography) is that produced by Merck, called the ChromBook and the associated compact disk, ChromCircle.

**Vapour phase chromatography (GC or gas-liquid chromatography)**

The mobile phase in vapour phase chromatography is a gas (e.g. hydrogen, helium, nitrogen or argon) and the stationary phase is a non-volatile liquid impregnated onto a porous material. The mixture to be purified is injected into a heated inlet whereby it is vapourised and taken into the column by the carrier gas. It is separated into its components by partition between the liquid on the porous support and the gas. For this reason vapour-phase chromatography is sometimes referred to as gas-liquid chromatography (g.l.c). Vapour phase chromatography is very useful in the resolution of a mixture of volatile compounds. This type of chromatography uses either packed or capillary columns. Packed columns have internal diameters of 3-5 mm with lengths of 2-6 m. These columns can be packed with a range of materials including firebrick derived materials (chromasorb P, for separation of non-polar hydrocarbons) or diatomaceous earth (chromasorb W, for separation of more polar molecules such as acids, amines). Capillary columns have stationary phase bonded to the walls of long capillary tubes. The diameters in capillary columns are less than 0.5 mm and the lengths of these columns can go up to 50 m! These columns have much superior separating powers than the packed columns. Elution times for equivalent resolutions with packed columns can be up to ten times shorter. It is believed that almost any mixture of compounds can be separated using one of the four stationary phases, OV-101, SE-30, OV-17 and Carbowax-20M. The use of capillary columns in gas chromatography for analysis is now routinely carried out. An extensive range of packed and capillary columns is available from chromatographic specialists such as Supelco, Alltech, Hewlett-Packard, Phenomenex etc.

Table 10 shows some typical liquids used for stationary phases in gas chromatography. Although vapour gas chromatography is routinely used for the analysis of mixtures, this form of chromatography can also be used for separation/purification of substances. This is known as preparative GC. In preparative GC, suitable packed columns are used and as substances emerge from the column, they are collected by condensing the vapour of these separated substances in suitable traps. The carrier gas blows the vapour through these traps hence these traps have to be very efficient. Improved collection of the effluent vapourised fractions in preparative work is attained by strong cooling, increasing the surface of the traps by packing them with glass wool, and by applying an electrical potential which neutralises the charged vapour and causes it to condense.

When the gas chromatograph is attached to a mass spectrometer, a very powerful analytical tool (gas chromatography-mass spectrometry, GC-MS) is produced. Vapour gas chromatography allows the analyses of mixtures but does not allow the definitive identification of unknown substances whereas mass spectrometry is good for the identification of a single compound but is less than ideal for the identification of mixtures of
Common Physical Techniques in Purification

compounds. This means that with GC-MS, both separation and identification of substances in mixtures can be achieved. Because of the relatively small amounts of material required for mass spectrometry, a splitting system is inserted between the column and the mass spectrometer. This enables only a small fraction of the effluent to enter the spectrometer, the rest of the effluent is usually collected or vented to the air.

Liquid chromatography
In contrast to vapour phase chromatography, the mobile phase in liquid chromatography is a liquid. In general, there are four main types of liquid chromatography: adsorption, partition, ion-chromatography, and gel filtration.

Adsorption chromatography is based on the difference in the extent to which substances in solution are adsorbed onto a suitable surface. The main techniques in adsorption chromatography are TLC (Thin Layer Chromatography), paper and column chromatography.

Thin layer chromatography (TLC). In thin layer chromatography, the mobile phase i.e. the solvent, creeps up the stationary phase (the absorbent) by capillary action. The adsorbent (e.g. silica, alumina, cellulose) is spread on a rectangular glass plate (or solid inert plastic sheet or aluminium foil). Some adsorbents (e.g. silica) are mixed with a setting material (e.g. CaSO₄) by the manufacturers which causes the film to set hard on drying. The adsorbent can be activated by heating at 100-110°C for a few hours. Other adsorbents (e.g. celluloses) adhere on glass plates without a setting agent. Thus some grades of absorbents have prefixes e.g. prefix G means that the absorbent can cling to a glass plate and is used for TLC (e.g. silica gel GF₅₄ for TLC plates which have a dye that fluoresces under 254nm UV light). Those lacking this binder have the letter H after any coding and is suitable for column chromatography e.g. silica gel 60H. The materials to be purified or separated are spotted in a solvent close to the lower end of the plate and allowed to dry. The spots will need to be placed at such a distance so as to ensure that when the lower end of the plate is immersed in the solvent, the spots are a few mm above the eluting solvent. The plate is placed upright in a tank containing the eluting solvent. Elution is carried out in a closed tank to ensure equilibrium. Good separations can be achieved with square plates if a second elution is performed at right angles to the first using a second solvent system. For rapid work, plates of the size of microscopic slides or even smaller are used which can decrease the elution time and cost without loss of resolution. The advantage of plastic backed and aluminium foil backed plates is that the size of the plate can be made as required by cutting the sheet with scissors or a sharp guillotine. Visualisation of substances on TLC can be carried out using UV light if they are UV absorbing or fluorescing substances or by spraying or dipping the plate with a reagent that gives coloured products with the substance (e.g. iodine solution or vapour gives brown colours with amines), or with dilute sulfuric acid (organic compounds become coloured or black when the plates are heated at 100°C if the plates are of alumina or silica, but not cellulose). (See Table 11 for some methods of visualisation.) Some alumina and silica powders are available with fluorescent materials in them, in which case the whole plate fluoresces under UV light. Non-fluorescing spots are thus clearly visible, and fluorescent spots invariably fluoresce with a different colour. The colour of the spots can be different under UV light at 254nm and at 365nm. Another useful way of showing up non-UV absorbing spots is to spray the plate with a 1-2% solution of Rhodamine 6G in acetone. Under UV light the dye fluoresces and reveals the non-fluorescing spots. For preparative work, if the material in the spot or fraction is soluble in ether or petroleum ether, the desired substance can be extracted from the absorbent with these solvents which leave the water soluble dye behind.

TLC can be used as an analytical technique, or as a guide to establishing conditions for column chromatography or as a preparative technique in its own right.

The thickness of the absorbent on the TLC plates could be between 0.2mm to 2mm or more. In preparative work, the thicker plates are used and hundreds of milligrams of mixtures can be purified conveniently and quickly. The spots or areas are easily scraped off the plates and the desired substances extracted from the absorbent with the required solvent. For preparative TLC, non destructive methods for visualising spots and fractions are required. As such, the use of UV light is very useful. If substances are not UV active, then a small section of the plate (usually the right or left edge of the plate) is sprayed with a visualising agent while the remainder of the plate is kept covered.

Thin layer chromatography (TLC) has been used successfully with ion-exchange celluloses as stationary phases and various aqueous buffers as mobile phases. Also, gels (e.g. Sephadex G-50 to G-200 superfine) have been adsorbed on glass plates and are good for fractionating substances of high molecular weights (1500 to 250,000). With this technique, which is called thin layer gel filtration (TLG), molecular weights of proteins can be determined when suitable markers of known molecular weights are run alongside (see Chapter 6). Commercially available pre-coated plates with a variety of adsorbents are generally very good for quantitative work because they are of a standard quality. Plates of a standardised silica gel 60 (as medium porosity silica gel with a mean porosity of 6mm) released by Merck have a specific surface of 500 m²/g and a specific pore volume of 0.75 mL/g. They are so efficient that they have been called high performance thin layer chromatography (HPTLC) plates (Ropphahn and Halpap J Chromatogr 112 81 1975). In another variant of thin layer chromatography the
adsorbent is coated with an oil as in gas chromatography thus producing reverse-phase thin layer chromatography. Reversed-phase TLC plates e.g. silica gel RP-18 are available from Fluka and Merck.

A very efficient form of chromatography makes use of a circular glass plate (rotor) coated with an adsorbent (silica, alumina or cellulose). As binding to a rotor is needed, the sorbents used may be of a special quality and/or binders are added to the sorbent mixtures. For example when silica gel is required as the absorbent, silica gel 60 PF-254 with calcium sulfate (Merck catalog 7749) is used. The thickness of the absorbent (1, 2 or 4 mm) can vary depending on the amount of material to be separated. The apparatus is called a Chromatotron (available from Harrison Research, USA). The glass plate is rotated by a motor, and the sample followed by the eluting solvent is allowed to drip onto a central position on the plate. As the plate rotates the solvent elutes the mixture, centrifugally, while separating the components in the form of circular bands radiating from the central point. The separated bands are usually visualised conveniently by UV and as the bands approach the edge of the plate, the eluent is collected. The plate with the adsorbent can be re-used many times if care is employed in the usage, and hence this form of chromatography utilises less absorbents as well as solvents.

Recipes and instructions for coating the rotors are available from the Harrison website (http://pw1.netcom.com/~ithres/harrisonresearch.html). In addition, information on how to regenerate the sorbents and binders are also included.

**Paper chromatography.** This is the technique from which thin layer chromatography developed. It uses cellulose paper (filter paper) instead of the TLC adsorbent and does not require a backing like the plastic sheet in TLC. It is used in the ascending procedure (like in TLC) whereby a sheet of paper is hung in a jar, the materials to be separated are spotted (after dissolving in a suitable solvent and drying) near the bottom of the sheet which dips into the eluting solvent just below the spot. As the solvent rises up the paper the spots are separated according to their adsorption properties. A variety of solvents can be used, the sheet is then dried in air (fume cupboard), and can then be run again with the solvent running at right angles to the first run to give a two dimensional separation. The spots can then be visualised as in TLC or can be cut out and analysed as required. A descending procedure had also been developed where the material to be separated is spotted near the top of the paper and the top end is made to dip into a tray containing the eluting solvent. The whole paper is placed in a glass jar and the solvent then runs down the paper causing the materials in the spots to separate also according to their adsorption properties and to the eluting ability of the solvent. This technique is much cheaper than TLC and is still used (albeit with thicker cellulose paper) with considerable success for the separation of protein hydrolysates for sequencising analysis and/or protein identification.

**Column Chromatography.** The substances to be purified are usually placed on the top of the column and the solvent is run down the column. Fractions are collected and checked for compounds using TLC (UV and/or other means of visualisation). The adsorbent for chromatography can be packed dry and solvents to be used for chromatography are used to equilibrate the adsorbent by flushing the column several times until equilibration is achieved. Alternatively, the column containing the adsorbent is packed wet (slurry method) and pressure is applied at the top of the column until the column is well packed (i.e. the adsorbent is settled).

**Graded Adsorbents and Solvents.** Materials used in columns for adsorption chromatography are grouped in Table 12 in an approximate order of effectiveness. Other adsorbents sometimes used include barium carbonate, calcium sulfate, calcium phosphate, charcoal (usually mixed with Kieselguhr or other form of diatomaceous earth, for example, the filter aid Celite) and cellulose. The alumina can be prepared in several grades of activity (see below).

In most cases, adsorption takes place most readily from non-polar solvents, such as petroleum ether and least readily from polar solvents such as alcohols, esters, and acetic acid. Common solvents, arranged in approximate order of increasing eluting ability are also given in Table 12. Eluting power roughly parallels the dielectric constants of solvents. The series also reflects the extent to which the solvent binds to the column material, thereby displacing the substances that are already adsorbed. This preference of alumina and silica gel for polar molecules explains, for example, the use of percolation through a column of silica gel for the following purposes—drying of ethylbenzene, removal of aromatics from 2,4-dimethylpentane and of ultraviolet absorbing substances from cyclohexane.

Mixed solvents are intermediate in strength and so provide a finely graded series. In choosing a solvent for use as an eluent it is necessary to consider the solubility of the substance in it, and the ease with which it can subsequently be removed.

**Preparation and Standardisation of Alumina.** The activity of alumina depends inversely on its water content, and a sample of poorly active material can be rendered more active by leaving for some time in a round bottomed flask heated up to about 200°C in an oil bath or a heating mantle while a slow stream of a dry inert gas is passed through it. Alternatively, it is heated to red heat (380-400°C) in an open vessel for 4-6h with
20 particles are removed by siphoning. The alumina is first suspended in 0.04M acetic acid, then in distilled water, and then washed with successive portions of ethyl acetate, acetone and finally with distilled water. Fine addition of about 3% (w/w) of water converts grade I alumina to grade II.

Alumina is normally slightly alkaline. A (less strongly adsorbing) neutral alumina can be prepared by making a slurry in water and adding 2M hydrochloric acid until the solution is acid to Congo red. The alumina is then filtered off, washed with distilled water until the wash water gives only a weak violet colour with Congo red paper, and dried. Alumina used in TLC can be recovered by washing in ethanol for 48h with occasional stirring, to remove binder material and then washed with successive portions of ethyl acetate, acetone and finally with distilled water. Fine particles are removed by siphoning. The alumina is first suspended in 0.04M acetic acid, then in distilled water, siphoning off 30 minutes after each wash. The process is repeated 7-8 times. It is then dried and activated at 200°C [Vogh and Thomson, Anal. Chim. Acta 53 (1981)].

Preparation of other adsorbents

Silica gel can be prepared from commercial water-glass by diluting it with water to a density of 1.19 and, while keeping it cooled to 5°C, adding concentrated hydrochloric acid with stirring until the solution is acid to thymol blue. After standing for 3h, the precipitate is filtered off, washed on a Büchner funnel with distilled water, then suspended in 0.2M hydrochloric acid. The suspension is set aside for 2-3 days, with occasional stirring, then filtered, washed well with water and dried at 110°C. It can be activated by heating up to about 200°C as described for alumina.

Powdered commercial silica gel can be purified by suspending and standing overnight in concentrated hydrochloric acid (6mL/g), decanting the supernatant and repeating with fresh acid until the latter remains colourless. After filtering with suction on a sintered-glass funnel, the residue is suspended in water and washed by decantation until free of chloride ions. It is then filtered, suspended in 95% ethanol, filtered again and washed on the filter with 95% ethanol. The process is repeated with anhydrous diethyl ether either before the gel is heated for 24h at 100°C and stored for another 24h in a vacuum desiccator over phosphorus pentoxide.

To buffer silica gel for flash chromatography (see later), 200g of silica is stirred in 1L of 0.2M NaH₂PO₄ for 30 minutes. The slurry is then filtered with suction using a sintered glass funnel. The silica gel is then activated at 110°C for 16 hours. The pH of the resulting silica gel is ~4. Similar procedures can be utilized to buffer the pH of the silica gel at various pHs (up to pH ~8: pH higher than this causes degradation of silica) using appropriate phosphate buffers.

Commercial silica gel has also been purified by suspension of 200g in 2L of 0.04M ammonia, allowed to stand for 5min before siphoning off the supernatant. The procedure was repeated 3-4 times, before rinsing with distilled water and drying, and activating the silica gel in an oven at 110°C [Vogh and Thomson, Anal. Chim. Acta 53 (1981)].

Although silica gel is not routinely recycled after use (due to fear of contamination as well as the possibility of reduced activity), the costs of using new silica gel for purification may be prohibitive. In these cases, recycling may be achieved by stirring the used silica gel (1 kg) in a mixture of methanol and water (2L MeOH/4L water) for 30-40 mins. The silica gel is filtered (as described above) and reactivated at 110°C for 16 hours.

Diatomaceous earth (Celite 535 or 545, Hyflo Super-cel, Dicalite, Kieselguhr, Diatophane) is purified before use by washing with 3M hydrochloric acid, then water, or it is made into a slurry with hot water, filtered at the pump and washed with water at 50°C until the filtrate is no longer alkaline to litmus. Organic materials can be removed by repeated extraction at 50°C with methanol or chloroform, followed by washing with methanol, filtering and drying at 90-100°C.

Charcoal is generally satisfactorily activated by heating gently to red heat in a crucible or quartz beaker in a muffle furnace, finally allowing to cool under an inert atmosphere in a desiccator. Good commercial activated charcoal is made from wood, e.g. Norit (from Birch wood), Darco and Nuchar. If the cost is important then the cheaper animal charcoal (bone charcoal) can be used. However, this charcoal contains calcium phosphate and other calcium salts and cannot be used with acidic materials. In this case the charcoal is boiled with dilute hydrochloric acid (1:1 by volume) for 2-3h, diluted with distilled water and filtered through a fine grade paper on a Büchner flask, washed with distilled water until the filtrate is almost neutral, and dried first in air then in a vacuum, and activated as above. To improve the porosity, charcoal columns are usually prepared in admixture with diatomaceous earth.
Cellulose for chromatography is purified by sequential washing with chloroform, ethanol, water, ethanol, chloroform and acetone. More extensive purification uses aqueous ammonia, water, hydrochloric acid, water, acetone and diethyl ether, followed by drying in a vacuum. Trace metals can be removed from filter paper by washing for several hours with 0.1M oxalic or citric acid, followed by repeated washing with distilled water.

Flash Chromatography
A faster method of separating components of a mixture is flash chromatography (see Still et al. J Org Chem 43 2923 1978). In flash chromatography the eluent flows through the column under a pressure of ca 1 to 4 atmospheres. The lower end of the chromatographic column has a relatively long taper closed with a tap. The upper end of the column is connected through a ball joint to a tap. Alternatively a specially designed chromatographic column with a solvent reservoir can also be used (for an example, see the Aldrich Chemical Catalog-glassware section). The tapered portion is plugged with cotton, or quartz, wool and as a dry powder or as a slurry in a solvent and allowed to fill to about one third of the column. A fine grade of adsorbent is required in order to slow the flow rate at the higher pressure, e.g. Silica 60, 230 to 400 mesh with particle size 0.040-0.063mm (from Merck). The adsorbent is then placed in the column as a dry powder or as a slurry in a solvent (the latter is optional). The top of the adsorbent is layered with 1 cm of fine washed sand (the latter is optional). The adsorbent is then placed in the column as a dry powder or as a slurry in a solvent and allowed to fill to about one third of the column. A fine grade of adsorbent is required in order to slow the flow rate at the higher pressure, e.g. Silica 60, 230 to 400 mesh with particle size 0.040-0.063mm (from Merck). The top of the adsorbent is layered with 1 cm of fine washed sand. The mixture in the smallest volume of solvent is applied at the top of the column and allowed to flow into the adsorbent under gravity by opening the lower tap momentarily. The top of the column is filled with eluent, the upper tap is connected by a tube to a nitrogen supply from a cylinder, or to compressed air, and turned on to the desired pressure (monitor with a gauge). The lower tap is turned on and fractions are collected rapidly until the level of eluent has reached the top of the adsorbent (do not allow the column to run dry). If further elution is desired then both taps are turned off, the column is filled with more eluting solvent and the process repeated. The top of the column can be modified so that gradient elution can be performed. Alternatively, an apparatus for producing the gradient is connected to the upper tap by a long tube and placed high above the column in order to produce the required hydrostatic pressure. Flash chromatography is more efficient and gives higher resolution than conventional chromatography at atmospheric pressure and is completed in a relatively shorter time. A successful separation of components of a mixture by TLC using the same adsorbent is a good indication that flash chromatography will give the desired separation on a larger scale.

Paired-ion Chromatography (PIC)
Mixtures containing ionic compounds (e.g. acids and/or bases), non-ionisable compounds, and zwitterions, can be separated successfully by paired-ion chromatography (PIC). It utilises the 'reverse-phase' technique (Eksberg and Schill Anal Chem 45 2092 1973). The stationary phase is lipophilic, such as ρ-BONDAPAK C18 or any other adsorbent that is compatible with water. The mobile phase is water or aqueous methanol containing the acidic or basic counter ion. Thus the mobile phase consists of dilute solutions of strong acids (e.g. 5mM 1-heptanesulfonic acid) or strong bases (e.g. 5 mM tetrabutylammonium phosphate) that are completely ionised at the operating pH values which are usually between 2 and 8. An equilibrium is set up between the neutral species of a mixture in the stationary phase and the respective ionised (anion or cation) species which dissolve in the mobile phase containing the counter ions. The extent of the equilibrium will depend on the ionisation constants of the respective components of the mixture, and the solubility of the unionised species in the stationary phase. Since the ionisation constants and the solubility in the stationary phase will vary with the water-methanol ratio of the mobile phase, the separation may be improved by altering this ratio gradually (gradient elution) or stepwise. If the compounds are eluted too rapidly the water content of the mobile phase should be increased, e.g. by steps of 10%. Conversely, if components do not move, or move slowly, the methanol content of the mobile phase should be increased by steps of 10%. The application of pressure to the liquid phase in liquid chromatography generally increases the separation (see HPLC). Also in PIC improved efficiency of the column is observed if pressure is applied to the mobile phase (Wittmer, Nuessle and Haney Anal Chem 47 1422 1975).

Ion-exchange Chromatography
Ion-exchange chromatography involves an electrostatic process which depends on the relative affinities of various types of ions for an immobilised assembly of ions of opposite charge. The stationary phase is an aqueous buffer with a fixed pH or an aqueous mixture of buffers in which the pH is continuously increased or decreased as the separation may require. This form of liquid chromatography can also be performed at high inlet pressures of liquid with increased column performances.

Ion-exchange Resins. An ion-exchange resin is made up of particles of an insoluble elastic hydrocarbon network to which is attached a large number of ionisable groups. Materials commonly used comprise synthetic ion-exchange resins made, for example, by crosslinking polystyrene to which has been attached non-
diffusible ionised or ionisable groups. Resins with relatively high crosslinkage (8-12%) are suitable for the chromatography of small ions, whereas those with low crosslinkage (2-4%) are suitable for larger molecules. Applications to hydrophobic systems are possible using aqueous gels with phenyl groups bound to the rigid matrix (Phenyl-Superose/Sepharose, Pharmacia-Amersham Biosciences) or neopentyl chains (Alkyl-Superose, Pharmacia-Amersham Biosciences). (Superose is a cross-linked agarose-based medium with an almost uniform bead size.) These groups are further distinguishable as strong [-SO\(_2\)OH, -NR\(_3^+\)] or weak [-OH, -CO\(_2\)H, -PO(OH)\(_2\), -NH\(_2\)]. Their charges are counterbalanced by diffusible ions, and the operation of a column depends on its ability and selectivity to replace these ions. The exchange that takes place is primarily an electrostatic process but adsorptive forces and hydrogen bonding can also be important. A typical sequence for the relative affinities of some common anions (and hence the inverse order in which they pass through such a column), is the following, obtained using a quaternary ammonium (strong base) anion-exchange column:

Fluoride < acetate < bicarbonate < hydroxide < formate < chloride < bromate < nitrite < cyanide < bromide < chromate < nitrate < iodide < thiocyanate < oxalate < sulfate < citrate.

For an amine (weak base) anion-exchange column in its chloride form, the following order has been observed:

Fluoride < chloride < bromide = iodide = acetate < molybdate < phosphate < arsenate < nitrate < tartrate < citrate < chromate < sulfate < hydroxide.

With strong cation-exchangers (e.g. with SO\(_3\)H groups), the usual sequence is that polyvalent ions bind more firmly than mono- or di-valent ones, a typical series being as follows:

\[ \text{Th}^{4+} > \text{Fe}^{3+} > \text{Al}^{3+} > \text{Ba}^{2+} > \text{Pb}^{2+} > \text{Sr}^{2+} > \text{Ca}^{2+} > \text{Co}^{2+} > \text{Ni}^{2+} = \text{Cu}^{2+} > \text{Zn}^{2+} = \text{Mg}^{2+} > \text{UO}^{2+} = \text{Mn}^{2+} > \text{Ag}^{+} > \text{Tl}^{+} > \text{Cs}^{+} > \text{Rb}^{+} > \text{NH}_4^+ = \text{K}^+ > \text{Na}^+ > \text{H}^+ > \text{Li}^+. \]

Thus, if an aqueous solution of a sodium salt contaminated with heavy metals is passed through the sodium form of such a column, the heavy metal ions will be removed from the solution and will be replaced by sodium ions from the column. This effect is greatest in dilute solution. Passage of sufficiently strong solutions of alkali metal salts or mineral acids readily displaces all other cations from ion-exchange columns. (The regeneration of columns depends on this property.) However, when the cations lie well to the left in the above series it is often advantageous to use a complex-forming species to facilitate removal. For example, iron can be displaced from ion-exchange columns by passage of sodium citrate or sodium ethylenediaminetetraacetate.

Some of the more common commercially available resins are listed in Table 13.

Ion-exchange resins swell in water to an extent which depends on the amount of crosslinking in the polymer, so that columns should be prepared from the wet material by adding it as a suspension in water to a tube already partially filled with water. (This also avoids trapping air bubbles.) The exchange capacity of a resin is commonly expressed as mg equiv./mL of wet resin. This quantity is pH-dependent for weak-acid or weak-base resins but is constant at about 0.6-2 for most strong-acid or strong-base types.

Apart from their obvious applications to inorganic species, sulfonic acid resins have been used in purifying amino acids, aminosugars, organic acids, peptides, purines, pyrimidines, nucleosides, nucleotides and polynucleotides. Thus, organic bases can be applied to the H\(^+\) form of such resins by adsorbing them from neutral solution and, after washing with water, they are eluted sequentially with suitable buffer solutions or dilute acids. Alternatively, by passing alkali solution through the column, the bases will be displaced in an order that is governed by their pK values. Similarly, strong-base anion exchangers have been used for aldehydes and ketones (as bisulfite addition compounds), carbohydrates (as their borate complexes), nucleosides, nucleotides, organic acids, phosphate esters and uronic acids. Weakly acidic and weakly basic exchange resins have also found extensive applications, mainly in resolving weakly basic and acidic species. For demineralisation of solutions, without large changes in pH, mixed-bed resins can be prepared by mixing a cation-exchange resin in its H\(^+\) form with an anion-exchange resin in its OH\(^-\) form. Commercial examples include Amberlite MB-1 (IR-120 + IRA-400) and Bio-Deminrolit (Zeo-Karb 225 and Zerolit FF). The latter is also available in a self-indicating form.

**Ion-exchange Celluloses and Sephadex.** A different type of ion-exchange column that finds extensive application in biochemistry for the purification of proteins, nucleic acids and acidic polysaccharides derives from cellulose by incorporating acidic and basic groups to give ion-exchangers of controlled acid and basic strengths. Commercially available cellulose-type resins are given in Tables 14 and 15. AG 501 x 8 (Bio-Rad) is a mixed-bed resin containing equivalents of AG 50W-x8 H\(^+\) form and AG 1-x8 HO\(^-\) form, and Bio-Rex MSZ 501 resin. A dye marker indicates when the resin is exhausted. Removal of unwanted cations, particularly of the transition metals, from amino acids and buffer can be achieved by passage of the solution through a column of Chelex 20 or Chelex 100. The metal-chelating abilities of the resin reside in the bonded iminodiacetate groups.

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### Table 13

<table>
<thead>
<tr>
<th>Resin Name</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Amberlite MB-1</td>
<td>IR-120 + IRA-400</td>
</tr>
<tr>
<td>Bio-Deminrolit</td>
<td>Zeo-Karb 225 and Zerolit FF</td>
</tr>
</tbody>
</table>

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### Table 14

<table>
<thead>
<tr>
<th>Resin Name</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>AG 501 x 8</td>
<td>Bio-Rad mixed-bed resin</td>
</tr>
</tbody>
</table>

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### Table 15

<table>
<thead>
<tr>
<th>Resin Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bio-Rex MSZ 501</td>
<td>Containing equivalents of AG 50W-x8 H(^+) form and AG 1-x8 HO(^-) form</td>
</tr>
</tbody>
</table>

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### References

For a more detailed discussion on the use of ion-exchange resins, see:[1](#) and [2](#).
Chelex can be regenerated by washing in two bed volumes of 1M HCl, two bed volumes of 1M NaOH and five bed volumes of water.

Ion-exchange celluloses are available in different particle sizes. It is important that the amounts of 'fines' are kept to a minimum otherwise the flow of liquid through the column can be extremely slow to the point of no liquid flow. Celluloses with a large range of particle sizes should be freed from 'fines' before use. This is done by suspending the powder in the required buffer and allowing it to settle for one hour and then decanting the 'fines'.

This separation appears to be wasteful but it is necessary for reasonable flow rates without applying high pressures at the top of the column. Good flow rates can be obtained if the cellulose column is packed dry whereby the 'fines' are evenly distributed throughout the column. Wet packing causes the 'fines' to rise to the top of the column, which thus becomes clogged.

Several ion-exchange celluloses require recycling before use, a process which must be applied for recovered celluloses. Recycling is done by stirring the cellulose with 0.1M aqueous sodium hydroxide, washing with water until neutral, then suspending in 0.1M hydrochloric acid and finally washing with water until neutral. When regenerating a column it is advisable to wash with a salt solution (containing the required counter ions) of increasing ionic strength up to 2M. The cellulose is then washed with water and recycled if necessary. Recycling can be carried out more than once if there are doubts about the purity of the cellulose and when the cellulose had been used previously for a different purification procedure than the one to be used. The basic matrix of these ion-exchangers is cellulose and it is important not to subject them to strong acid (> 1M) and strongly basic (> 1M) solutions.

When storing ion-exchange celluloses, or during prolonged usage, it is important to avoid growth of microorganisms or moulds which slowly destroy the cellulose. Good inhibitors of microorganisms are phenyl mercuric salts (0.001%, effective in weakly alkaline solutions), chlorhexidine (Hibitane at 0.002% for anion exchangers), 0.02% aqueous sodium azide or 0.005% of ethyl mercuric thiosalicylate (Merthiolate) are most effective in weakly acidic solutions for cation exchangers. Trichlorobutanol (Chloretone, at 0.05% is only effective in weakly acidic solutions) can be used for both anion and cation exchangers. Most organic solvents (e.g. methanol) are effective antimicrobial agents but only at high concentrations. These inhibitors must be removed by washing the columns thoroughly before use because they may have adverse effects on the material to be purified (e.g. inactivation of enzymes or other active preparations).

**Sephadex.** Other carbohydrate matrices such as Sephadex (based on dextran) have more uniform particle sizes. Their advantages over the celluloses include faster and more reproducible flow rates and they can be used directly without removal of ‘fines’. **Sephadex,** which can also be obtained in a variety of ion-exchange forms (see Table 15) consists of beads of a cross-linked dextran gel which swells in water and aqueous salt solutions. The smaller the bead size, the higher the resolution that is possible but the slower the flow rate. Typical applications of Sephadex gels are the fractionation of mixtures of polypeptides, proteins, nucleic acids, polysaccharides and for desalting solutions.

**Sephadex** is a bead form of cross-linked dextran gel. **Sephatoose CL** and **Bio-Gel A** are derived from agarose (see below). Sephadex ion-exchangers, unlike celluloses, are available in narrow ranges of particle sizes. These are of two medium types, the G-25 and G-50, and their dry bead diameter sizes are 30-40 µm. They are available as cation and anion exchange Sephadex. One of the disadvantages of using Sephadex ion-exchangers is that the bed volume can change considerably with alteration of pH. **Ultragel** also suffer from this disadvantage to a varying extent, but ion-exchangers of the bead type have been developed e.g. Fractogel, Toyopearl, which do not suffer from this disadvantage.

**Sephatoose.** (e.g. **Sephatoose CL** and **Bio-Gel A**) is a bead form of agarose gel which is useful for the fractionation of high molecular weight substances, for molecular weight determinations of large molecules (molecular weight > 5000), and for the immobilisation of enzymes, antibodies, hormones and receptors usually for affinity chromatography applications. In preparing any of the above for use in columns, the dry powder is evacuated, then mixed under reduced pressure with water or the appropriate buffer solution. Alternatively it is stirred gently with the solution until all air bubbles are removed. Because some of the wet powders change volumes reversibly with alteration of pH or ionic strength (see above), it is imperative to make allowances when packing columns (see above) in order to avoid overflowing of packing when the pH or salt concentrations are altered.

**Cellex CM** ion-exchange cellulose can be purified by treatment of 30-40g (dry weight) with 500mL of 1mM cysteine hydrochloride. It is then filtered through a Büchner funnel and the filter cake is suspended in 500mL of 0.05M NaCl/0.5M NaOH. This is filtered and the filter cake is resuspended in 500mL of distilled water and filtered again. The process is repeated until the washings are free from chloride ions. The filter cake is then suspended in 500mL of 0.01M buffer at the desired pH for chromatography, filtered, and the last step repeated several times.
Cellex D and other anionic cellulosics are washed with 0.25M NaCl/0.25M NaOH solution, then twice with deionised water. This is followed with 0.25M NaCl and then washed with water until chloride-free. The Cellex is then equilibrated with the desired buffer as above.

Crystalline Hydroxylapatite is a structurally organised, highly polar material which, in aqueous solution (in buffers) strongly adsorbs macromolecules such as proteins and nucleic acids, permitting their separation by virtue of the interaction with charged phosphate groups and calcium ions, as well as physical adsorption. The procedure therefore is not entirely ion-exchange in nature. Chromatographic separations of singly and doubly stranded DNA are readily achievable whereas there is negligible adsorption of low molecular weight species.

Gel Filtration
The gel-like, bead nature of wet Sephadex enables small molecules such as inorganic salts to diffuse freely into it while, at the same time, protein molecules are unable to do so. Hence, passage through a Sephadex column can be used for complete removal of salts from protein solutions. Polysaccharides can be freed from monosaccharides and other small molecules because of their differential retardation. Similarly, amino acids can be separated from proteins and large peptides. Gel filtration using Sephadex G-types (50 to 200) is essentially useful for fractionation of large molecules with molecular weights above 1000. For Superose, the range is given as 5000 to 5 x 10^6. Fractionation of lower molecular weight solutes (e.g. ethylene glycols, benzyl alcohols) can now be achieved with Sephadex G-10 (up to Mol.Wt 700) and G-25 (up to Mol.Wt 1500). These dextrans are used only in aqueous solutions. In contrast, Sephadex LH-20 and LH-60 (prepared by hydroxypropylation of Sephadex) are used for the separation of small molecules (Mol.Wt less than 500) using most of the common organic solvents as well as water. Sephasorb HP (ultrafine, prepared by hydroxypropylation of crossed-linked dextran) can also be used for the separation of small molecules in organic solvents and water, and in addition it can withstand pressures up to 1400 psi making it useful in HPLC. These gels are best operated at pH values between 2 and 12, because solutions with high and low pH values slowly decompose them (see further in Chapter 6).

High Performance Liquid Chromatography (HPLC)
When pressure is applied at the inlet of a liquid chromatographic column the performance of the column can be increased by several orders of magnitude. This is partly because of the increased speed at which the liquid flows through the column and partly because fine column packings which have larger surface areas can be used. Because of the improved efficiency of the columns, this technique has been referred to as high performance, high pressure, or high speed liquid chromatography and has found great importance in chemistry and biochemistry.

The equipment consists of a hydraulic system to provide the pressure at the inlet of the column, a detector, data storage and output, usually in the form of a computer. The pressures used in HPLC vary from a few psi to 4000-5000 psi. The most convenient pressures are, however, between 500 and 1800psi. The plumbing is made of stainless steel or non-corrosive metal tubing to withstand high pressures. Plastic tubing and connectors are used for low pressures, e.g. up to ~500psi. Increase of temperature has a very small effect on the performance of a column in liquid chromatography. Small variations in temperatures, however, do upset the equilibrium of the column, hence it is advisable to place the column in an oven at ambient temperature in order to achieve reproducibility. The packing (stationary phase) is specially prepared for withstanding high pressures. It may be an adsorbent (for adsorption or solid-liquid HPLC), a material impregnated with a high boiling liquid (e.g. octadecyl sulfate, in reverse-phase or liquid-liquid or paired-ion HPLC), an ion-exchange material (in ion-exchange HPLC), or a highly porous non-ionic gel (for high performance gel filtration). The mobile phase is water, aqueous buffers, salt solutions, organic solvents or mixtures of these. The more commonly used detectors have UV, visible, diode array or fluorescence monitoring for light absorbing substances, and refractive index monitoring and evaporative light scattering for transparent compounds. UV detection is not useful when molecules do not have UV absorbing chromophores and solvents for elution should be carefully selected when UV monitoring is used so as to ensure the lack of interference in detection. The sensitivity of the refractive index monitoring is usually lower than the light absorbing monitoring by a factor of ten or more. It is also difficult to use a refractive index monitoring system with gradient elution of solvents. When substances have readily oxidised and reduced forms, e.g. phenols, nitro compounds, heterocyclic compounds etc, then electrochemical detectors are useful. These detectors oxidise and reduce these substances and make use of this process to provide a peak on the recorder. The cells of the monitoring devices are very small (ca 5 µl) and the detection is very good. The volumes of the analytical columns are quite small (ca 2mL for a 1 metre column) hence the result of an analysis is achieved very quickly. Larger columns have been used for preparative work and can be used with the same equipment. Most
machines have solvent mixing chambers for solvent gradient or ion gradient elution. The solvent gradient (for two solvents) or pH or ion gradient can be adjusted in a linear, increasing or decreasing exponential manner. In general two different types of HPLC columns are available. Prepacked columns are those with metal casings with threads at both ends onto which capillary connections are attached. The cartridge HPLC columns are cheaper and are used with cartridge holders. As the cartridge is fitted with a groove for the holding device, no threads are necessary and the connection pieces can be reused. A large range of HPLC columns (including guard columns, i.e. small pre-columns) are available from Alltech, Supelco (see www.sigmaaldrich.com), Waters (www.waters.com), Agilent Technologies (www.chem.agilent.com), Phenomenex (www.phenomenex.com), YMC (www.ymc.co.jp/en/), Merck (www.merck.de), SGE (www.sge.com) and other leading companies. Included in this range of columns are also columns with chiral bonded phases capable of separating enantiomeric mixtures, such as Chiralpak AS and Chirex™ columns (e.g. from Restek-www.restekcorp.com, Daicel-www.daicel.co.jp/indexe.html).

HPLC systems coupled to mass spectrometers (LC-MS) are extremely important methods for the separation and identification of substances. If not for the costs involved in LC-MS, these systems would be more commonly found in research laboratories.

**Other Types of Liquid Chromatography**

New stationary phases for specific purposes in chromatographic separation are being continually proposed. Charge transfer adsorption chromatography makes use of a stationary phase which contains immobilised aromatic compounds and permits the separation of aromatic compounds by virtue of the ability to form charge transfer complexes (sometimes coloured) with the stationary phase. The separation is caused by the differences in stability of these complexes (Porath and Dahlgren-Caldwell J Chromatogr. 133 180 1977).

In metal chelate adsorption chromatography a metal is immobilised by partial chelation on a column which contains bi- or tri-dentate ligands. Its application is in the separation of substances which can complex with the bound metals and depends on the stability constants of the various ligands (Porath, Carlsson, Olsson and Belfrage Nature 258 598 1975; Loennerdal, Carlsson and Porath FEBS Lett 75 89 1977).

An application of chromatography which has found extensive use in biochemistry and has brought a new dimension in the purification of enzymes is affinity chromatography. A specific enzyme inhibitor is attached by covalent bonding to a stationary phase (e.g. AH-Sepharose 4B for acidic inhibitors and CH-Sepharose 4B for basic inhibitors), and will strongly bind only the specific enzyme which is inhibited, allowing all other proteins to flow through the column. The enzyme is then eluted with a solution of high ionic strength (e.g. 1M sodium chloride) or a solution containing a substrate or reversible inhibitor of the specific enzyme. (The ionic medium can be removed by gel filtration using a mixed-bed gel.) Similarly, an immobilised lectin may interact with the carbohydrate moiety of a glycoprotein. The most frequently used matrixes are cross-linked (4-6%) agarose and polyacrylamide gel. Many adsorbents are commercially available for nucleotides, coenzymes and vitamins, amino acids, peptides, lectins and related macromolecules and immunoglobulins. Considerable purification can be achieved by one passage through the column and the column can be reused several times. The affinity method may be biospecific, for example as an antibody-antigen interaction, or chemical as in the chelation of boronate by cis-diols, or of unknown origin as in the binding of certain dyes to albumin and other proteins.

Hydrophobic adsorption chromatography takes advantage of the hydrophobic properties of substances to be separated and has also found use in biochemistry (Hoftsee Biochem Biophys Res Commun 59 751 1973; Jennissen and Heilmayer Jr Biochemistry 14 754 1975). Specific covalent binding with the stationary phase, a procedure that was called covalent chromatography, has been used for separation of compounds and for immobilising enzymes on a support: the column was then used to carry out specific biologic reactions (Mosbach Method Enzymol 44 1976; A.Rosevear, J.F.Kennedy and J.M.S.Cabral, Immobilised Enzymes and Cells: A Laboratory Manual, Adam Hilger, Bristol, 1987, ISBN 085274515X).

**DRYING**

**Removal of Solvents**

Where substances are sufficiently stable, removal of solvent from recrystallised materials presents no problems. The crystals, after filtering at the pump (and perhaps air-drying by suction), are heated in an oven above the boiling point of the solvent (but below this melting point of the crystals), followed by cooling in a desiccator. Where this treatment is inadvisable, it is still often possible to heat to a lower temperature under reduced pressure, for example in an Abderhalden pistol. This device consists of a small chamber which is heated externally by the vapour of a boiling solvent. Inside this chamber, which can be evacuated by a water pump or some other vacuum pump, is
placed a small boat containing the sample to be dried and also a receptacle with a suitable drying agent. Convenient liquids for use as boiling liquids in an Abderhalden pistol, and their temperatures, are given in Table 16. Alternatively an electrically heated drying pistol can also be used. In cases where heating above room temperature cannot be used, drying must be carried out in a vacuum desiccator containing suitable absorbents. For example, hydrocarbons, such as cyclohexane and petroleum ether, can be removed by using shredded paraffin wax, and acetic acid and other acids can be absorbed by pellets of sodium or potassium hydroxide. However, in general, solvent removal is less of a problem than ensuring that the water content of solids and liquids is reduced below an acceptable level.

**Removal of Water**

Methods for removing water from solids depends on the thermal stability of the solids or the time available. The safest way is to dry in a vacuum desiccator over concentrated sulfuric acid, phosphorus pentoxide, silica gel, calcium chloride, or some other desiccant. Where substances are stable in air and melt above 100°C, drying in an air oven may be adequate. In other cases, use of an Abderhalden pistol may be satisfactory.

Often, in drying inorganic salts, the final material that is required is a hydrate. In such cases, the purified substance is left in a desiccator to equilibrate above an aqueous solution having a suitable water-vapour pressure. A convenient range of solutions used in this way is given in Table 17.

The choice of desiccants for drying liquids is more restricted because of the need to avoid all substances likely to react with the liquids themselves. In some cases, direct distillation of an organic liquid is a suitable method for drying both solids and liquids, especially if low-boiling azeotropes are formed. Examples include acetone, aniline, benzene, chloroform, carbon tetrachloride, heptane, hexane, methanol, nitrobenzene, petroleum ether, toluene and xylene. Addition of benzene can be used for drying ethanol by distillation. In carrying out distillations intended to yield anhydrous products, the apparatus should be fitted with guard-tubes containing calcium chloride or silica gel to prevent entry of moist air into the system. (Many anhydrous organic liquids are appreciably hygroscopic).

Traces of water can be removed from solvents such as benzene, 1,2-dimethoxyethane, diethyl ether, pentane, toluene and tetrahydrofuran by refluxing under nitrogen a solution containing sodium wire and benzophenone, and fractionally distilling. Drying with, and distilling from CaH₂ is applicable to a number of solvents including toluene and tetrahydrofuran. Addition of benzene can be used for drying ethanol by distillation. In carrying out distillations intended to yield anhydrous products, the apparatus should be fitted with guard-tubes containing calcium chloride or silica gel to prevent entry of moist air into the system. (Many anhydrous organic liquids are appreciably hygroscopic).

Removal of water from gases may be by physical or chemical means, and is commonly by adsorption on to a drying agent in a low-temperature trap. The effectiveness of drying agents depends on the vapour pressure of the hydrated compound - the lower the vapour pressure the less the remaining moisture in the gas.

The most usually applicable of the specific methods for detecting and determining water in organic liquids is due to Karl Fischer. (See J.Mitchell and D.M.Smith, *Aquametry*, 2nd Ed, J Wiley & Sons, New York, 1977-1984, ISBN 0471022640; Fieser and Fieser *Reagents for Organic Synthesis*, J.Wiley & Sons, NY, Vol 1, 528 1967, ISBN 02711616X). Other techniques include electrical conductivity measurements and observation of the temperature at which the first cloudiness appears as the liquid is cooled (applicable to liquids in which water is only slightly soluble). Addition of anhydrous cobalt (II) iodide (blue) provides a convenient method (colour change to pink on hydration) for detecting water in alcohols, ketones, nitriles and some esters. Infrared absorption measurements of the broad band for water near 3500 cm⁻¹ can also sometimes be used for detecting water in non-hydroxylic substances.

For further useful information on mineral adsorbents and drying agents, go to the SigmaAldrich website, under technical library (Aldrich) for technical bulletin AL-143.

**Intensity and Capacity of Common Desiccants**

Drying agents are conveniently grouped into three classes, depending on whether they combine with water reversibly, they react chemically (irreversibly) with water, or they are molecular sieves. The first group vary in their drying intensity with the temperature at which they are used, depending on the vapour pressure of the hydrate that is formed. This is why, for example, drying agents such as anhydrous sodium sulfate, magnesium sulfate or calcium chloride should be filtered off from the liquids before the latter are heated. The intensities of drying agents belonging to this group fall in the sequence:

\[
\begin{align*}
\text{P}_2\text{O}_5 & \gg \text{BaO} \gg \text{Mg(ClO}_4)\text{)}_2, \text{CaO, MgO, KOH (fused), conc H}_2\text{SO}_4, \text{CaSO}_4, \text{Al}_2\text{O}_3 \gg \text{KO} \text{H (pellets)}, \\
\text{silica gel, Mg(ClO}_4)\text{)}_2, \text{3H}_2\text{O} & \gg \text{NaOH (fused), 95% H}_2\text{SO}_4, \text{CaBr}_2, \text{CaCl}_2 \gg \text{NaOH (pellets),} \\
\text{Ba(ClO}_4)\text{)}_2, \text{ZnCl}_2, \text{ZnBr}_2 & \gg \text{CaCl}_2 \text{(technical)} \gg \text{CuSO}_4 \gg \text{Na}_2\text{SO}_4, \text{K}_2\text{CO}_3.
\end{align*}
\]

Where large amounts of water are to be removed, a preliminary drying of liquids is often possible by shaking with concentrated solutions of sodium sulfate or potassium carbonate, or by adding sodium chloride to salt out the organic phase (for example, in the drying of lower alcohols), as long as the drying agent does not react (e.g. CaCl₂ with alcohols and amines, see below).
Drying agents that combine irreversibly with water include the alkali metals, the metal hydrides (discussed in Chapter 2), and calcium carbide.

### Suitability of Individual Desiccants

**Alumina.** (Preheated to 175°C for about 7h). Mainly as a drying agent in a desiccator or as a column through which liquid is percolated.

**Aluminium amalgam.** Mainly used for removing traces of water from alcohols via refluxing followed by distillation.

**Barium oxide.** Suitable for drying organic bases.

**Barium perchlorate.** Expensive. Used in desiccators (covered with a metal guard). Unsuitable for drying solvents or organic material where contact is necessary, because of the danger of EXPLOSION.

**Boric anhydride.** (Prepared by melting boric acid in an air oven at a high temperature, cooling in a desiccator, and powdering.) Mainly used for drying formic acid.

**Calcium chloride (anhydrous).** Cheap. Large capacity for absorption of water, giving the hexahydrate below 30°C, but is fairly slow in action and not very efficient. Its main use is for preliminary drying of alkyl and aryl halides, most esters, saturated and aromatic hydrocarbons and ethers. Unsuitable for drying alcohols and amines (which form addition compounds), fatty acids, amides, amino acids, ketones, phenols, or some aldehydes and esters. Calcium chloride is suitable for drying the following gases: hydrogen, hydrogen chloride, carbon monoxide, carbon dioxide, sulfur dioxide, nitrogen, methane, oxygen, also paraffins, ethers, olefins and alkyl chlorides.

**Calcium hydride.** See Chapter 2.

**Calcium oxide.** (Preheated to 700-900°C before use.) Suitable for alcohols and amines (but does not dry them completely). Need not be removed before distillation, but in that case the head of the distillation column should be packed with glass wool to trap any calcium oxide powder that might be carried over. Unsuitable for acidic compounds and esters. Suitable for drying gaseous amines and ammonia.

**Calcium sulfate (anhydrous).** (Prepared from the heptahydrate by drying at 300°C under reduced pressure.) More rapid and effective than sodium sulfate but is slightly acidic. It has a large capacity, forming MgSO₄·7H₂O below 48°C. Suitable for the preliminary drying of most organic compounds.

**Copper (II) sulfate (anhydrous).** Suitable for esters and alcohols. Preferable to sodium sulfate in cases where solvents are sparingly soluble in water (for example, benzene or toluene).

**Lithium aluminum hydride.** See Chapter 2.

**Magnesium amalgam.** Mainly used for removing traces of water from alcohols by refluxing the alcohol in the presence of the Mg amalgam followed by distillation.

**Magnesium perchlorate (anhydrous).** (Available commercially as Dehydrite.) Used in desiccators. Unsuitable for drying solvents or any organic material where contact is necessary, because of the danger of EXPLOSION.

**Magnesium sulfate (anhydrous).** (Prepared from the heptahydrate by drying at 300°C under reduced pressure.) More rapid and effective than sodium sulfate but is slightly acidic. It has a large capacity, forming MgSO₄·7H₂O below 48°C. Suitable for the preliminary drying of most organic compounds.

**Molecular sieves.** See later.

**Phosphorus pentoxide.** Very rapid and efficient, but difficult to handle and should only be used after the organic material has been partially dried, for example with magnesium sulfate. Suitable for anhydrides, alkyl and aryl halides, ethers, esters, hydrocarbons and nitriles, and for use in desiccators. Not suitable with acids, alcohols, amines or ketones, or with organic molecules from which a molecule of water can be eliminated. Suitable for drying the following gases: hydrogen, oxygen, carbon dioxide, carbon monoxide, sulfur dioxide, nitrogen, methane, ethene and paraffins. It is available on a solid support with an indicator under the name Sicapent (from Merck). The colour changes in Sicapent depend on the percentage of water present (e.g. in the absence of water, Sicapent is colorless but becomes green with 20% water and blue with 33% w/w water). When the quantity of water in the desiccator is high a crust of phosphoric acid forms a layer over the phosphorus pentoxide powder and decreases its efficiency. The crust can be removed with a spatula to expose the dry powder and restore the desiccant property.

**Potassium (metal).** Properties and applications are similar to those for sodium but as the reactivity is greater than that of sodium, the hazards are greater than that of sodium. **Handle with extreme care.**
Potassium carbonate (anhydrous). Has a moderate efficiency and capacity, forming the dihydrate. Suitable for an initial drying of alcohols, bases, esters, ketones and nitriles by shaking with them, then filtering off. Also suitable for salting out water-soluble alcohols, amines and ketones. Unsuitable for acids, phenols, thiols and other acidic substances.

Potassium carbonate. Solid potassium hydroxide is very rapid and efficient. Its use is limited almost entirely to the initial drying of organic bases. Alternatively, sometimes the base is shaken first with a concentrated solution of potassium hydroxide to remove most of the water present. Unsuitable for acids, aldehydes, ketones, phenols, thiols, amides and esters. Also used for drying gaseous amines and ammonia.

Silica gel. Granulated silica gel is a commercially available drying agent for use with gases, in desiccators, and (because of its chemical inertness) in physical instruments (pH meters, spectrometers, balances). Its drying action depends on physical adsorption, so that silica gel must be used at room temperature or below. By incorporating cobalt chloride into the material it can be made self indicating (blue when dry, pink when wet), re-drying in an oven at 110° being necessary when the colour changes from blue to pink.

Sodium (metal). Used as a fine wire or as chips, for more completely drying ethers, saturated hydrocarbons and aromatic hydrocarbons which have been partially dried (for example with calcium chloride or magnesium sulfate). Unsuitable for acids, alcohols, alkyl halides, aldehydes, ketones, amines and esters. Reacts violently if water is present and can cause a fire with highly flammable liquids.

Sodium hydroxide. Properties and applications are similar to those for potassium hydroxide.

Sodium-potassium alloy. Used as lumps. Lower melting than sodium, so that its surface is readily renewed by shaking. Properties and applications are similar to those for sodium.

Sodium sulfate (anhydrous). Has a large capacity for absorption of water, forming the decahydrate below 330, but drying is slow and inefficient, especially for solvents that are sparingly soluble in water. It is suitable for the preliminary drying of most types of organic compounds.

Sulfuric acid (concentrated). Widely used in desiccators. Suitable for drying bromine, saturated hydrocarbons, alkyl and aryl halides. Also suitable for drying the following gases: hydrogen, nitrogen, carbon dioxide, carbon monoxide, chlorine, methane and paraffins. Unsuitable for alcohols, bases, ketones or phenols. Also available on a solid support with an indicator under the name Sicacide (from Merck) for desiccators. The colour changes in Sicacide depends on the percentage of water present (e.g. when dry Sicacide is red-violet but becomes pale violet with 27% water and pale yellow to colorless with 33% w/w water).

For convenience, many of the above drying agents are listed in Table 18 under the classes of organic compounds for which they are commonly used.

Molecular sieves

Molecular sieves are types of adsorbents composed of crystalline zeolites (sodium and calcium aluminosilicates). By heating them, water of hydration is removed, leaving holes of molecular dimensions in the crystal lattices. These holes are of uniform size and allow the passage into the crystals of small molecules, but not of large ones. This sieving action explains their use as very efficient drying agents for gases and liquids. The pore size of these sieves can be modified (within limits) by varying the cations built into the lattices. The four types of molecular sieves currently available are:

Type 3A sieves. A crystalline potassium aluminosilicate with a pore size of about 3 Angstroms. This type of molecular sieves is suitable for drying liquids such as acetone, acetonitrile, methanol, ethanol and 2-propanol, and drying gases such as acetylene, carbon dioxide, ammonia, propylene and butadiene. The material is supplied as beads or pellets.

Type 4A sieves. A crystalline sodium aluminosilicate with a pore size of about 4 Angstroms, so that, besides water, ethane molecules (but not butane) can be adsorbed. This type of molecular sieves is suitable for drying chloroform, dichloromethane, diethyl ether, dimethylformamide, ethyl acetate, cyclohexane, benzene, toluene, xylene, pyridine and diisopropyl ether. It is also useful for low pressure air drying. The material is supplied as beads, pellets or powder.

Type 5A sieves. A crystalline calcium aluminosilicate with a pore size of about 5 Angstroms, these sieves adsorb larger molecules than type 4A. For example, as well as the substances listed above, propane, butane, hexane, butene, higher n-olefins, n-butyl alcohol and higher n-alcohols, and cyclopropane can be adsorbed, but not branched-chain C6 hydrocarbons, cyclic hydrocarbons such as benzene and cyclohexane, or secondary and tertiary alcohols, carbon tetrachloride or boron trifluoride. This is the type generally used for drying gases, though organic liquids such as THF and dioxane can be dried with this type of molecular sieves.
Type 13X sieves. A crystalline sodium aluminosilicate with a pore size of about 10 Angstroms which enables many branched-chain and cyclic compounds to be adsorbed, in addition to all the substances removed by type 5A sieves.

They are unsuitable for use with strong acids but are stable over the pH range 5-11. Because of their selectivity, molecular sieves offer advantages over silica gel, alumina or activated charcoal, especially in their very high affinity for water, polar molecules and unsaturated organic compounds. Their relative efficiency is greatest when the impurity to be removed is present at low concentrations. Thus, at 25°C and a relative humidity of 2%, type 5A molecular sieves adsorb 18% by weight of water, whereas for silica gel and alumina the figures are 3.5 and 2.5% respectively. Even at 100°C and a relative humidity of 1.3% molecular sieves adsorb about 15% by weight of water.

The greater preference of molecular sieves for combining with water molecules explains why this material can be used for drying ethanol and why molecular sieves are probably the most universally useful and efficient drying agents. Percolation of ethanol with an initial water content of 0.5% through a 144 cm long column of type 4A molecular sieves reduced the water content to 10 ppm. Similar results have been obtained with pyridine.

The main applications of molecular sieves to purification comprise:

1. Drying of gases and liquids containing traces of water.
2. Drying of gases at elevated temperatures.
3. Selective removal of impurities (including water) from gas streams.

(For example, carbon dioxide from air or ethene; nitrogen oxides from nitrogen; methanol from diethyl ether. In general, carbon dioxide, carbon monoxide, ammonia, hydrogen sulfide, mercaptans, ethane, ethene, acetylene (ethyne), propane and propylene are readily removed at 25°C. In mixtures of gases, the more polar ones are preferentially adsorbed).

The following applications include the removal of straight-chain from branched-chain or cyclic molecules. For example, type 5A sieves will adsorb n-butyl alcohol but not its branched-chain isomers. Similarly, it separates n-tetradecane from benzene, or n-heptane from methylcyclohexane.

The following liquids have been dried with molecular sieves: acetone, acetonitrile, acrylonitrile, allyl chloride, amyl acetate, benzene, butadiene, n-butane, butene, butyl acetate, n-butylamine, n-butyl chloride, carbon tetrachloride, chloroethane, 1-chloro-2-ethylhexane, cyclohexane, dichloromethane, dichloroethane, 1,2-dichloropropene, 1,1-dimethoxyethane, dimethyl ether, 2-ethylhexanol, 2-ethylhexylamine, n-heptane, n-hexane, isoprene, isopropyl alcohol, diisopropyl ether, methanol, methyl ethyl ketone, oxygen, n-pentane, phenol, propane, n-propyl alcohol, propylene, pyridine, styrene, tetrachloroethylene, toluene, trichloroethylene and xylene.

In addition, the following gases have been dried: acetylene, argon, carbon dioxide, chlorine, ethene, helium, hydrogen, hydrogen chloride, hydrogen sulfide, nitrogen, oxygen and sulfur hexafluoride.

After use, molecular sieves can be regenerated by heating at between 300°C-350°C for several hours, preferably in a stream of dry inert gas such as nitrogen or preferably under vacuum, then cooling in a desiccator. Special precautions must be taken before regeneration of molecular sieves used in the drying of flammable solvents. However, care must be exercised in using molecular sieves for drying organic liquids. Appreciable amounts of impurities were formed when samples of acetone, 1,1,1-trichloroethane and methyl-t-butyl ether were dried in the liquid phase by contact with molecular sieves 4A (Connett Lab Prac 21 545 1972). Other, less reactive types of sieves may be more suitable but, in general, it seems desirable to make a preliminary test to establish that no unwanted reaction takes place. Useful comparative data for Type 4A and 5A sieves are in Table 19.

MISCELLANEOUS TECHNIQUES

Freeze-pump-thaw and purging

Volatile contaminants, e.g. traces of low boiling solvent residue or oxygen, in liquid samples or solutions can be very deleterious to the samples on storage. These contaminants can be removed by repeated freeze-pump-thaw cycles. This involves freezing the liquid material under high vacuum in an appropriate vessel (which should be large enough to avoid contaminating the vacuum line with liquid that has bumped) connected to the vacuum line via efficient liquid nitrogen traps. The frozen sample is then thawed until it liquefies, kept in this form for some time (ca 10-15 min), refreezing the sample and the cycle repeated several times without interrupting the vacuum. This procedure applies equally well to solutions, as well as purified liquids, e.g. as a means of removing oxygen from solutions for NMR and other measurements. If the presence of nitrogen, helium or argon, is not a serious contaminant then solutions can be freed from gases, e.g. oxygen, carbon dioxide, and volatile impurities by purging with N₂, He or Ar at room, or slightly elevated, temperature. The gases used for purging are then removed by freeze-pump-thaw cycles or simply by keeping in a vacuum for several hours. Special NMR tubes
with a screw cap thread and a PTFE valve (Wilmad) are convenient for freeze thawing of NMR samples. Alternatively NMR tubes with "J Young" valves (Wilmad) can also be used.

Vacuum-lines, Schlenk and glovebox techniques
Manipulations involving materials sensitive to air or water vapour can be carried out by these procedures. Vacuum-line methods make use of quantitative transfers, and P(pressure)-V(volume)-T(temperature) measurements, of gases, and trap-to-trap separations of volatile substances. It is usually more convenient to work under an inert-gas atmosphere using Schlenk type apparatus. The principle of Schlenk methods involve a flask/vessel which has a standard ground-glass joint and a sidearm with a tap. The system can be purged by evacuating and flushing with an inert gas (usually nitrogen, or in some cases, argon), repeating the process until the contaminants in the vapour phases have been diminished to acceptable limits. A large range of Schlenk glassware is commercially available (e.g. see Aldrich Chemical Catalog and the associated technical bulletin AL-166). With these, and tailor-made pieces of glassware, inert atmospheres can be maintained during crystallisation, filtration, sublimation and transfer.

Syringe techniques have been developed for small volumes, while for large volumes or where much manipulation is required, dryboxes (glove boxes) or dry chambers should be used.

ABBREVIATIONS
Titles of periodicals are defined as in the Chemical Abstracts Service Source Index (CASSI), except that full stops have been omitted after each abbreviated word. Abbreviations of words in the texts of Chapters 4, 5 and 6 are those in common use and are self evident, e.g. distn, filtd, conc and vac are used for distillation, filtered, concentrated and vacuum.

TABLES

<table>
<thead>
<tr>
<th>TABLE 1. SOME COMMON IMMISCIBLE OR SLIGHTLY MISCIBLE PAIRS OF SOLVENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon tetrachloride with ethanolamine, ethylene glycol, formamide or water.</td>
</tr>
<tr>
<td>Dimethyl formamide with cyclohexane or petroleum ether.</td>
</tr>
<tr>
<td>Dimethyl sulfoxide with cyclohexane or petroleum ether.</td>
</tr>
<tr>
<td>Ethyl ether with ethanolamine, ethylene glycol or water.</td>
</tr>
<tr>
<td>Methanol with carbon disulfide, cyclohexane or petroleum ether.</td>
</tr>
<tr>
<td>Petroleum ether with aniline, benzyl alcohol, dimethyl formamide, dimethyl sulfoxide, formamide, furfuryl alcohol, phenol or water.</td>
</tr>
<tr>
<td>Water with aniline, benzene, benzyl alcohol, carbon disulfide, carbon tetrachloride, chloroform, cyclohexane, cyclohexanol, cyclohexanone, diethyl ether, ethyl acetate, isoamyl alcohol, methyl ethyl ketone, nitromethane, tributyl phosphate or toluene.</td>
</tr>
</tbody>
</table>
### TABLE 2. **AQUEOUS BUFFERS**

<table>
<thead>
<tr>
<th>Approx. pH</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2N sulfuric acid or N hydrochloric acid</td>
</tr>
<tr>
<td>1</td>
<td>0.1N hydrochloric acid or 0.18N sulfuric acid</td>
</tr>
<tr>
<td>2</td>
<td>Both 0.01N hydrochloric acid or 0.013N sulfuric acid. Or 50 mL of 0.1M glycine (also 0.1M NaCl) + 50 mL of 0.1N hydrochloric acid</td>
</tr>
<tr>
<td>3</td>
<td>Either 20 mL of the 0.2M Na₂HPO₄ + 80 mL of 0.1M citric acid Or 50 mL of 0.1M glycine + 22.8 mL of 0.1N hydrochloric acid in 100 mL</td>
</tr>
<tr>
<td>4</td>
<td>Either 38.5 mL of 0.2M Na₂HPO₄ + 61.5 mL of 0.1M citric acid Or 18 mL of 0.2M NaOAc + 82 mL of 0.2M acetic acid</td>
</tr>
<tr>
<td>5</td>
<td>Either 70 mL of 0.2M NaOAc + 30 mL of 0.2M acetic acid Or 51.5 mL of 0.2M Na₂HPO₄ + 48.5 mL of 0.1M citric acid</td>
</tr>
<tr>
<td>6</td>
<td>63 mL of 0.2M Na₂HPO₄ + 37 mL of 0.1M citric acid</td>
</tr>
<tr>
<td>7</td>
<td>82 mL of 0.2M Na₂HPO₄ + 18 mL of 0.1M citric acid</td>
</tr>
<tr>
<td>8</td>
<td>Either 50 mL of 0.1M Tris buffer + 29 mL of 0.1N hydrochloric acid, in 100 mL Or 50 mL of 0.05M borax + 70 mL of 0.2M boric acid</td>
</tr>
<tr>
<td>9</td>
<td>80 mL of 0.05M borax + 20 mL of 0.2M boric acid</td>
</tr>
<tr>
<td>10</td>
<td>Either 25 mL of 0.05M borax + 43 mL of 0.1N NaOH, in 100 mL Or 50 mL of 0.1M glycine + 32 mL of 0.1N NaOH, in 100 mL</td>
</tr>
<tr>
<td>11</td>
<td>50 mL of 0.15M Na₂HPO₄ + 15 mL of 0.1N NaOH</td>
</tr>
<tr>
<td>12</td>
<td>50 mL of 0.15M Na₂HPO₄ + 75 mL of 0.1N NaOH</td>
</tr>
<tr>
<td>13</td>
<td>0.1N NaOH or KOH</td>
</tr>
<tr>
<td>14</td>
<td>N NaOH or KOH</td>
</tr>
</tbody>
</table>

These buffers are suitable for use in obtaining ultraviolet spectra. Alternatively, for a set of accurate buffers of low, but constant, ionic strength (I = 0.01) covering a pH range 2.2 to 11.6 at 20°, see Perrin Aust J Chem 16 572 1963. "In 100 mL" means that the solution is made up to 100 mL with pure water.
TABLE 3A. PREDICTED EFFECT OF PRESSURE ON BOILING POINT*

<table>
<thead>
<tr>
<th>Temperature in degrees Centigrade</th>
<th>760 mmHg</th>
<th>0</th>
<th>20</th>
<th>40</th>
<th>60</th>
<th>80</th>
<th>100</th>
<th>120</th>
<th>140</th>
<th>160</th>
<th>180</th>
</tr>
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<td>0.2</td>
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<td>0.6</td>
<td>0.8</td>
<td>1.0</td>
<td>2.0</td>
<td>4.0</td>
<td>6.0</td>
<td>8.0</td>
<td>10.0</td>
<td>12.0</td>
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<td>0.4</td>
<td>0.6</td>
<td>0.8</td>
<td>1.0</td>
<td>2.0</td>
<td>4.0</td>
<td>6.0</td>
<td>8.0</td>
<td>10.0</td>
</tr>
<tr>
<td>-90 -82 -72 -60 -48 -37 -27 -17</td>
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<td>0.4</td>
<td>0.6</td>
<td>0.8</td>
<td>1.0</td>
<td>2.0</td>
<td>4.0</td>
<td>6.0</td>
<td>8.0</td>
<td>10.0</td>
</tr>
<tr>
<td>-81 -72 -60 -48 -36 -27 -17 -8</td>
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<td>0.2</td>
<td>0.4</td>
<td>0.6</td>
<td>0.8</td>
<td>1.0</td>
<td>2.0</td>
<td>4.0</td>
<td>6.0</td>
<td>8.0</td>
<td>10.0</td>
</tr>
<tr>
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<td>0.4</td>
<td>0.6</td>
<td>0.8</td>
<td>1.0</td>
<td>2.0</td>
<td>4.0</td>
<td>6.0</td>
<td>8.0</td>
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</tr>
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<td>-65 -50 -38 -27 -16 -8  -4  -2</td>
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<td>0.4</td>
<td>0.6</td>
<td>0.8</td>
<td>1.0</td>
<td>2.0</td>
<td>4.0</td>
<td>6.0</td>
<td>8.0</td>
<td>10.0</td>
</tr>
<tr>
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<td>0.4</td>
<td>0.6</td>
<td>0.8</td>
<td>1.0</td>
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<td>4.0</td>
<td>6.0</td>
<td>8.0</td>
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<tr>
<td>-48 -34 -21 -8  -4  -2  -1  0</td>
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<td>0.4</td>
<td>0.6</td>
<td>0.8</td>
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<td>0.4</td>
<td>0.6</td>
<td>0.8</td>
<td>1.0</td>
<td>2.0</td>
<td>4.0</td>
<td>6.0</td>
<td>8.0</td>
<td>10.0</td>
</tr>
<tr>
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<td>0.4</td>
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<td>0.8</td>
<td>1.0</td>
<td>2.0</td>
<td>4.0</td>
<td>6.0</td>
<td>8.0</td>
<td>10.0</td>
</tr>
<tr>
<td>-12  0    0</td>
<td>0 0</td>
<td>0.2</td>
<td>0.4</td>
<td>0.6</td>
<td>0.8</td>
<td>1.0</td>
<td>2.0</td>
<td>4.0</td>
<td>6.0</td>
<td>8.0</td>
<td>10.0</td>
</tr>
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<td>4.0</td>
<td>6.0</td>
<td>8.0</td>
<td>10.0</td>
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<td>0    0    0</td>
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<td>0.4</td>
<td>0.6</td>
<td>0.8</td>
<td>1.0</td>
<td>2.0</td>
<td>4.0</td>
<td>6.0</td>
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<td>4.0</td>
<td>6.0</td>
<td>8.0</td>
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</tr>
</tbody>
</table>

*How to use the Table:* Take as an example a liquid with a boiling point of 80°C at 760 mm Hg. The Table gives values of the boiling points of this liquid at pressures from 0.1 to 800 mm Hg. Thus at 50 mm Hg this liquid has a boiling point of 19°C, and at 2 mm Hg its boiling point would be -30°C.
### TABLE 3B. PREDICTED EFFECT OF PRESSURE ON BOILING POINT

#### Temperature in degrees Centigrade

<table>
<thead>
<tr>
<th>760mmHg</th>
<th>200</th>
<th>220</th>
<th>240</th>
<th>260</th>
<th>280</th>
<th>300</th>
<th>320</th>
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<th>360</th>
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<td>157</td>
<td>174</td>
<td>190</td>
<td>207</td>
<td>224</td>
<td>241</td>
<td>257</td>
<td>274</td>
<td>291</td>
</tr>
<tr>
<td>80.0</td>
<td>131</td>
<td>148</td>
<td>165</td>
<td>182</td>
<td>199</td>
<td>216</td>
<td>233</td>
<td>250</td>
<td>267</td>
<td>284</td>
<td>301</td>
</tr>
<tr>
<td>100.0</td>
<td>137</td>
<td>154</td>
<td>171</td>
<td>189</td>
<td>206</td>
<td>223</td>
<td>241</td>
<td>258</td>
<td>275</td>
<td>293</td>
<td>310</td>
</tr>
<tr>
<td>150.0</td>
<td>148</td>
<td>166</td>
<td>184</td>
<td>201</td>
<td>219</td>
<td>237</td>
<td>255</td>
<td>273</td>
<td>290</td>
<td>308</td>
<td>326</td>
</tr>
<tr>
<td>200.0</td>
<td>156</td>
<td>174</td>
<td>193</td>
<td>211</td>
<td>229</td>
<td>247</td>
<td>265</td>
<td>283</td>
<td>302</td>
<td>320</td>
<td>338</td>
</tr>
<tr>
<td>300.0</td>
<td>169</td>
<td>187</td>
<td>206</td>
<td>225</td>
<td>243</td>
<td>262</td>
<td>281</td>
<td>299</td>
<td>318</td>
<td>337</td>
<td>355</td>
</tr>
<tr>
<td>400.0</td>
<td>178</td>
<td>197</td>
<td>216</td>
<td>235</td>
<td>254</td>
<td>273</td>
<td>292</td>
<td>311</td>
<td>330</td>
<td>350</td>
<td>369</td>
</tr>
<tr>
<td>500.0</td>
<td>185</td>
<td>205</td>
<td>224</td>
<td>244</td>
<td>263</td>
<td>282</td>
<td>302</td>
<td>321</td>
<td>340</td>
<td>360</td>
<td>379</td>
</tr>
<tr>
<td>600.0</td>
<td>192</td>
<td>211</td>
<td>231</td>
<td>251</td>
<td>270</td>
<td>290</td>
<td>310</td>
<td>330</td>
<td>350</td>
<td>370</td>
<td>388</td>
</tr>
<tr>
<td>700.0</td>
<td>197</td>
<td>217</td>
<td>237</td>
<td>257</td>
<td>277</td>
<td>296</td>
<td>316</td>
<td>336</td>
<td>356</td>
<td>376</td>
<td>396</td>
</tr>
<tr>
<td>750.0</td>
<td>200</td>
<td>220</td>
<td>239</td>
<td>259</td>
<td>279</td>
<td>299</td>
<td>319</td>
<td>339</td>
<td>359</td>
<td>379</td>
<td>399</td>
</tr>
<tr>
<td>770.0</td>
<td>200</td>
<td>220</td>
<td>241</td>
<td>261</td>
<td>281</td>
<td>301</td>
<td>321</td>
<td>341</td>
<td>361</td>
<td>381</td>
<td>401</td>
</tr>
<tr>
<td>800.0</td>
<td>202</td>
<td>222</td>
<td>242</td>
<td>262</td>
<td>282</td>
<td>302</td>
<td>322</td>
<td>342</td>
<td>362</td>
<td>382</td>
<td>403</td>
</tr>
</tbody>
</table>

*How to use the Table:* Taking as an example a liquid with a boiling point of 340°C at 760mm Hg, the column headed 340°C gives values of the boiling points of this liquid at each value of pressures from 0.1 to 800mm Hg. Thus, at 100mm Hg its boiling point is 258°C, and at 0.8mm Hg its boiling point will be 130°C.
How to use Figure 1:
You can use a nomogram to estimate the boiling points of a substance at a particular pressure. For example, the boiling point of 4-methoxybenzenesulfonyl chloride is 173°C/14mm. Thus to find out what the boiling point of this compound will be at 760mm (atmospheric), draw a point on curve A (pressure) at 14mm (this is shown in (i). Then draw a point on curve C (observed boiling point) corresponding to 173°C (or as close as possible). This is shown in (ii). Using a ruler, find the point of intersection on curve B, drawing a line between points (i) and (ii). This is the point (iii) and is the boiling point of 4-methoxybenzenesulfonyl chloride (i.e. approx. 310°C) at atmospheric pressure. If you want to distil 4-methoxybenzenesulfonyl chloride at 20mm, then you will need to draw a point on curve A (at 20mm). Using a ruler, find the point of intersection on curve C drawing through the line intersecting (iii, curve B, i.e. 310°C) and the point in curve A corresponding to 20mm. You should have a value of 185°C, that is, the boiling point of 4-methoxybenzenesulfonyl chloride is estimated to be at 185°C at 20mm.
TABLE 4. HEATING BATHS

<table>
<thead>
<tr>
<th>Temperature Range</th>
<th>Heating Bath</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 100°C</td>
<td>Water baths</td>
</tr>
<tr>
<td>-20 to 200°C</td>
<td>Glycerol or di-n-butyl phthalate</td>
</tr>
<tr>
<td>Up to about 200°C</td>
<td>Medicinal paraffin</td>
</tr>
<tr>
<td>Up to about 250°C</td>
<td>Hard hydrogenated cotton-seed oil (m 40-60°) or a 1:1 mixture of cotton-seed oil and castor oil containing about 1% of hydroquinone.</td>
</tr>
<tr>
<td>-40 to 250°C (to 400°C under N₂)</td>
<td>D.C. 550 silicone fluid</td>
</tr>
<tr>
<td>Up to about 260°C</td>
<td>A mixture of 85% orthophosphoric acid (4 parts) and metaphosphoric acid (1 part)</td>
</tr>
<tr>
<td>Up to 340°C</td>
<td>A mixture of 85% orthophosphoric acid (2 parts) and metaphosphoric acid (1 part)</td>
</tr>
<tr>
<td>60 to 500°C</td>
<td>Fisher bath wax (highly unsaturated)</td>
</tr>
<tr>
<td>73 to 350°C</td>
<td>Wood's Metal*</td>
</tr>
<tr>
<td>250 to 800°C</td>
<td>Solder*</td>
</tr>
<tr>
<td>350 to 800°C</td>
<td>Lead*</td>
</tr>
</tbody>
</table>

* In using metal baths, the container (usually a metal crucible) should be removed while the metal is still molten.

TABLE 5. WHATMAN FILTER PAPERS

<table>
<thead>
<tr>
<th>Grade No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>113</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size retained (in microns)</td>
<td>11</td>
<td>8</td>
<td>5</td>
<td>12</td>
<td>2.4</td>
<td>2.8</td>
<td>28</td>
</tr>
<tr>
<td>Filtration speed* (sec/100mL)</td>
<td>40</td>
<td>55</td>
<td>155</td>
<td>20</td>
<td>&lt;300</td>
<td>125</td>
<td>9</td>
</tr>
</tbody>
</table>

**Routine ashless filters**

<table>
<thead>
<tr>
<th>Grade No.</th>
<th>40</th>
<th>41</th>
<th>42</th>
<th>43</th>
<th>44</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size retained (in microns)</td>
<td>7.5</td>
<td>12</td>
<td>3</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>Filtration speed* (sec/100mL)</td>
<td>68</td>
<td>19</td>
<td>200</td>
<td>38</td>
<td>125</td>
</tr>
</tbody>
</table>

**Hardened**

<table>
<thead>
<tr>
<th>Grade No.</th>
<th>50</th>
<th>52</th>
<th>54</th>
<th>540</th>
<th>541</th>
<th>542</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size retained (in microns)</td>
<td>3</td>
<td>8</td>
<td>20</td>
<td>9</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>Filtration speed* (sec/100mL)</td>
<td>250</td>
<td>55</td>
<td>10</td>
<td>55</td>
<td>12</td>
<td>250</td>
</tr>
</tbody>
</table>

**Hardened ashless**

<table>
<thead>
<tr>
<th>Grade No.</th>
<th>GF/A</th>
<th>GF/B</th>
<th>GF/C</th>
<th>GF/D</th>
<th>GF/F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size retained (in microns)</td>
<td>1.6</td>
<td>1.0</td>
<td>1.1</td>
<td>2.2</td>
<td>0.8</td>
</tr>
<tr>
<td>Filtration speed (sec/100mL)*</td>
<td>8.3</td>
<td>20.0</td>
<td>8.7</td>
<td>5.5</td>
<td>17.2</td>
</tr>
</tbody>
</table>

*Filtration speeds are rough estimates of initial flow rates and should be considered on a relative basis.
### TABLE 6. MICRO FILTERS*

| **Nucleopore (polycarbonate) Filters** |  |
| Mean Pore Size (microns) | 8.0 | 2.0 | 1.0 | 0.1 | 0.03 | 0.015 |
| Av. pores/cm² | \(10^5\) | \(2 \times 10^6\) | \(2 \times 10^7\) | \(3 \times 10^8\) | \(6 \times 10^8\) | 1-6\(\times 10^9\) |
| Water flow rate (mL/min/cm²) | 2000 | 2000 | 300 | 8 | 0.03 | 0.1-0.5 |

| **Millipore Filters** |  |
| Type | —Cellulose ester— | —Teflon— | —Microweb#— |
| MF/SC | MF/VF | LC | LS | WS | WH |
| Mean Pore Size (microns) | 8 | 0.01 | 10 | 5 | 3 | 0.45 |
| Water flow rate (mL/min/cm²) | 850 | 0.2 | 170 | 70 | 155 | 55 |

| **Gelman Membranes** |  |
| Type | —Cellulose ester— | —Copolymer— |
| GA-1 | TCM-450 | AN-200 | Tuffryn-450 |
| Mean Pore Size (microns) | 5 | 0.45 | 5 | 0.8 | 0.2 | 0.45 |
| Water flow rate (mL/min/cm²) | 320 | 50 | 700 | 200 | 17 | 50 |

| **Sartorius Membrane Filters (SM)** |  |
| Application | Gravimetric | Biological clarification | Sterilisation | Particle count in \(H_2O\) | For acids & bases |
| Type No. | 11003 | 11004 | 11006 | 11011 | 12801 |
| Mean Pore Size (microns) | 1.2 | 0.6 | 0.45 | 0.01 | 8 |
| Water flow rate (mL/min/cm²) | 300 | 150 | 65 | 0.6 | 1100 |

* Only a few representative filters are tabulated (available ranges are more extensive). # Reinforced nylon.
TABLE 7. COMMON SOLVENTS USED IN RECRYSTALLISATION

<table>
<thead>
<tr>
<th>Solvent</th>
<th>Boiling Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetic acid (118°C)</td>
<td></td>
</tr>
<tr>
<td>*Acetone (56°C)</td>
<td></td>
</tr>
<tr>
<td>Acetylaceton (139°C)</td>
<td></td>
</tr>
<tr>
<td>Acetonitrile (82°C)</td>
<td></td>
</tr>
<tr>
<td>*Benzene (80°C)</td>
<td></td>
</tr>
<tr>
<td>Benzyl alcohol (93°/10mm)</td>
<td></td>
</tr>
<tr>
<td>n-Butanol (118°C)</td>
<td></td>
</tr>
<tr>
<td>Butyl acetate (126.5°C)</td>
<td></td>
</tr>
<tr>
<td>n-Butyl ether (142°C)</td>
<td></td>
</tr>
<tr>
<td>γ-Butyrolactone (206°C)</td>
<td></td>
</tr>
<tr>
<td>Carbon tetrachloride (77°C)</td>
<td></td>
</tr>
<tr>
<td>Chlorobenzene (132°C)</td>
<td></td>
</tr>
<tr>
<td>Chloroform (61°C)</td>
<td></td>
</tr>
<tr>
<td>*Cyclohexane (81°C)</td>
<td></td>
</tr>
<tr>
<td>Dichloromethane (41°C)</td>
<td></td>
</tr>
<tr>
<td>*Diethyl ether (34.5°C)</td>
<td></td>
</tr>
<tr>
<td>Dimethyl formamide (76°C/39mm)</td>
<td></td>
</tr>
<tr>
<td>*Dioxane (101°C)</td>
<td></td>
</tr>
<tr>
<td>*Ethanol (78°C)</td>
<td></td>
</tr>
<tr>
<td>2-Ethoxyethanol (cellosolve 135°C)</td>
<td></td>
</tr>
<tr>
<td>*Ethyl acetate (78°C)</td>
<td></td>
</tr>
<tr>
<td>Ethyl benzoate (98°/19mm)</td>
<td></td>
</tr>
<tr>
<td>Ethylene glycol (68°/4mm)</td>
<td></td>
</tr>
<tr>
<td>Formamide (110°/10mm)</td>
<td></td>
</tr>
<tr>
<td>Glycerol (126°/11mm)</td>
<td></td>
</tr>
<tr>
<td>Isoamyl alcohol (131°C)</td>
<td></td>
</tr>
<tr>
<td>Methanol (64.5°C)</td>
<td></td>
</tr>
<tr>
<td>*Methyl ethyl ketone (80°C)</td>
<td></td>
</tr>
<tr>
<td>Methyl iso-butyl ketone (116°C)</td>
<td></td>
</tr>
<tr>
<td>Nitrobenzene (210°C)</td>
<td></td>
</tr>
<tr>
<td>Nitromethane (101°C)</td>
<td></td>
</tr>
<tr>
<td>Petroleum ether (various)</td>
<td></td>
</tr>
<tr>
<td>Pyridine (115.5°C)</td>
<td></td>
</tr>
<tr>
<td>Pyridine trihydrate (93°C)</td>
<td></td>
</tr>
<tr>
<td>*Tetrahydrofuran (64-66°C)</td>
<td></td>
</tr>
<tr>
<td>Toluene (110°C)</td>
<td></td>
</tr>
<tr>
<td>Trimethylene glycol (59°/11mm)</td>
<td></td>
</tr>
<tr>
<td>Water (100°C)</td>
<td></td>
</tr>
<tr>
<td>Xylenes (α 143-145°C, m 138-139°C, p 128°C)</td>
<td></td>
</tr>
</tbody>
</table>

*Highly flammable, should be heated or evaporated on steam or electrically heated water baths only (preferably under nitrogen). None of these solvents should be heated over a naked flame.

TABLE 8. PAIRS OF MISCIBLE SOLVENTS

<table>
<thead>
<tr>
<th>Solvent</th>
<th>Miscible with</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetic acid</td>
<td>chloroform, ethanol, ethyl acetate, acetonitrile, petroleum ether, or water.</td>
</tr>
<tr>
<td>Acetone</td>
<td>benzene, butyl acetate, butyl alcohol, carbon tetrachloride, chloroform, cyclohexane, ethanol, ethyl acetate, methyl acetate, acetonitrile, petroleum ether or water.</td>
</tr>
<tr>
<td>Acetonitrile</td>
<td>benzene, carbon tetrachloride, ethyl ether, n-heptane, methanol, acetonitrile or nitrobenzene.</td>
</tr>
<tr>
<td>Ammonia</td>
<td>ethanol, methanol, pyridine.</td>
</tr>
<tr>
<td>Aniline</td>
<td>acetone, benzene, carbon tetrachloride, ethyl ether, n-heptane, methanol, acetonitrile or nitrobenzene.</td>
</tr>
<tr>
<td>Benzene</td>
<td>acetone, butyl alcohol, carbon tetrachloride, chloroform, cyclohexane, ethanol, acetonitrile, petroleum ether or pyridine.</td>
</tr>
<tr>
<td>Butyl alcohol</td>
<td>acetone or ethyl acetate.</td>
</tr>
<tr>
<td>Carbon disulfide</td>
<td>petroleum ether.</td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>cyclohexane.</td>
</tr>
<tr>
<td>Chloroform</td>
<td>acetic acid, acetone, benzene, ethanol, ethyl acetate, hexane, methanol or pyridine.</td>
</tr>
<tr>
<td>Cyclohexane</td>
<td>acetone, benzene, carbon tetrachloride, ethanol or diethyl ether.</td>
</tr>
<tr>
<td>Diethyl ether</td>
<td>acetone, cyclohexane, ethanol, methanol, methylal (dimethoxymethane), acetonitrile, pentane or petroleum ether.</td>
</tr>
<tr>
<td>Dimethyl formamide</td>
<td>benzene, ethanol or ether.</td>
</tr>
<tr>
<td>Dimethyl sulfide</td>
<td>benzene, chloroform, ethanol, diethyl ether or water.</td>
</tr>
<tr>
<td>Dioxane</td>
<td>benzene, carbon tetrachloride, chloroform, ethanol, diethyl ether, petroleum ether, pyridine or water.</td>
</tr>
<tr>
<td>Ethanol</td>
<td>acetic acid, acetone, benzene, chloroform, cyclohexane, dioxane, ethyl ether, pentane, toluene, water or xylene.</td>
</tr>
<tr>
<td>Ethyl acetate</td>
<td>acetic acid, acetone, butyl alcohol, chloroform, or methanol.</td>
</tr>
<tr>
<td>Glycerol</td>
<td>ethanol, methanol or water.</td>
</tr>
<tr>
<td>Hexane</td>
<td>benzene, chloroform or ethanol.</td>
</tr>
<tr>
<td>Methanol</td>
<td>chloroform, diethyl ether, glycerol or water.</td>
</tr>
<tr>
<td>Methylal</td>
<td>diethyl ether.</td>
</tr>
<tr>
<td>Methyl ethyl ketone</td>
<td>acetic acid, benzene, ethanol or methanol.</td>
</tr>
<tr>
<td>Nitrobenzene</td>
<td>aniline, methanol or acetonitrile.</td>
</tr>
<tr>
<td>Pentane</td>
<td>ethanol or diethyl ether.</td>
</tr>
<tr>
<td>Petroleum ether</td>
<td>acetic acid, acetone, benzene, carbon disulfide or diethyl ether.</td>
</tr>
<tr>
<td>Phenol</td>
<td>carbon tetrachloride, ethanol, diethyl ether or xylene.</td>
</tr>
<tr>
<td>Pyridine</td>
<td>acetone, ammonia, benzene, chloroform, dioxane, petroleum ether, toluene or water.</td>
</tr>
<tr>
<td>Toluene</td>
<td>ethanol, diethyl ether or pyridine.</td>
</tr>
<tr>
<td>Water</td>
<td>acetic acid, acetone, ethanol, methanol, or pyridine.</td>
</tr>
<tr>
<td>Xylene</td>
<td>ethanol or phenol.</td>
</tr>
</tbody>
</table>
### TABLE 9. MATERIALS FOR COOLING BATHS

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Composition</th>
<th>Temperature</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°C</td>
<td>Crushed ice</td>
<td>-77°C</td>
<td>Solid CO₂ with chloroform or acetone</td>
</tr>
<tr>
<td>-5°C to -20°C</td>
<td>Ice-salt mixtures</td>
<td>-78°C</td>
<td>Solid CO₂ (powdered; CO₂ snow)</td>
</tr>
<tr>
<td>-3°C to -20°C</td>
<td>Ice-MeOH mixtures</td>
<td>-90°C</td>
<td>Solid CO₂ with diethyl ether</td>
</tr>
<tr>
<td>-40°C to -50°C</td>
<td>Ice (3.5-4 parts) - CaCl₂ 6H₂O (5 parts)</td>
<td>-100°C</td>
<td>Solid CO₂ with diethyl ether</td>
</tr>
<tr>
<td>-72°C</td>
<td>Solid CO₂ with ethanol</td>
<td>-196°C</td>
<td>liquid nitrogen (see footnote*)</td>
</tr>
</tbody>
</table>

Alternatively, the following liquids can be used, partially frozen, as cryostats, by adding solid CO₂ from time to time to the material in a Dewar-type container and stirring to make a slush:

| 13°C      | p-Xylene                             | -55°C       | Diacetone                                        |
| 12°C      | Dioxane                              | -56°C       | n-Octane                                         |
| 6°C       | Cyclohexane                          | -60°C       | Di-isopropyl ether                               |
| 5°C       | Benzene                              | -73°C       | Trichloroethylene or isopropyl acetate          |
| 2°C       | Formamide                            | -74°C       | o-Cymene or p-cymene                            |
| -8.6°C    | Methyl salicylate                    | -77°C       | Butyl acetate                                   |
| -9°C      | Hexane-2,5-dione                     | -79°C       | Isoamyl acetate                                 |
| -10.5°C   | Ethylene glycol                      | -83°C       | Propylamine                                      |
| -11.9°C   | tert-Amyl alcohol                    | -83.6°C     | Ethyl acetate                                   |
| -12°C     | Cycloheptane or methyl benzoate      | -86°C       | Methyl ethyl ketone                             |
| -15°C     | Benzyl alcohol                       | -89°C       | n-Butanol                                        |
| -16.3°C   | n-Octanol                            | -90°C       | Nitroethane                                      |
| -18°C     | 1,2-Dichlorobenzene                  | -91°C       | Heptane                                          |
| -22°C     | Tetrahydrofuran                     | -92°C       | n-Propyl acetate                                 |
| -22.4°C   | Butyl benzoate                       | -93°C       | 2-Nitropropane or cyclopentane                  |
| -22.8°C   | Carbon tetrachloride                 | -94°C       | Ethyl benzene or hexane                          |
| -24.5°C   | Diethyl sulphate                     | -94.6°C     | Acetone                                          |
| -25°C     | 1,3-Dichlorobenzene                  | -95.1°C     | Toluene                                          |
| -29°C     | o-Xylene or pentachloroethane        | -97°C       | Cumene                                           |
| -30°C     | Bromobenzene                         | -98°C       | Methanol or methyl acetate                       |
| -32°C     | m-Toluol                             | -99°C       | Isobutyl acetate                                |
| -32.6°C   | Dipropyl ketone                      | -104°C      | Cyclohexene                                      |
| -38°C     | Thiophene                            | -107°C      | Isooctane                                        |
| -41°C     | Acetonitrile                         | -108°C      | 1-Nitropropane                                   |
| -42°C     | Pyridine or diethyl ketone           | -116°C      | Ethanol or diethyl ether                         |
| -44°C     | Cyclohexyl chloride                  | -117°C      | Isoamyl alcohol                                  |
| -45°C     | Chlorobenzene                        | -126°C      | Methylcyclohexane                                |
| -47°C     | m-Xylene                             | -131°C      | n-Pentane                                        |
| -50°C     | Ethyl malonate or n-butylamine       | -160°C      | Isopentane                                       |
| -52°C     | Benzyl acetate or diethylcarbitol    |             |                                                  |

For other organic materials used in low temperature slush-baths with liquid nitrogen see R.E.Rondeau [J Chem Eng Data 11 124 1966]. *NOTE: Use high quality pure nitrogen, do not use liquid air or liquid nitrogen that has been in contact with air for a long period (due to the dissolution of oxygen in it) as this could EXPLODE in contact with organic matter.*
### TABLE 10. LIQUIDS FOR STATIONARY PHASES IN GAS CHROMATOGRAPHY

<table>
<thead>
<tr>
<th>Material</th>
<th>Temp.</th>
<th>Retards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimethylsulfolane</td>
<td>0-40°C</td>
<td>Olefins and aromatic hydrocarbons</td>
</tr>
<tr>
<td>Di-n-butyl phthalate</td>
<td>0-40°C</td>
<td>General purposes</td>
</tr>
<tr>
<td>Squalane</td>
<td>0-150°C</td>
<td>Volatile hydrocarbons and polar molecules</td>
</tr>
<tr>
<td>Silicone oil or grease</td>
<td>0-250°C</td>
<td>General purposes</td>
</tr>
<tr>
<td>Diglycerol</td>
<td>20-120°C</td>
<td>Water, alcohols, amines, esters, and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>aromatic hydrocarbons</td>
</tr>
<tr>
<td>Dinonyl phthalate</td>
<td>20-130°C</td>
<td>General purposes</td>
</tr>
<tr>
<td>Polydiethylene glycol succinate</td>
<td>50-200°C</td>
<td>Aromatic hydrocarbons, alcohols, ketones, esters.</td>
</tr>
<tr>
<td>Polyethylene glycol</td>
<td>50-200°C</td>
<td>Water, alcohols, amines, esters and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>aromatic hydrocarbons</td>
</tr>
<tr>
<td>Apiezon grease</td>
<td>50-200°C</td>
<td>Volatile hydrocarbons and polar molecules</td>
</tr>
<tr>
<td>Tricresyl phosphate</td>
<td>50-250°C</td>
<td>General purposes</td>
</tr>
</tbody>
</table>

### TABLE 11. METHODS OF VISUALISATION OF TLC SPOTS

<table>
<thead>
<tr>
<th>Reagent</th>
<th>Compound</th>
<th>Preparation</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iodine</td>
<td>General</td>
<td>Iodine crystals in a closed chamber or spray 1% methanol solution of Iodine</td>
<td>Brown spots which may disappear upon standing. Limited sensitivity.</td>
</tr>
<tr>
<td>H₂SO₄</td>
<td>General</td>
<td>50% solution, followed by heating to 150°C</td>
<td>Black or coloured spots</td>
</tr>
<tr>
<td>Molybdate</td>
<td>General</td>
<td>5% (NH₄)₆Mo₇O₂₄ + 0.2% Ce(SO₄)₂ in 5% H₂SO₄, followed by heating to 150°C.</td>
<td>Deep blue spots</td>
</tr>
<tr>
<td>Vanillin</td>
<td>General</td>
<td>0.5g vanillin, 0.5 mL H₂SO₄, 9 mL ethanol</td>
<td>various coloured spots</td>
</tr>
<tr>
<td>Ammonia</td>
<td>phenols</td>
<td>Ammonia vapour in a closed chamber</td>
<td>various coloured spots</td>
</tr>
<tr>
<td>FeCl₃</td>
<td>phenols, enolic compounds</td>
<td>1% aqueous FeCl₃</td>
<td>various coloured spots</td>
</tr>
<tr>
<td>2,4-DNP</td>
<td>aldehydes, ketones</td>
<td>0.5% 2,4-dinitrophenylhydrazine/2M HCl</td>
<td>red to yellow spots</td>
</tr>
<tr>
<td>HCl</td>
<td>aromatic acids and amines</td>
<td>HCl vapour in a closed chamber</td>
<td>various coloured spots</td>
</tr>
<tr>
<td>Ninhydrin</td>
<td>amino acids, and amines</td>
<td>0.3% ninhydrin in n-BuOH with 3% AcOH, followed by heating to 125°C/10 min</td>
<td>blue spots</td>
</tr>
<tr>
<td>PdCl₂</td>
<td>S and Se comds</td>
<td>0.5% aq. PdCl₂ + few drops of conc. HCl</td>
<td>red and yellow spots</td>
</tr>
<tr>
<td>Anisaldehyde</td>
<td>carbohydrates</td>
<td>0.5 mL anisaldehyde in 0.5 mL conc H₂SO₄ + 95% EtOH + a few drops of AcOH</td>
<td>various blue spots</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heat at 100-110°C for 20-30 minutes</td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 12. GRADED ADSORBENTS AND SOLVENTS

<table>
<thead>
<tr>
<th>Adsorbents (decreasing effectiveness)</th>
<th>Solvents (increasing eluting ability)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuller's earth (hydrated aluminosilicate)</td>
<td>Petroleum ether, b. 40-60°.</td>
</tr>
<tr>
<td>Magnesium oxide</td>
<td>Petroleum ether, b. 60-80°.</td>
</tr>
<tr>
<td>Charcoal</td>
<td>Carbon tetrachloride.</td>
</tr>
<tr>
<td>Alumina</td>
<td>Cyclohexane.</td>
</tr>
<tr>
<td>Magnesium trisilicate</td>
<td>Benzene.</td>
</tr>
<tr>
<td>Silica gel</td>
<td>Diethyl ether.</td>
</tr>
<tr>
<td>Calcium hydroxide</td>
<td>Chloroform.</td>
</tr>
<tr>
<td>Magnesium carbonate</td>
<td>Ethyl acetate.</td>
</tr>
<tr>
<td>Calcium phosphate</td>
<td>Acetone.</td>
</tr>
<tr>
<td>Calcium carbonate</td>
<td>Ethanol.</td>
</tr>
<tr>
<td>Sodium carbonate</td>
<td>Methanol.</td>
</tr>
<tr>
<td>Talc</td>
<td>Pyridine.</td>
</tr>
<tr>
<td>Inulin</td>
<td>Acetic acid.</td>
</tr>
<tr>
<td>Sucrose = starch</td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 13. REPRESENTATIVE ION-EXCHANGE RESINS

<table>
<thead>
<tr>
<th>Sulfonated polystyrene Strong-acid cation exchanger</th>
<th>Aliphatic amine-type weak base anion exchangers</th>
</tr>
</thead>
<tbody>
<tr>
<td>AG 50W-x8</td>
<td>Amberlites IR-45 and IRA-67</td>
</tr>
<tr>
<td>Amberlite IR-120</td>
<td>Dowex 3-x4A</td>
</tr>
<tr>
<td>Dowex 50W-x8</td>
<td>Permutit E</td>
</tr>
<tr>
<td>Duolite 225</td>
<td>Permutit A 240A</td>
</tr>
<tr>
<td>Permutit RS</td>
<td></td>
</tr>
<tr>
<td>Permutit C50D</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Carboxylic acid-type Weak acid cation exchangers</th>
<th>Strong Base, anion exchangers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amberlite IRC-50</td>
<td>AG 2×8</td>
</tr>
<tr>
<td>Bio-Rex 70</td>
<td>Amberlite IRA-400</td>
</tr>
<tr>
<td>Chelex 100</td>
<td>Dowex 2×8</td>
</tr>
<tr>
<td>Duolite 436</td>
<td>Duolite 113</td>
</tr>
<tr>
<td>Permutit C</td>
<td>Permutit ESB</td>
</tr>
<tr>
<td>Permutits H and H-70</td>
<td>Permutite 330D</td>
</tr>
</tbody>
</table>

### TABLE 14. MODIFIED FIBROUS CELLULOSES FOR ION-EXCHANGE

<table>
<thead>
<tr>
<th>Cation exchange</th>
<th>Anion exchange</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM cellulose (carboxymethyl)</td>
<td>DEAE cellulose (diethylaminoethyl)</td>
</tr>
<tr>
<td>CM 22, 23 cellulose</td>
<td>DE 22, 23 cellulose</td>
</tr>
<tr>
<td>P cellulose (phosphate)</td>
<td>PAB cellulose (p-aminobenzyl)</td>
</tr>
<tr>
<td>SE cellulose (sulfate)</td>
<td>TEAE cellulose (triethylaminoethyl)</td>
</tr>
<tr>
<td>SM cellulose (sulfomethyl)</td>
<td>ECTEOLA cellulose</td>
</tr>
</tbody>
</table>

SE and SM are much stronger acids than CM, whereas P has two ionisable groups (pK 2-3, 6-7), one of which is stronger, the other weaker, than for CM (3.5-4.5). For basic strengths, the sequence is: TEAE > DEAE (pK 8-9.5) > ECTEOLA (pK 5.5-7) > PAB. Their exchange capacities lie in the range 0.3 to 1.0 mg equiv/g.
### TABLE 15. BEAD FORM ION-EXCHANGE PACKAGINGS

<table>
<thead>
<tr>
<th>Cation exchange</th>
<th>Capacity (meq/g)</th>
<th>Anion exchange</th>
<th>Capacity (meq/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM-Sephadex C-25, C-50,2(weak acid)</td>
<td>4.5±0.5</td>
<td>DEAE-Sephadex A-25, A-50,7 (weak base)</td>
<td>3.5±0.5</td>
</tr>
<tr>
<td>SP-Sephadex C-25, C-50,3(strong acid)</td>
<td>2.3±0.3</td>
<td>QAE-Sephadex A-25, A-50,8 (strong base)</td>
<td>3.0±0.4</td>
</tr>
<tr>
<td>CM-Sepharose CL-6B,4</td>
<td>0.12±0.02</td>
<td>DEAE-Sepharose CL-6B 4</td>
<td>0.13±0.02</td>
</tr>
<tr>
<td>Fractogel EMD,CO₂ (pK -4.5)</td>
<td></td>
<td>Fractogel EMD, DMAE (pK -9)</td>
<td></td>
</tr>
<tr>
<td>SO₃⁻ (pK -&lt;1)</td>
<td></td>
<td>DEAE (pK ~10.8), TMAE (pK &gt;13).5</td>
<td></td>
</tr>
<tr>
<td>CM-32 Cellulose.</td>
<td></td>
<td>DE-32 Cellulose.</td>
<td></td>
</tr>
<tr>
<td>CM-52 Cellulose.6</td>
<td></td>
<td>DE-52 Cellulose.</td>
<td></td>
</tr>
</tbody>
</table>

1 May be sterilised by autoclaving at pH 7 and below 120°. 2 Carboxymethyl. 3 Sulfopropyl. 4 Crosslinked agarose gel, no pre-cycling required, pH range 3-10. 5 Hydrophilic methacrylate polymer with very little volume change on change of pH (equivalent to Toyopearl, Sigma), available in superfine 650S, and medium 650M particle sizes. 6 Microgranular, pre-swollen, no pre-cycling required. 7 Diethylaminoethyl. 8 Diethyl(2-hydroxypropyl)aminoethyl. 9 Bead form cellulose, pH range 2-12, no pre-cycling required. Sephadex and Sepharose from Pharmacia-Amersham Biosciences, Fractogel from Merck, Cellulose from Whatman.

### TABLE 16. LIQUIDS FOR DRYING PISTOLS

<table>
<thead>
<tr>
<th>Boiling points (760mm)</th>
<th>LIQUIDS FOR DRYING PISTOLS</th>
<th>Boiling points (760mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethyl chloride</td>
<td>12.2°</td>
<td>Toluene</td>
</tr>
<tr>
<td>Dichloromethane</td>
<td>39.8°</td>
<td>Tetrachloroethylene</td>
</tr>
<tr>
<td>Acetone</td>
<td>56.1°</td>
<td>Chlorobenzene</td>
</tr>
<tr>
<td>Chloroform</td>
<td>62.0°</td>
<td>m-Xylene</td>
</tr>
<tr>
<td>Methanol</td>
<td>64.5°</td>
<td>Isoamyl acetate</td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>76.5°</td>
<td>Tetrachloroethane</td>
</tr>
<tr>
<td>Ethanol</td>
<td>78.3°</td>
<td>Bromobenzene</td>
</tr>
<tr>
<td>Benzene</td>
<td>79.8°</td>
<td>p-Cymene</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>86.0°</td>
<td>Tetrallin</td>
</tr>
<tr>
<td>Water</td>
<td>100.0°</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 17. VAPOUR PRESSURES (mm Hg) OF SATURATED AQUEOUS SOLUTIONS IN EQUILIBRIUM WITH SOLID SALTS

<table>
<thead>
<tr>
<th>Salt</th>
<th>10°</th>
<th>15°</th>
<th>20°</th>
<th>25°</th>
<th>30°</th>
<th>% Humidity at 20°</th>
</tr>
</thead>
<tbody>
<tr>
<td>LiCl, H₂O</td>
<td>2.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>CaBr₂,6H₂O</td>
<td>2.1</td>
<td>2.7</td>
<td>3.3</td>
<td>4.0</td>
<td>4.8</td>
<td>19</td>
</tr>
<tr>
<td>KOAc</td>
<td>3.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>CaCl₂,6H₂O</td>
<td>3.5</td>
<td>4.5</td>
<td>5.6</td>
<td>6.9</td>
<td>8.3</td>
<td>20</td>
</tr>
<tr>
<td>CrO₃</td>
<td>6.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>32</td>
</tr>
<tr>
<td>Zn(NO₃)₂,6H₂O</td>
<td>7.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>42</td>
</tr>
<tr>
<td>K₂CO₃,2H₂O</td>
<td>7.7</td>
<td></td>
<td>10.7</td>
<td></td>
<td></td>
<td>44</td>
</tr>
<tr>
<td>KCNS</td>
<td>8.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>47</td>
</tr>
<tr>
<td>Na₂Cr₂O₇,2H₂O</td>
<td>9.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>52</td>
</tr>
<tr>
<td>Ca(NO₃)₂,4H₂O</td>
<td>6.0</td>
<td>7.7</td>
<td>9.6</td>
<td>11.9</td>
<td>14.2</td>
<td>55</td>
</tr>
<tr>
<td>Mg(NO₃)₂,6H₂O</td>
<td>9.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>56</td>
</tr>
<tr>
<td>NaBr,2H₂O</td>
<td>5.8</td>
<td>7.8</td>
<td>10.3</td>
<td>13.5</td>
<td>17.5</td>
<td>58</td>
</tr>
<tr>
<td>NaN₂O₂</td>
<td>11.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>66</td>
</tr>
<tr>
<td>NaClO₃</td>
<td>13.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>75</td>
</tr>
<tr>
<td>NaCl</td>
<td>6.9</td>
<td>9.6</td>
<td>13.2</td>
<td>17.8</td>
<td>21.4</td>
<td>75</td>
</tr>
<tr>
<td>NaOAc</td>
<td>13.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>76</td>
</tr>
<tr>
<td>NH₄Cl</td>
<td>13.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>79</td>
</tr>
<tr>
<td>(NH₄)₂SO₄</td>
<td>14.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>81</td>
</tr>
<tr>
<td>KBr</td>
<td>14.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>84</td>
</tr>
<tr>
<td>KHSO₄</td>
<td>15.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>86</td>
</tr>
<tr>
<td>KCl</td>
<td>15.1</td>
<td>20.2</td>
<td>27.0</td>
<td></td>
<td></td>
<td>86</td>
</tr>
<tr>
<td>K₂CrO₄</td>
<td>15.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>88</td>
</tr>
<tr>
<td>ZnSO₄,7H₂O</td>
<td>15.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>90</td>
</tr>
<tr>
<td>NH₄H₂PO₄</td>
<td>16.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>93</td>
</tr>
<tr>
<td>KNO₃</td>
<td>16.7</td>
<td>22.3</td>
<td>29.8</td>
<td></td>
<td></td>
<td>95</td>
</tr>
<tr>
<td>Pb(NO₃)₂</td>
<td>17.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>98</td>
</tr>
<tr>
<td>H₂O</td>
<td>9.21</td>
<td>12.79</td>
<td>17.53</td>
<td>23.76</td>
<td>31.82</td>
<td>100</td>
</tr>
</tbody>
</table>
### Table 18.
**Drying Agents for Classes of Compounds**

<table>
<thead>
<tr>
<th>Class</th>
<th>Dried with</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetals</td>
<td>Potassium carbonate.</td>
</tr>
<tr>
<td>Acids (organic)</td>
<td>Calcium sulfate, magnesium sulfate, sodium sulfate.</td>
</tr>
<tr>
<td>Acyl halides</td>
<td>Magnesium sulfate, sodium sulfate.</td>
</tr>
<tr>
<td>Alcohols</td>
<td>Calcium oxide, calcium sulfate, magnesium sulfate, potassium carbonate, followed by magnesium and iodine.</td>
</tr>
<tr>
<td>Aldehydes</td>
<td>Calcium sulfate, magnesium sulfate, sodium sulfate.</td>
</tr>
<tr>
<td>Alkyl halides</td>
<td>Calcium chloride, calcium sulfate, magnesium sulfate, phosphorus pentoxide, sodium sulfate.</td>
</tr>
<tr>
<td>Amines</td>
<td>Barium oxide, calcium oxide, potassium hydroxide, sodium carbonate, sodium hydroxide.</td>
</tr>
<tr>
<td>Aryl halides</td>
<td>Calcium chloride, calcium sulfate, magnesium sulfate, phosphorus pentoxide, sodium sulfate.</td>
</tr>
<tr>
<td>Esters</td>
<td>Magnesium sulfate, potassium carbonate, sodium sulfate.</td>
</tr>
<tr>
<td>Ethers</td>
<td>Calcium chloride, calcium sulfate, magnesium sulfate, sodium, lithium aluminium hydride.</td>
</tr>
<tr>
<td>Heterocyclic bases</td>
<td>Magnesium sulfate, potassium carbonate, sodium hydroxide.</td>
</tr>
<tr>
<td>Hydrocarbons</td>
<td>Calcium chloride, calcium sulfate, magnesium sulfate, phosphorus pentoxide, sodium (not for olefins).</td>
</tr>
<tr>
<td>Ketones</td>
<td>Calcium sulfate, magnesium sulfate, potassium carbonate, sodium sulfate.</td>
</tr>
<tr>
<td>Mercaptans</td>
<td>Magnesium sulfate, sodium sulfate.</td>
</tr>
<tr>
<td>Nitro compounds and</td>
<td>Calcium chloride, magnesium sulfate, sodium sulfate.</td>
</tr>
<tr>
<td>Nitriles</td>
<td>Calcium chloride, calcium sulfate.</td>
</tr>
<tr>
<td>Sulfides</td>
<td>Calcium chloride, magnesium sulfate, sodium sulfate.</td>
</tr>
</tbody>
</table>

### Table 19.
**Static Drying for Selected Liquids (25°C)**

<table>
<thead>
<tr>
<th>Liquid</th>
<th>Water</th>
<th>Linde Type 4 A</th>
<th>Linde Type 5 A</th>
<th>Activated Alumina</th>
<th>Silicic Acid Gel</th>
</tr>
</thead>
<tbody>
<tr>
<td>MeOH</td>
<td>Residual H₂O %</td>
<td>0.54</td>
<td>0.55</td>
<td>—</td>
<td>0.60</td>
</tr>
<tr>
<td></td>
<td>Wt % absorbed</td>
<td>2.50</td>
<td>1.50</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>EtOH</td>
<td>Residual H₂O %</td>
<td>0.25</td>
<td>0.25</td>
<td>0.45</td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td>Wt % absorbed</td>
<td>7.00</td>
<td>6.80</td>
<td>1.50</td>
<td>—</td>
</tr>
<tr>
<td>1-Butylamine</td>
<td>Residual H₂O %</td>
<td>1.65</td>
<td>1.31</td>
<td>1.93</td>
<td>2.07</td>
</tr>
<tr>
<td></td>
<td>Wt % absorbed</td>
<td>10.40</td>
<td>18.20</td>
<td>3.40</td>
<td>—</td>
</tr>
<tr>
<td>2-Ethylhexylamine</td>
<td>Residual H₂O %</td>
<td>0.25</td>
<td>0.08</td>
<td>0.43</td>
<td>0.53</td>
</tr>
<tr>
<td></td>
<td>Wt % absorbed</td>
<td>15.10</td>
<td>21.10</td>
<td>6.10</td>
<td>1.70</td>
</tr>
<tr>
<td>Diethyl ether</td>
<td>Residual H₂O %</td>
<td>0.001</td>
<td>0.013</td>
<td>0.16</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>Wt % absorbed</td>
<td>9.50</td>
<td>9.20</td>
<td>6.20</td>
<td>4.30</td>
</tr>
<tr>
<td>Amyl acetate</td>
<td>Residual H₂O %</td>
<td>0.002</td>
<td>—</td>
<td>0.33</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>Wt % absorbed</td>
<td>9.30</td>
<td>—</td>
<td>7.40</td>
<td>1.80</td>
</tr>
</tbody>
</table>
Common Physical Techniques in Purification

**TABLE 20.** BOILING POINTS OF SOME USEFUL GASES AT 760 mm

<table>
<thead>
<tr>
<th>Gas</th>
<th>Temperature °C</th>
<th>MeOH</th>
<th>EtOH</th>
<th>Et₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argon</td>
<td>-185.6°</td>
<td>-152.3°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>-78.5°</td>
<td>-164.0°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(sublimes)</td>
<td>-191.3°</td>
<td>-246.0°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>-88.6°</td>
<td>-209.0°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethane</td>
<td>-268.6°</td>
<td>-88.5°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helium</td>
<td>-252.6°</td>
<td>-195.8°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrogen</td>
<td>-268.6°</td>
<td>-182.96°</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 21.** SOLUBILITIES OF HCl AND NH₃ AT 760mm (g/100g OF SOLUTION)

<table>
<thead>
<tr>
<th>Gas</th>
<th>Temperature °C</th>
<th>MeOH</th>
<th>EtOH</th>
<th>Et₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen Chloride*</td>
<td>-10</td>
<td>54.6</td>
<td>—</td>
<td>37.5 (-9.2°)</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>51.3</td>
<td>45.4</td>
<td>35.6</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>47.0 (18⁰)</td>
<td>41.0</td>
<td>24.9</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>43.0</td>
<td>38.1</td>
<td>19.47</td>
</tr>
<tr>
<td>Ammonia</td>
<td>15</td>
<td>21.6</td>
<td>13.2</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>16.5</td>
<td>10.0</td>
<td>—</td>
</tr>
</tbody>
</table>

* Saturated EtOH with HCl is ~ 5.7M at 25°c, i.e. 21.5g/100mL of solution.

**TABLE 22.** PREFIXES FOR QUANTITIES

<table>
<thead>
<tr>
<th>Fractional</th>
<th>Deci (d)</th>
<th>Centi (c)</th>
<th>Milli (m)</th>
<th>Micro (μ)</th>
<th>Nano (n)</th>
<th>Pico (p)</th>
<th>Femto (f)</th>
<th>Atto (atto)</th>
</tr>
</thead>
<tbody>
<tr>
<td>d</td>
<td>10⁻¹</td>
<td>10⁻²</td>
<td>10⁻³</td>
<td>10⁻⁶</td>
<td>10⁻⁹</td>
<td>10⁻¹²</td>
<td>10⁻¹⁵</td>
<td>10⁻¹⁸</td>
</tr>
<tr>
<td>Multiple</td>
<td>Deca (d)</td>
<td>Hecto (h)</td>
<td>Kilo (k)</td>
<td>Mega (M)</td>
<td>Giga (G)</td>
<td>Tera (T)</td>
<td>Penta (P)</td>
<td>Eka (E)</td>
</tr>
<tr>
<td></td>
<td>10¹</td>
<td>10²</td>
<td>10³</td>
<td>10⁶</td>
<td>10⁹</td>
<td>10¹²</td>
<td>10¹⁵</td>
<td>10¹⁸</td>
</tr>
</tbody>
</table>
BIBLIOGRAPHY

The following books and reviews provide fuller details of the topics indicated in this chapter. The authors' recommendations for excellent introductory and/or reference texts to the topics are indicated with.* [For earlier bibliographies see *Purification of Laboratory Chemicals*, 4th Edn, ISBN 0750628391 (1996, hardback) and 0750637617 (1997, paperback).

AFFINITY CHROMATOGRAPHY


CHIRAL CHROMATOGRAPHY


CHROMATOGRAPHY


Common Physical Techniques in Purification


CRYSTALLISATION


DISTILLATION


DRYING


GAS CHROMATOGRAPHY


GEL FILTRATION

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**HIGH PERFORMANCE LIQUID CHROMATOGRAPHY**


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**IONIC EQUILIBRIA**


**ION EXCHANGE**


**LABORATORY TECHNIQUE AND THEORETICAL DISCUSSION**


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SAFETY IN THE CHEMICAL LABORATORY


SOLVENTS, SOLVENT EXTRACTION AND DISTRIBUTION


SPECTROSCOPY


THIN LAYER CHROMATOGRAPHY


CHAPTER 2

CHEMICAL METHODS USED IN PURIFICATION

GENERAL REMARKS

Greater selectivity in purification can often be achieved by making use of differences in chemical properties between the substance to be purified and the contaminants. Unwanted metal ions may be removed by precipitation in the presence of a collector (see p. 54). Sodium borohydride and other metal hydrides transform organic peroxides and carbonyl-containing impurities such as aldehydes and ketones in alcohols and ethers. Many classes of organic chemicals can be purified by conversion into suitable derivatives, followed by regeneration. This chapter describes relevant procedures.

REMOVAL OF TRACES OF METALS FROM REAGENTS

METAL IMPURITIES

The presence of metal contaminants in reagents may sometimes affect the chemical or biochemical outcomes of an experiment. In these cases, it is necessary to purify the reagents used. Metal impurities can be determined qualitatively and quantitatively by atomic absorption spectroscopy and the required purification procedures can be formulated. Metal impurities in organic compounds are usually in the form of ionic salts or complexes with organic compounds and very rarely in the form of free metal. If they are present in the latter form then they can be removed by crystallising the organic compound (whereby the insoluble metal can be removed by filtration), or by distillation in which case the metal remains behind with the residue in the distilling flask. If the impurities are in the ionic or complex forms, then extraction of the organic compound in a suitable organic solvent with aqueous acidic or alkaline solutions will reduce their concentration to acceptable levels.

When the metal impurities are present in inorganic compounds as in metals or metal salts, then advantage of the differences in chemical properties should be taken. Properties of the impurities like the solubility, the solubility product (product of the metal ion and the counter-ion concentrations), the stability constants of the metal complexes with organic complexing agents and their solubilities in organic solvents should be considered. Alternatively the impurities can be masked by the addition of complexing agents which could lower the concentration of the metal ion impurities to such low levels that they would not interfere with the main compound (see complexation below). Specific procedures and examples are provided below.

DISTILLATION

Reagents such as water, ammonia, hydrochloric acid, nitric acid, perchloric acid, and sulfuric acid can be purified via distillation (preferably under reduced pressure and particularly with perchloric acid) using an all-glass still. Isothermal distillation is convenient for ammonia: a beaker containing concentrated ammonia is placed alongside a beaker of distilled water for several days in an empty desiccator so that some of the ammonia distils over into the water. The redistilled ammonia should be kept in polyethylene or paraffin-waxed bottles. Hydrochloric acid can be purified in the same way. To ensure the absence of metal contaminants from some salts (e.g. ammonium acetate), it may be more expedient to synthesise the salts using distilled components rather than to attempt to purify the salts themselves.

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USE OF ION EXCHANGE RESINS

Application of ion-exchange columns has greatly facilitated the removal of heavy metal ions such as Cu\(^{2+}\), Zn\(^{2+}\) and Pb\(^{2+}\) from aqueous solutions of many reagents. Thus, sodium salts and sodium hydroxide can be purified by passage through a column of a cation-exchange resin in its sodium form, prepared by washing the resin with 0.1M aqueous NaOH then washing with water until the pH of the effluent is ~7. Similarly, for acids, a resin in its H\(^+\) form [prepared by washing the column with 0.1M aqueous mineral acid (HCl, H\(_2\)SO\(_4\)) followed by thorough washing with water until the effluent has pH ~7] is used. In some cases, where metals form anionic complexes, they can be removed by passage through an anion-exchange resin. Iron in hydrochloric acid solution can be removed in this way.

Ion exchange resins are also useful for demineralising biochemical preparations such as proteins. Removal of metal ions from protein solutions using polystyrene-based resins, however, may lead to protein denaturation. This difficulty may be avoided by using a weakly acidic cation exchanger such as Bio-Rex 70. Heavy metal contamination of pH buffers can be removed by passage of the solutions through a Chelex X-100 column. For example, when a solution of 0.02M HEPES (4-(2-HydroxyEthyl)Piperazine-1-Ethanesulfonic acid) containing 0.2M KCl (5L, pH 7.5) alone or with calmodulin, is passed through a column of Chelex X-100 (60g) in the K\(^+\) form, the level of Ca\(^{2+}\) ions falls to less than 2 x 10\(^{-7}\) M as shown by atomic absorption spectroscopy. Such solutions should be stored in polyethylene containers that have been washed with boiling deionised water (5min) and rinsed several times with deionised water. TES [NJV,N',N'-Tetraethylsulfamide] and TRIS [Tris-(hydroxymethyl)aminomethane] have been similarly decontaminated from metal ions.

Water, with very low concentrations of ionic impurities (and approaching conductivity standards), is very readily obtained by percolation through alternate columns of cation- and anion-exchange resins, or through a mixed-bed resin, and many commercial devices are available for this purpose. For some applications, this method is unsatisfactory because the final deionised water may contain traces of organic material after passage through the columns. However, organic matter can also be removed by using yet another special column in series for this purpose (see Milli Q water preparation, Millipore Corp., www.millipore.com).

PRECIPITATION

In removing traces of impurities by precipitation it is necessary to include a material to act as a collector of the precipitated substance so as to facilitate its removal by filtration or decantation. The following are a few examples:

**Removal of lead contaminants**

Aqueous hydrofluoric acid can be freed from lead by adding 1mL of 10% strontium chloride per 100mL of acid, lead being co-precipitated as lead fluoride with the strontium fluoride. If the hydrofluoric acid is decanted from the precipitate and the process repeated, the final lead content in the acid is less than 0.003 ppm. Similarly, lead can be precipitated from a nearly saturated sodium carbonate solution by adding 10% strontium chloride dropwise (1-2mL per 100mL) followed by filtration. (If the sodium carbonate is required as a solid, the solution can be evaporated to dryness in a platinum dish.) Removal of lead from potassium chloride uses precipitation as lead sulfide by bubbling H\(_2\)S, followed, after filtration, by evaporation and recrystallisation of the potassium chloride.

**Removal of iron contaminants**

Iron contaminants have been removed from potassium thiocyanate solutions by adding a slight excess of an aluminium salt, then precipitating aluminum and iron as their hydroxides by adding a few drops of ammonia. Iron is also carried down on the hydrated manganese dioxide precipitate formed in cadmium chloride or cadmium sulfate solutions by adding 0.5% aqueous potassium permanganate (0.5mL per 100mL of solution), sufficient ammonia to give a slight precipitate, and 1mL of ethanol. The solution is heated to boiling to coagulate the precipitate, then filtered. Ferrous ion can be removed from copper solutions by adding some hydrogen peroxide to the solution to oxidise the iron, followed by precipitation of ferric hydroxide by adding a small amount of sodium hydroxide.

**Removal of other metal contaminants**

Traces of calcium can be removed from solutions of sodium salts by precipitation at pH 9.5-10 as the 8-hydroxyquinolinolate. The excess 8-hydroxyquinoline acts as a collector.

EXTRACTION

In some cases, a simple solvent extraction is sufficient to remove a particular impurity. For example, traces of gallium can be removed from titanous chloride in hydrochloric acid by extraction with disopropyl ether.
Similarly, ferric chloride can be removed from aluminium chloride solutions containing hydrochloric acid by extraction with diethyl ether. Usually, however, it is necessary to extract an undesired metal with an organic solvent in the presence of a suitable complexing agent such as dithizone (diphenylthiocarbazone) or sodium diethyl dithiocarbamate. When the former is used, weakly alkaline solutions of the substance containing the metal impurity are extracted with dithizone in chloroform (at about 25mg/L of chloroform) or carbon tetrachloride until the colour of some fresh dithizone solution remains unchanged after shaking. Dithizone complexes metals more strongly in weakly alkaline solutions. Excess dithizone in extraction with diethyl ether. Usually, however, it is necessary to extract an undesired metal with an organic solvent in the presence of a suitable complexing agent such as dithizone (diphenylthiocarbazone) or sodium diethyl dithiocarbamate.

7-Hydroxyquinoline (oxine) can also be used in removing metals from aqueous hydroxylamine hydrochloride (made just alkaline to thymol blue by adding hydrochloric acid). This group of reagents is commercially available in large quantities; some of its members - notably lithium aluminium hydride (LiAlH₄), calcium hydride (CaH₂), sodium borohydride (NaBH₄) and potassium borohydride (KBH₄) - have found widespread use in the purification of chemicals.

LITHIUM ALUMINIUM HYDRIDE

This solid is stable at room temperature, and is soluble in ether-type solvents. It reacts violently with water, liberating hydrogen, and is a powerful drying and reducing agent for organic compounds. It reduces aldehydes, ketones, esters, carboxylic acids, peroxides, acid anhydrides and acid chlorides to the corresponding alcohols. Similarly, amides, nitriles, aldimes and aliphatic nitro compounds yield amines, while aromatic nitro compounds are converted to azo compounds. For this reason it finds extensive application in purifying organic chemical substances by the removal of water and carbonyl containing impurities as well as peroxides formed by autoxidation. Reactions can generally be carried out at room temperature, or in refluxing diethyl ether, at atmospheric pressure. When drying organic liquids with this reagent it is important that the concentration of water in the liquid is below 0.1% - otherwise a violent reaction or explosion may occur. LiAlH₄ should be added cautiously to a cooled solution of organic liquid in a flask equipped with a reflux condenser.

CALCIUM HYDRIDE

This powerful drying agent is suitable for use with hydrogen, argon, helium, nitrogen, hydrocarbons, chlorinated hydrocarbons, esters and higher alcohols.

SODIUM BOROHYDRIDE

This solid which is stable in dry air up to 300°C, is a less powerful reducing agent than lithium aluminium hydride, from which it differs also by being soluble in hydroxylic solvents and to a lesser extent in ether-type solvents. Sodium borohydride forms a dihydrate melting at 36-37°C, and its aqueous solutions decompose slowly unless stabilised to above pH 9 by alkali. (For example, a useful sodium borohydride solution is one that is nearly saturated at 30-40°C and containing 0.2% sodium hydroxide.) Its solubility in water is 25, 55 and 88g per 100mL of water at 0°C, 25°C and 60°C, respectively. Boiling or acidification rapidly decomposes aqueous sodium borohydride solutions. The reagent, available either as a hygroscopic solid or as an aqueous sodium hydroxide solution, is useful as a water soluble reducing agent for aldehydes, ketones and organic peroxides. This explains its use for the removal of carbonyl-containing impurities and peroxides from alcohols, polyols, esters, polyesters, amino alcohols, olefins, chlorinated hydrocarbons, ethers, polyethers, amines (including aniline), polyamines and aliphatic sulfonates.
Purifications using sodium borohydride can be carried out conveniently using alkaline aqueous or methanolic solutions of sodium borohydride, allowing the reaction mixture to stand at room temperature for several hours. Other solvents that can be used with this reagent include isopropyl alcohol (without alkali), amines (including liquid ammonia, in which its solubility is 104g per 100g of ammonia at 25°C, and ethylenediamine), diglyme, formamide, dimethylformamide and tetrahydrofurfuryl alcohol. Alternatively, the material to be purified can be percolated through a column of the borohydride. In the absence of water, sodium borohydride solutions in organic solvents such as dioxane or amines decompose only very slowly at room temperature. Treatment of ethers with sodium borohydride appears to inhibit peroxide formation.

**POTASSIUM BOROHYDRIDE**

Potassium borohydride is similar in properties and reactions to sodium borohydride, and can similarly be used as a reducing agent for removing aldehydes, ketones and organic peroxides. It is non-hygroscopic and can be used in water, ethanol, methanol or water-alcohol mixtures, provided some alkali is added to minimise decomposition, but it is somewhat less soluble than sodium borohydride in most solvents. For example, the solubility of potassium borohydride in water at 25°C is 19g per 100mL of water (as compared to sodium borohydride, 55g).

**PURIFICATION via DERIVATIVES**

Relatively few derivatives of organic substances are suitable for use as aids to purification. This is because of the difficulty in regenerating the starting material. For this reason, we list below, the common methods of preparation of derivatives that can be used in this way.

Whether or not any of these derivatives is likely to be satisfactory for the use of any particular case will depend on the degree of difference in properties, such as solubility, volatility or melting point, between the starting material, its derivative and likely impurities, as well as on the ease with which the substance can be recovered. Purification *via* a derivative is likely to be of most use when the quantity of pure material that is required is not too large. Where large quantities (for example, more than 50g) are available, it is usually more economical to purify the material directly (for example, in distillations and recrystallisations).

The most generally useful purifications *via* derivatives are as follows:

**ALCOHOLS**

Aliphatic or aromatic alcohols are converted to solid esters. p-Nitrobenzoates are examples of convenient esters to form because of their sharp melting points, and the ease with which they can be recrystallised as well as the ease with which the parent alcohol can be recovered. The p-nitrobenzoyl chloride used in the esterification is prepared by refluxing dry p-nitrobenzoic acid with a 3 molar excess of thionyl chloride for 30min on a steam bath (*in a fume cupboard*). The solution is cooled slightly and the excess thionyl chloride is distilled off under vacuum, keeping the temperature below 40°C. Dry toluene is added to the residue in the flask, then distilled off under vacuum, the process being repeated two or three times to ensure complete removal of thionyl chloride, hydrogen chloride and sulfur dioxide. (This freshly prepared p-nitrobenzoyl chloride cannot be stored without decomposition; it should be used directly.) A solution of the acid chloride (1mol) in dry toluene or alcohol-free chloroform (distilled from P₂O₅ or by passage through an activated Al₂O₃ column) under a reflux condenser is cooled in an ice bath while the alcohol (1mol), with or without a solvent (preferably miscible with toluene or alcohol-free chloroform), is added dropwise to it. When addition is over and the reaction subsides, the mixture is refluxed for 30min and the solvent is removed under reduced pressure. The solid ester is then recrystallised to constant melting point from toluene, acetone, low boiling point petroleum ether or mixtures of these, but not from alcohols.

Hydrolysis of the ester is achieved by refluxing in aqueous N or 2N NaOH solution until the insoluble ester dissolves. The solution is then cooled, and the alcohol is extracted into a suitable solvent, e.g. ether, toluene or alcohol-free chloroform. The extract is dried (CaSO₄, MgSO₄) and distilled, then fractionally distilled if liquid or recrystallised if solid. (The p-nitrobenzoic acid can be recovered by acidification of the aqueous layer.) In most cases where the alcohol to be purified can be readily extracted from ethanol, the hydrolysis of the ester is best achieved with N or 2N ethanolic NaOH or 85% aqueous ethanolic N NaOH. The former is prepared by dissolving the necessary alkali in a minimum volume of water and diluting with absolute alcohol. The ethanolic solution is refluxed for one to two hours and hydrolysis is complete when an aliquot gives a clear solution on dilution with four or five times its volume of water. The bulk of the ethanol is distilled off and the residue is...
extracted as above. Alternatively, use can be made of ester formation with benzoic acid, toluic acid or 3,5-
dinitrobenzoic acid, by the above method.

Other derivatives can be prepared by reaction of the alcohol with an acid anhydride. For example, phthalic or 3-
nitrophthalic anhydride (1 mol) and the alcohol (1 mol) are refluxed for half to one hour in a non-hydroxylic
solvent, e.g. toluene or alcohol-free chloroform, and then cooled. The phthalate ester crystallises out, is
precipitated by the addition of low boiling petroleum ether or is isolated by evaporation of the solvent. It is
recrystallised from water, 50% aqueous ethanol, toluene or low boiling petroleum ether. Such an ester has a
characteristic melting point and the alcohol can be recovered by acid or alkaline hydrolysis.

ALDEHYDES

The best derivative from which an aldehyde can be recovered readily is its bisulfite addition compound, the
main disadvantage being the lack of a sharp melting point. The aldehyde (sometimes in ethanol) is shaken with
a cold saturated solution of sodium bisulfite until no more solid adduct separates. The adduct is filtered off,
washed with a little water, followed by alcohol. A better reagent to use is a freshly prepared saturated aqueous
sodium bisulfite solution to which 75% ethanol is added to near-saturation. (Water may have to be added
dropwise to render this solution clear.) With this reagent the aldehyde need not be dissolved separately in
alcohol and the adduct is finally washed with alcohol. The aldehyde is recovered by dissolving the adduct in the
least volume of water and adding an equivalent quantity of sodium carbonate (not sodium hydroxide) or
concentrated hydrochloric acid to react with the bisulfite, followed by steam distillation or solvent extraction.

Other derivatives that can be prepared are the Schiff bases and semicarbazones. Condensation of the aldehyde
with an equivalent of primary aromatic amine yields the Schiff base, for example aniline at 100° for 10-30min.
Semicarbazones are prepared by dissolving semicarbazide hydrochloride (ca 1g) and sodium acetate (ca 1.5g)
in water (8-10mL) and adding the aldehyde or ketone (0.5-1g) with stirring. The semicarbazone crystallises out
and is recrystallised from ethanol or aqueous ethanol. These are hydrolysed by steam distillation in the presence
of oxalic acid or better by exchange with pyruvic acid (Hershberg J Org Chem 13 542 1948) [see entry under
Ketones].

AMINES

Picrates

The most versatile derivative from which the free base can be readily recovered is the picrate. This is very
satisfactory for primary and secondary aliphatic amines and aromatic amines and is particularly so for
heterocyclic bases. The amine, dissolved in water or alcohol, is treated with excess of a saturated solution of
picric acid in water or alcohol, respectively, until separation of the picrate is complete. If separation does not
occur, the solution is stirred vigorously and warmed for a few minutes, or diluted with a solvent in which the
picrate is insoluble. Thus, a solution of the amine and picric acid in ethanol can be treated with petroleum ether
to precipitate the picrate. Alternatively, the amine can be dissolved in alcohol and aqueous picric acid added.
The picrate is filtered off, washed with water or ethanol and recrystallised from boiling water, ethanol,
methanol, aqueous ethanol, methanol or chloroform. The solubility of picric acid in water and ethanol is 1.4
and 6.23 % respectively at 20°.

It is not advisable to store large quantities of picrates for long periods, particularly when they are dry due to
their potential EXPLOSIVE nature. The free base should be recovered as soon as possible. The picrate is
suspended in an excess of 2N aqueous NaOH and warmed a little. Because of the limited solubility of sodium
picrate, excess hot water must be added. Alternatively, because of the greater solubility of lithium picrate,
aqueous 10% lithium hydroxide solution can be used. The solution is cooled, the amine is extracted with a
suitable solvent such as diethyl ether or toluene, washed with 5N NaOH until the alkaline solution remains
colourless, then with water, and the extract is dried with anhydrous sodium carbonate. The solvent is distilled
off and the amine is fractionally distilled (under reduced pressure if necessary) or recrystallised.

If the amines are required as their hydrochlorides, picrates can often be decomposed by suspending them in
acetone and adding two equivalents of 10N HCl. The hydrochloride of the base is filtered off, leaving the picric
acid in the acetone. Dowex No 1 anion-exchange resin in the chloride form is useful for changing solutions of
the more soluble picrates (for example, of adenosine) into solutions of their hydrochlorides, from which sodium
hydroxide precipitates the free base.

Salts

Amines can also be purified via their salts, e.g. hydrochlorides. A solution of the amine in dry toluene, diethyl
ether, dichloromethane or chloroform is saturated with dry hydrogen chloride (generated by addition of
concentrated sulfuric acid to dry sodium chloride, or to concentrated HCl followed by drying the gas through
sulfuric acid, or from a hydrogen chloride cylinder) and the insoluble hydrochloride is filtered off and dissolved
in water. The solution is made alkaline and the amine is extracted, as above. Hydrochlorides can also be
prepared by dissolving the amine in ethanolic HCl and adding diethyl ether or petroleum ether. Where
Chemical Methods used in Purification

Hydrochlorides are too hygroscopic or too soluble for satisfactory isolation, other salts, e.g. nitrate, sulfate, bisulfate or oxalate, can be used.

Double salts
The amine (1 mol) is added to a solution of anhydrous zinc chloride (1 mol) in concentrated hydrochloric acid (42 mL) in ethanol (200 mL, or less depending on the solubility of the double salt). The solution is stirred for 1 h and the precipitated salt is filtered off and recrystallised from ethanol. The free base is recovered by adding excess of 5-10N NaOH (to dissolve the zinc hydroxide that separates) and is steam distilled. Mercuric chloride in hot water can be used instead of zinc chloride and the salt is crystallised from 1% hydrochloric acid. Other double salts have been used, e.g. cuprous salts, but are not as convenient as the above salts.

N-Acetyl derivatives
Purification as their N-acetyl derivatives is satisfactory for primary, and to a limited extent secondary, amines. The base is refluxed with slightly more than one equivalent of acetic anhydride for half to one hour, cooled and poured into ice-cold water. The insoluble derivative is filtered off, dried, and recrystallised from water, ethanol, aqueous ethanol or benzene (CAUTION toxic!). The derivative can be hydrolysed to the parent amine by refluxing with 70% sulfuric acid for a half to one hour. The solution is cooled, poured onto ice, and made alkaline. The amine is steam distilled or extracted as above. Alkaline hydrolysis is very slow.

N-Tosyl derivatives
Primary and secondary amines are converted into their tosyl derivatives by mixing equimolar amounts of amine and p-toluenesulfonyl chloride in dry pyridine (ca 5-10 mol) and allowing to stand at room temperature overnight. The solution is poured into ice-water and the pH adjusted to 2 with HCl. The solid derivative is filtered off, washed with water, dried (vac. desiccator) and recrystallised from an alcohol or aqueous alcohol solution to a sharp melting point. The derivative is decomposed by dissolving in liquid ammonia (fume cupboard) and adding sodium metal (in small pieces with stirring) until the blue colour persists for 10-15 min. Ammonia is allowed to evaporate (fume cupboard), the residue treated with water and the solution checked that the pH is above 10. If the pH is below 10 then the solution has to be basified with 2N NaOH. The mixture is extracted with diethyl ether or toluene, the extract is dried (K2CO3), evaporated and the residual amine recrystallised if solid or distilled if liquid.

AROMATIC HYDROCARBONS
Adducts
Aromatic hydrocarbons can be purified as their picrates using the procedures described for amines. Instead of picric acid, 1,3,5-trinitrobenzene or 2,4,7-trinitrofluorenone can also be used. In all these cases, following recrystallisation, the hydrocarbon can be isolated either as described for amines or by passing a solution of the adduct through an activated alumina column and eluting with toluene or petroleum ether. The picric acid and nitro compounds are more strongly adsorbed on the column.

Sulfonation
Naphthalene, xylenes and alkyl benzenes can be purified by sulfonation with concentrated sulfuric acid and crystallisation of the sodium sulfonates. The hydrocarbon is distilled out of the mixture with superheated steam.

CARBOXYLIC ACIDS
4-Bromophenacyl esters
A solution of the sodium salt of the acid is prepared. If the salt is not available, the acid is dissolved in an equivalent of aqueous NaOH and the pH adjusted to 8-9 with this base. A solution of one equivalent of 4-bromophenacyl bromide (for a monobasic acid, two equivalents for a dibasic acid, etc) in ten times its volume of ethanol is then added. The mixture is heated to boiling, and, if necessary, enough ethanol is added to clarify the solution which is then refluxed for half an hour to three hours depending on the number of carboxylic groups that have to be esterified. (One hour is generally sufficient for monocarboxylic acids.) On cooling, the ester should crystallise out. If it does not, then the solution is heated to boiling, and enough water is added to produce a slight turbidity. The solution is again cooled. The ester is collected, and recrystallised or fractionally distilled.

The ester is hydrolysed by refluxing for 1-2 h with 1-5% of barium carbonate suspended in water or with aqueous sodium carbonate solution. The solution is cooled and extracted with diethyl ether, toluene or chloroform. It is then acidified and the acid is collected by filtration or extraction, and recrystallised or fractionally distilled.

p-Nitrobenzyl esters can be prepared in an analogous manner using the sodium salt of the acid and p-nitrobenzyl bromide. They are readily hydrolysed.

Alkyl esters
Of the alkyl esters, methyl esters are the most useful because of their rapid hydrolysis. The acid is refluxed with one or two equivalents of methanol in excess alcohol-free chloroform (or dichloromethane) containing about 0.1 g of p-toluenesulfonic acid (as catalyst), using a Dean-Stark apparatus. (The water formed by the
esterification is carried away into the trap.) When the theoretical amount of water is collected in the trap, esterification is complete. The chloroform solution in the flask is washed with 5% aqueous sodium carbonate solution, then water, and dried over anhydrous sodium sulfate or magnesium sulfate. The chloroform is distilled off and the ester is fractionally distilled through an efficient column. The ester is hydrolysed by refluxing with 5-10% aqueous NaOH solution until the insoluble ester has completely dissolved. The aqueous solution is concentrated a little by distillation to remove all of the methanol. It is then cooled and acidified. The acid is either extracted with diethyl ether, toluene or chloroform, or filtered off and isolated as above. Other methods for preparing esters are available.

**Salts**

The most useful salt derivatives for carboxylic acids are the isothiouronium salts. These are prepared by mixing almost saturated solutions containing the acid (carefully neutralised with N NaOH using phenolphthalein indicator) then adding two drops of N HCl and an equimolar amount of S-benzylisothiouronium chloride in ethanol and filtering off the salt that crystallises out. After recrystallisation from water, alcohol or aqueous alcohol the salt is decomposed by suspending or dissolving in 2N HCl and extracting the carboxylic acid from aqueous solution into diethyl ether, chloroform or toluene.

**HYDROPEROXIDES**

These can be converted to their sodium salts by precipitation below 30° with aqueous 25% NaOH. The salt is then decomposed by addition of solid (powdered) carbon dioxide and extracted with low-boiling petroleum ether. The solvent should be removed under reduced pressure below 20°. The manipulation should be adequately shielded at all times to guard against EXPLOSIONS for the safety of the operator.

**KETONES**

**Bisulfite adduct**

The adduct can be prepared and decomposed as described for aldehydes. Alternatively, because no Cannizzaro reaction is possible, it can also be decomposed with 0.5N NaOH.

**Semicarbazones**

A powdered mixture of semicarbazide hydrochloride (1mol) and anhydrous sodium acetate (1.3mol) is dissolved in water by gentle warming. A solution of the ketone (1mol) in the minimum volume of ethanol needed to dissolve it is then added. The mixture is warmed on a water bath until separation of the semicarbazone is complete. The solution is cooled, and the solid is filtered off. After washing with a little ethanol followed by water, it is recrystallised from ethanol or dilute aqueous ethanol. The derivative should have a characteristic melting point. The semicarbazone is decomposed by refluxing with excess of oxalic acid or with aqueous sodium carbonate solution. The ketone (which steam distils) is distilled off. It is extracted or separated from the distillate (after saturating with NaCl), dried with CaSO₄ or MgSO₄ and fractionally distilled using an efficient column (under vacuum if necessary). [See entry under Aldehydes.]

**PHENOLS**

The most satisfactory derivatives for phenols that are of low molecular weight or monohydric are the benzoate esters. (Their acetate esters are generally liquids or low-melting solids.) Acetates are more useful for high molecular weight and polyhydric phenols.

**Benzoates**

The phenol (1mol) in 5% aqueous NaOH is treated (while cooling) with benzoyl chloride (1mol) and the mixture is stirred in an ice bath until separation of the solid benzoyl derivative is complete. The derivative is filtered off, washed with alkali, then water, and dried (in a vacuum desiccator over NaOH). It is recrystallised from ethanol or dilute aqueous ethanol. The benzylation can also be carried out in dry pyridine at low temperature (ca 0°) instead of in NaOH solution, finally pouring the mixture into water and collecting the solid as above. The ester is hydrolysed by refluxing in an alcohol (for example, ethanol, n-butanol) containing two or three equivalents of the alkoxide of the corresponding alcohol (for example sodium ethoxide or sodium n-butoxide) and a few (ca 5-10) millilitres of water, for half an hour to three hours. When hydrolysis is complete, an aliquot will remain clear on dilution with four to five times its volume of water. Most of the solvent is distilled off. The residue is diluted with cold water and acidified, and the phenol is steam distilled. The latter is collected from the distillate, dried and either fractionally distilled or recrystallised.

**Acetates**

These can be prepared as for the benzoates using either acetic anhydride with 3N NaOH or acetyl chloride in pyridine. They are hydrolysed as described for the benzoates. This hydrolysis can also be carried out with aqueous 10% NaOH solution, completion of hydrolysis being indicated by the complete dissolution of the acetate in the aqueous alkaline solution. On steam distillation, acetic acid also distils off but in these cases the phenols (see above) are invariably solids which can be filtered off and recrystallised.
PHOSPHATE AND PHOSPHONATE ESTERS
These can be converted to their uranyl nitrate addition compounds. The crude or partially purified ester is saturated with uranyl nitrate solution and the adduct filtered off. It is recrystallised from n-hexane, toluene or ethanol. For the more soluble members crystallisation from hexane using low temperatures (-40°) has been successful. The adduct is decomposed by shaking with sodium carbonate solution and water, the solvent is steam distilled (if hexane or toluene is used) and the ester is collected by filtration. Alternatively, after decomposition, the organic layer is separated, dried with CaCl₂ or BaO, filtered, and fractionally distilled under high vacuum.

MISCELLANEOUS
Impurities can sometimes be removed by conversion to derivatives under conditions where the major component does not react or reacts much more slowly. For example, normal (straight-chain) paraffins can be freed from unsaturated and branched-chain components by taking advantage of the greater reactivity of the latter with chlorosulfonic acid or bromine. Similarly, the preferential nitration of aromatic hydrocarbons can be used to remove e.g. benzene or toluene from cyclohexane by shaking for several hours with a mixture of concentrated nitric acid (25%), sulfuric acid (58%), and water (17%).

GENERAL METHODS FOR THE PURIFICATION OF CLASSES OF COMPOUNDS
Chapters 4, 5 and 6 list a large number of individual compounds, with a brief statement of how each one may be purified. For substances that are not included in these chapters the following procedures may prove helpful.

PROCEDURES
If the laboratory worker does not know of a reference to the preparation of a commercially available substance, he may be able to make a reasonable guess at the synthetic method used from published laboratory syntheses. This information, in turn, can simplify the necessary purification steps by suggesting probable contaminants. However, for other than macromolecules it is important that at least the ¹H NMR spectrum and/or the mass spectrum of the substance should be measured. These measurements require no more than two to three milligrams of material and provide a considerable amount of information about the substance. From the bibliography at the end of this chapter, references to NMR, IR and mass spectral data for a large number of the compounds in the Aldrich catalogue are available and are extremely useful for identifying compounds and impurities. If the material appears to have several impurities these spectra should be followed by examination of their chromatographic properties and spot tests. Purification methods can then be devised to remove these impurities, and a monitoring method will have already been established.

Physical methods of purification depend largely on the melting and boiling points of the materials. For gases and low-boiling liquids use is commonly made of the freeze-pump-thaw procedure (see Chapter 1). Gas chromatography is also useful, especially for low-boiling point liquids. Liquids are usually purified by refluxing with drying agents, acids or bases, reducing agents, charcoal, etc., followed by fractional distillation under reduced pressure. For solids, general methods include fractional freezing of the melted material, taking the middle fraction. Another procedure is sublimation of the solid under reduced pressure. The other commonly used method for purifying solids is by recrystallisation from a solution in a suitable solvent, by cooling with or without the prior addition of a solvent in which the solute is not very soluble.

The nature of the procedure will depend to a large extent on the quantity of purified material that is required. For example, for small quantities (50-250mg) of a pure volatile liquid, preparative gas chromatography is probably the best method. Two passes through a suitable column may well be sufficient. Similarly, for small amounts (100-500mg) of an organic solid, column chromatography is likely to be very satisfactory, the eluate being collected as a number of separate fractions (ca 5-10mL) which are examined by FT-IR, NMR or UV spectroscopy, TLC or by some other appropriate analytical technique. (For information on suitable adsorbents and eluents the texts referred to in the bibliography at the end of Chapters 1 and 2 should be consulted.) Preparative thin layer chromatography or HPLC can also be used successfully for purifying up to 500mg of solid. HPLC is the more and more commonly used procedure for the purification of small molecules as well as large molecules such as polypeptides and DNA.
Where larger quantities (upwards of 1g) are required, most of the impurities should be removed by preliminary treatments, such as solvent extraction, liquid-liquid partition, or conversion to a derivative (vide supra) which can be purified by crystallisation or fractional distillation before being reconverted to the starting material. The substance is then crystallised or distilled. If the final amounts must be in excess of 25g, preparation of a derivative is sometimes omitted because of the cost involved. In all of the above cases, purification is likely to be more laborious if the impurity is an isomer or a derivative with closely similar physical properties.

CRITERIA OF PURITY
Purification becomes meaningful only insofar as adequate tests of purity are applied: the higher the degree of purity that is sought, the more stringent must these tests be. If the material is an organic solid, its melting point should first be taken and compared with the recorded value. Note that the melting points of most salts, organic or inorganic, are generally decomposition points and are not reliable criteria of purity. As part of this preliminary examination, the sample might be examined by thin layer chromatography in several different solvent systems and in high enough concentrations to facilitate the detection of minor components. On the other hand, if the substance is a liquid, its boiling point should be measured. If, further, it is a high boiling liquid, its chromatographic behaviour should be examined. Liquids, especially volatile ones, can be studied very satisfactorily by gas chromatography, preferably using at least two different stationary and/or mobile phases. Atomic absorption spectroscopy is a useful and sensitive method for detecting metal impurities and the concentrations of metals and metal salts or complexes.

Application of these tests at successive steps will give a good indication of whether or not the purification is satisfactory and will also show when adequate purification has been achieved. Finally elemental analyses, e.g. of carbon, hydrogen, nitrogen, sulfur, metals etc. are very sensitive to impurities (other than with isomers), and are good criteria of purity.

GENERAL PROCEDURES FOR THE PURIFICATION OF SOME CLASSES OF ORGANIC COMPOUNDS
In the general methods of purification described below, it is assumed that the impurities belong essentially to a class of compounds different from the one being purified. They are suggested for use in cases where substances are not listed in Chapters 4, 5 and the low molecular weight compounds in Chapter 6. In such cases, the experimenter is advised to employ them in conjunction with information given in these chapters for the purification of suitable analogues. Also, for a wider range of drying agents, solvents for extraction and solvents for recrystallisation, the reader is referred to Chapter 1. See Chapter 6 for general purification procedures used for macromolecules.

ACETALS
These are generally diethyl or dimethyl acetal derivatives of aldehydes. They are more stable to alkali than to acids. Their common impurities are the corresponding alcohol, aldehyde and water. Drying with sodium wire removes alcohols and water, and polymerizes aldehydes so that, after decantation, the acetal can be fractionally distilled. In cases where the use of sodium is too drastic, aldehydes can be removed by shaking with alkaline hydrogen peroxide solution and the acetal is dried with sodium carbonate or potassium carbonate. Residual water and alcohols (up to n-propyl) can be removed with Linde type 4A molecular sieves. The acetal is then filtered and fractionally distilled. Solid acetals (i.e. acetals of high molecular weight aldehydes) are generally low-melting and can be recrystallised from low-boiling petroleum ether, toluene or a mixture of both.

ACIDS
Carboxylic acids
Liquid carboxylic acids are first freed from neutral and basic impurities by dissolving them in aqueous alkali and extracting with diethyl ether. (The pH of the solution should be at least three units above the pKa of the acid, see pK in Chapter 1). The aqueous phase is then acidified to a pH at least three units below the pKa of the acid and again extracted with ether. The extract is dried with magnesium sulfate or sodium sulfate and the ether is distilled off. The acid is fractionally distilled through an efficient column. It can be further purified by
conversion to its methyl or ethyl ester (*vide supra*) which is then fractionally distilled. Hydrolysis yields the original acid which is again purified as above.

Acids that are solids can be purified in this way, except that distillation is replaced by repeated crystallisation (preferable from at least two different solvents such as water, alcohol or aqueous alcohol, toluene, toluene/petroleum ether or acetic acid.) Water-insoluble acids can be partially purified by dissolution in N sodium hydroxide solution and precipitation with dilute mineral acid. If the acid is required to be free from sodium ions, then it is better to dissolve the acid in hot N ammonia, heat to ca 80°, adding slightly more than an equal volume of N formic acid and allowing to cool slowly for crystallisation. Any ammonia, formic acid or ammonium formate that adhere to the acid are removed when the acid is dried in a vacuum — they are volatile. The separation and purification of naturally occurring fatty acids, based on distillation, salt solubility and low temperature crystallisation, are described by K.S. Markley (Ed.), *Fatty Acids*, 2nd Edn, part 3, Chap. 20, Interscience, New York, 1964.

Aromatic carboxylic acids can be purified by conversion to their sodium salts, recrystallisation from hot water, and reconversion to the free acids.

**Sulfonic acids**

The low solubility of sulfonic acids in organic solvents and their high solubility in water makes necessary a treatment different from that for carboxylic acids. Sulfonic acids are strong acids, they have the tendency to hydrate, and many of them contain water of crystallisation. The lower-melting and liquid acids can generally be purified with only slight decomposition by fractional distillation, preferably under reduced pressure. A common impurity is sulfuric acid, but this can be removed by recrystallisation from concentrated aqueous solutions. The wet acid can be dried by azeotropic removal of water with toluene, followed by distillation. The higher-melting acids, or acids that melt with decomposition, can be recrystallised from water or, occasionally, from ethanol. For a typical purification of aromatic sulfonic acids using their barium salts refer to benzenesulfonic acid in Chapter 4.

**Sulfinic acids**

These acids are less stable, less soluble and less acidic than the corresponding sulfonic acids. The common impurities are the respective sulfonyl chlorides from which they have been prepared, and the thiolsulfonates (neutral) and sulfonic acids into which they decompose. The first two of these can be removed by solvent extraction from an alkaline solution of the acid. On acidification of an alkaline solution, the sulfinic acid crystallises out leaving the sulfonic acid behind. The lower molecular weight members are isolated as their metal (e.g. ferric) salts, but the higher members can be crystallised from water (made slightly acidic), or alcohol.

**ACID CHLORIDES**

The corresponding acid and hydrogen chloride are the most likely impurities. Usually these can be removed by efficient fractional distillation. Where acid chlorides are not readily hydrolysed (e.g. aryl sulfonyl chlorides) the compound can be freed from contaminants by dissolving in a suitable solvent such as alcohol-free chloroform, dry toluene or petroleum ether and shaking with dilute sodium bicarbonate solution. The organic phase is then washed with water, dried with anhydrous sodium sulfate or magnesium sulfate, and distilled or recrystallised. This procedure is *hazardous* with readily hydrolysable acid chlorides such as acetyl chloride and benzoyl chloride. Solid acid chlorides should be thoroughly dried *in vacuo* over strong drying agents and are satisfactorily recrystallised from toluene, toluene-petroleum ether, petroleum ethers, alcohol-free chloroform/toluene, and, occasionally, from dry diethyl ether. Hydroxylic or basic solvents should be strictly avoided. *All operations should be carried out in a fume cupboard because of the irritant nature of these compounds which also attack the skin.*

**ALCOHOLS**

**Monohydric alcohols**

The common impurities in alcohols are aldehydes or ketones, and water. [*Ethanol* in Chapter 4 is typical.] Aldehydes and ketones can be removed by adding a small amount of sodium metal and refluxing for 2 hours, followed by distillation. Water can be removed in a similar way but it is preferable to use magnesium metal instead of sodium because it forms a more insoluble hydroxide, thereby shifting the equilibrium more completely from metal alkoxide to metal hydroxide. The magnesium should be activated with iodine (or a small amount of methyl iodide), and the water content should be low, otherwise the magnesium will be deactivated.

If the amount of water is large it should be removed by azeotropic distillation (see below), or by drying over anhydrous MgSO₄ (not CaCl₂ which combines with alcohols). Acidic materials can be removed by treatment
Chemical Methods used in Purification

with anhydrous Na₂CO₃, followed by a suitable drying agent, such as calcium hydride, and fractional distillation, using gas chromatography to establish the purity of the product [Ballinger and Long, J Am Chem Soc 82 795 1960]. Alternatively, the alcohol can be refluxed with freshly ignited CaO for 4 hours and then fractionally distilled [McCurdy and Ladler, Can J Chem 41 1867 1963]. With higher-boiling alcohols it is advantageous to add some freshly prepared magnesium ethoxide solution (only slightly more than required to remove the water), followed by fractional distillation. Alternatively, in such cases, water can be removed by azeotropic distillation with toluene. Higher-melting alcohols can be purified by crystallisation from methanol or ethanol, toluene/petroleum ether or petroleum ether. Sublimation in vacuum, molecular distillation and gas chromatography are also useful means of purification. For purification via derivatives, vide supra.

**Polyhydric alcohols**
These alcohols are more soluble in water than are monohydric alcohols. Liquids can be freed from water by shaking with type 4A Linde molecular sieves and can safely be distilled only under high vacuum. Carbohydrate alcohols can be crystallised from strong aqueous solution or, preferably, from mixed solvents such as ethanol/petroleum ether or dimethyl formamide/toluene. Crystallisation usually requires seeding and is extremely slow. Further purification can be effected by conversion to the acetyl or benzoyl derivatives which are much less soluble in water and which can readily be recrystallised, e.g. from ethanol. Hydrolysis of the acetyl derivatives, followed by removal of acetate or benzoate and metal ions by ion-exchange chromatography, gives the purified material. On no account should solutions of carbohydrates be concentrated above 40% because of darkening and formation of caramel. Ion exchange, charcoal or cellulose column chromatography has been used for the purification and separation of carbohydrates.

**ALDEHYDES**
Common impurities found in aldehydes are the corresponding alcohols, aldols and water from self-condensation, and the corresponding acids formed by autoxidation. Acids can be removed by shaking with aqueous 10% sodium bicarbonate solution. The organic liquid is then washed with water. It is dried with anhydrous sodium sulfate or magnesium sulfate and then fractionally distilled. Water soluble aldehydes must be dissolved in a suitable solvent such as diethyl ether before being washed in this way. Further purification can be effected via the bisulfite derivative (see pp. 57 and 59) or the Schiff base formed with aniline or benzidine. Solid aldehydes can be dissolved in diethyl ether and purified as above. Alternatively, they can be steam distilled, then sublimed and crystallised from toluene or petroleum ether.

**AMIDES**
Amides are stable compounds. The lower-melting members (such as acetamide) can be readily purified by fractional distillation. Most amides are solids which have low solubilities in water. They can be recrystallised from large quantities of water, ethanol, ethanol/ether, aqueous ethanol, chloroform/toluene, chloroform or acetic acid. The likely impurities are the parent acids or the alkyl esters from which they have been made. The former can be removed by thorough washing with aqueous ammonia followed by recrystallisation, whereas elimination of the latter is by titration or recrystallisation from an organic solvent. Amides can be freed from solvent or water by drying below their melting points. These purifications can also be used for sulfonamides and acid hydrazides.

**AMINES**
The common impurities found in amines are nitro compounds (if prepared by reduction), the corresponding halides (if prepared from them) and the corresponding carbamate salts. Amines are dissolved in aqueous acid, the pH of the solution being at least three units below the pKₐ value of the base to ensure almost complete formation of the cation. They are extracted with diethyl ether to remove neutral impurities and to decompose the carbamate salts. The solution is then made strongly alkaline and the amines that separate are extracted into a suitable solvent (ether or toluene) or steam distilled. The latter process removes coloured impurities. Note that chloroform cannot be used as a solvent for primary amines because, in the presence of alkali, poisonous carbamylamines (isocyanides) are formed. However, chloroform is a useful solvent for the extraction of heterocyclic bases. In this case it has the added advantage that while the extract is being freed from the chloroform most of the moisture is removed with the solvent. Alternatively, the amine may be dissolved in a suitable solvent (e.g. toluene) and dry HCl gas is passed through the solution to precipitate the amine hydrochloride. This is purified by recrystallisation from a suitable solvent mixture (e.g. ethanol/diethyl ether). The free amine can be regenerated by adding sodium hydroxide and isolated as above.
Chemical Methods used in Purification

Liquid amines can be further purified \textit{via} their acetyl or benzoyl derivatives (\textit{vide supra}). Solid amines can be recrystallised from water, alcohol, toluene or toluene-petroleum ether. \textit{Care should be taken in handling large quantities of amines because their vapours are harmful (possibly carcinogenic) and they are readily absorbed through the skin.}

**AMINO ACIDS**

Because of their zwitterionic nature, amino acids are generally soluble in water. Their solubility in organic solvents rises as the fat-soluble portion of the molecule increases. The likeliest impurities are traces of salts, heavy metal ions, proteins and other amino acids. Purification of these is usually easy, by recrystallisation from water or ethanol/water mixtures. The amino acid is dissolved in the boiling solvent, decolorised if necessary by boiling with 1g of acid-washed charcoal/100g amino acid, then filtered hot, chilled, and set aside for several hours to crystallise. The crystals are filtered off, washed with ethanol, then ether, and dried.

Amino acids have high melting or decomposition points and are best examined for purity by paper or thin layer chromatography. The spots are developed with ninhydrin. Customary methods for the purification of small quantities of amino acids obtained from natural sources (i.e. 1-5g) are ion-exchange chromatography (see Chapter 1). For general treatment of amino acids see Greenstein and Winitz \textit{[The Amino Acids, Vols 1-3, J.Wiley & Sons, New York 1961] and individual amino acids in Chapters 4 and 6.}

A useful source of details such as likely impurities, stability and tests for homogeneity of amino acids is \textit{Specifications and Criteria for Biochemical Compounds}, 3rd edn, National Academy of Sciences, USA, 1972.

**ANHYDRIDES**

The corresponding acids, resulting from hydrolysis, are the most likely impurities. Distillation from phosphorus pentoxide, followed by fractional distillation, is usually satisfactory. With high boiling or solid anhydrides, another method involves boiling under reflux for 0.5-1h with acetic anhydride, followed by fractional distillation. Acetic acid distils first, then acetic anhydride and finally the desired anhydride. Where the anhydride is a solid, removal of acetic acid and acetic anhydride at atmospheric pressure is followed by heating under vacuum. The solid anhydride is then either crystallised as for acid chlorides or (in some cases) sublimed in a vacuum. A preliminary purification when large quantities of acid are present in a solid anhydride (such as phthalic anhydride) is by preferential solvent extraction of the (usually) more soluble anhydride from the acid (e.g. with CFCl₃ in the case of phthalic anhydride). \textit{All operations with liquid anhydrides should be carried out in a fume cupboard because of their LACHRYMATORY properties. Almost all anhydrides attack skin.}

**CAROTENOIDS**

These usually are decomposed by light, air and solvents, so that degradation products are probable impurities. Chromatography and adsorption spectra permit the ready detection of coloured impurities, and separations are possible using solvent distribution, chromatography or crystallisation. Thus, in partition between immiscible solvents, xanthophyll remains in 90% methanol while carotenes pass into the petroleum ether phase. For small amounts of material, thin-layer or paper chromatography may be used, while column chromatography is suitable for larger amounts. Colorless impurities may be detected by IR, NMR or mass spectrometry. The more common separation procedures are described by P. Karrer and E. Jucker in \textit{Carotenoids, E.A. Braude (translator), Elsevier, NY, 1950.}

Purity can be checked by chromatography (on thin-layer plates, Kieselguhr, paper or columns), by UV or NMR procedures.

**ESTERS**

The most common impurities are the corresponding acid and hydroxy compound (i.e. alcohol or phenol), and water. A liquid ester from a carboxylic acid is washed with 2N sodium carbonate or sodium hydroxide to remove acid material, then shaken with calcium chloride to remove ethyl or methyl alcohols (if it is a methyl or ethyl ester). It is dried with potassium carbonate or magnesium sulfate, and distilled. Fractional distillation then removes residual traces of hydroxy compounds. This method does not apply to esters of inorganic acids (e.g. dimethyl sulfate) which are more readily hydrolysed in aqueous solution when heat is generated in the neutralisation of the excess acid. In such cases, several fractional distillations, preferably under vacuum, are usually sufficient.

Solid esters are easily crystallisable materials. It is important to note that esters of alcohols must be recrystallised either from non-hydroxylic solvents (e.g. toluene) or from the alcohol from which the ester is derived. Thus methyl esters should be crystallised from methanol or methanol/toluene, but not from ethanol, n-butanol or other alcohols, in order to avoid alcohol exchange and contamination of the ester with a second ester. Useful solvents for crystallisation are the corresponding alcohols or aqueous alcohols, toluene, toluene/petroleum ether, and chloroform (ethanol-free)/toluene. Esters of carboxylic acid derived from phenols...
are more difficult to hydrolyse and exchange, hence any alcoholic solvent can be used freely. Sulfonic acid esters of phenols are even more resistant to hydrolysis: they can safely be crystallised not only from the above solvents but also from acetic acid, aqueous acetic acid or boiling n-butanol. Fully esterified phosphoric acid and phosphonic acids differ only in detail from the above mentioned esters. Their major contaminants are alcohols or phenols, phosphoric or phosphonic acids (from hydrolysis), and water. After drying with calcium chloride they are fractionally distilled. Water-soluble esters should first be dissolved in a suitable organic solvent and, in the washing process, water should be replaced by saturated aqueous sodium chloride. Some esters (e.g. phosphate and phosphonate esters) can be further purified through their uranyl adducts (vide supra). Traces of water or hydroxy compounds can be removed by percolation through, or shaking with, activated alumina (about 100g/L of liquid solution), followed by filtration and fractional distillation in a vacuum. For high molecular weight esters (which cannot be distilled without some decomposition) it is advisable to carry out distillation at as low a pressure as possible. Solid esters can be crystallised from toluene or petroleum ether. Alcohols can be used for recrystallising phosphoric or phosphonic esters of phenols.

ETHERS

The purification of diethyl ether (see Chapter 4) is typical of liquid ethers. The most common contaminants are the alcohols or hydroxy compounds from which the ethers are prepared, their oxidation products (e.g. aldehydes), peroxides and water. Peroxides, aldehydes and alcohols can be removed by shaking with alkaline potassium permanganate solution for several hours, followed by washing with water, concentrated sulfuric acid [CARE], then water. After drying with calcium chloride, the ether is distilled. It is then dried with sodium or with lithium aluminium hydride, redistilled and given a final fractional distillation. The drying process should be repeated if necessary. Alternatively, methods for removing peroxides include leaving the ether to stand in contact with iron filings or copper powder, shaking with a solution of ferrous sulfate acidified with N sulfuric acid, shaking with a copper-zinc couple, passage through a column of activated alumina, and refluxing with phenothiazine. Cerium(III) hydroxide has also been used.

A simple test for ether peroxides is to add 10mL of the ether to a stoppered cylinder containing 1mL of freshly prepared 10% solution of potassium iodide containing a drop of starch indicator. No colour should develop during one minute if free from peroxides. Alternatively, a 1% solution of ferrous ammonium sulfate, 0.1M in sulfuric acid and 0.01M in potassium thiocyanate should not increase appreciably in red colour when shaken with two volumes of the ether.

As a safety precaution against EXPLOSION (in case the purification has been insufficiently thorough) at least a quarter of the total volume of ether should remain in the distilling flask when the distillation is discontinued as peroxides are generally higher boiling. To minimize peroxide formation, ethers should be stored in dark bottles and, if they are liquids, they should be left in contact with type 4A Linde molecular sieves, in a cold place, over sodium amalgam. The rate of formation of peroxides depends on storage conditions and is accelerated by heat, light, air and moisture. The formation of peroxides is inhibited in the presence of diphenylamine, di-tert-butylphenol, or other antioxidants as stabiliser.

Ethers that are solids (e.g. phenyl ethers) can be steam distilled from an alkaline solution which will hold back any phenolic impurity. After the distillate is made alkaline with sodium carbonate, the insoluble ether is collected either by extraction (e.g. with chloroform, diethyl ether or toluene) or by filtration. It is then crystallised from alcohols, alcohol/petroleum ether, petroleum ether, toluene or mixtures of these solvents, sublimed in a vacuum and recrystallised if necessary.

HALIDES

Aliphatic halides are likely to be contaminated with halogen acids and the alcohols from which they have been prepared, whereas in aromatic halides the impurities are usually aromatic hydrocarbons, amines or phenols. In both groups the halogen is less reactive than it is in acid halides. Purification is by shaking with concentrated hydrochloric acid, followed by washing successively with water, 5% sodium carbonate or bicarbonate, and water. After drying with calcium chloride, the halide is distilled and then fractionally distilled using an efficient column. For a solid halide the above purification is carried out by dissolving it in a suitable solvent such as toluene. Solid halides can also be purified by chromatography using an alumina column and eluting with toluene or petroleum ether. They can be crystallised from toluene, petroleum ethers, toluene/petroleum ether or toluene/chloroform/petroleum ether. Care should be taken when handling organic halogen compounds because of their TOXICITY. It should be noted that methyl iodide is a cancer suspect.

Liquid aliphatic halides are obtained alcohol-free by distillation from phosphorus pentoxide. They are stored in dark bottles to prevent oxidation and, in some cases, the formation of phosgene.
A general method for purifying chlorohydrocarbons uses repeated shaking with concentrated sulfuric acid [CARE] until no further colour develops in the acid, then washing with water then a solution of sodium bicarbonate, followed by water again. After drying with calcium chloride, the chlorohydrocarbon is fractionally redistilled to constant boiling point.

**HYDROCARBONS**

Gaseous hydrocarbons are best freed from water and gaseous impurities by passage through suitable adsorbents and (if olefinic material is to be removed) oxidants such as alkaline potassium permanganate solution, followed by fractional cooling (see Chapter 1 for cooling baths) and fractional distillation at low temperature. To effect these purifications and also to store the gaseous sample, a vacuum line is necessary. Impurities in hydrocarbons can be characterised and evaluated by gas chromatography and mass spectrometry. The total amount of impurities present can be estimated from the thermometric freezing curve.

Liquid aliphatic hydrocarbons are freed from aromatic impurities by shaking with concentrated sulfuric acid [CARE] whereby the aromatic compounds are sulfonated. Shaking is carried out until the sulfuric acid layer remains colourless for several hours. The hydrocarbon is then freed from the sulfuric acid and the sulfonic acids by separating the two phases and washing the organic layer successively with water, 2N sodium hydroxide, and water. It is dried with CaCl₂ or Na₂SO₄, and then distilled. The distillate is dried with sodium wire, P₂O₅, or metallic hydrides, or passage through a dry silica gel column, or preferably, and more safely, with molecular sieves (see Chapter 1) before being finally fractionally distilled through an efficient column. If the hydrocarbon is contaminated with olefinic impurities, shaking with aqueous alkaline permanganate is necessary prior to the above purification. Alicyclic and paraffinic hydrocarbons can be freed from water, non-hydrocarbon and aromatic impurities by passage through a silica gel column before the final fractional distillation. This may also remove isomers. (For the use of chromatographic methods to separate mixtures of aromatic, paraffinic and alicyclic hydrocarbons see references in the bibliography in Chapter 1 under Chromatography, Gas Chromatography and High Performance Liquid Chromatography). Another method of removing branched-chain and unsaturated hydrocarbons from straight-chain hydrocarbons depends on the much faster reaction of the former with chlorosulfonic acid.

Isomeric materials which have closely similar physical properties can be serious contaminants in hydrocarbons. With aromatic hydrocarbons, e.g. xylene and alkyl benzenes, advantage is taken of differences in ease of sulfonation. If the required compound is sulfonated more readily, the sulfonic acid is isolated, crystallised (e.g. from water), and decomposed by passing superheated steam through the flask containing the acid. The sulfonic acid undergoes hydrolysis and the liberated hydrocarbon distils with the steam. It is separated from the distillate, dried, distilled and then fractionally distilled. For small quantities (10-100mg), vapour phase chromatography is the most satisfactory method for obtaining a pure sample (for column materials for packings see Chapter 1).

Azeotropic distillation with methanol or 2-ethoxyethanol (cellosolve) has been used to obtain highly purified saturated hydrocarbons and aromatic hydrocarbons such as xylene and isopropylbenzenes. Carbonyl-containing impurities can be removed from hydrocarbons (and other oxygen-lacking solvents such as CHCl₃ and CCL₄) by passage through a column of Celite 545 (100g) mixed with concentrated sulfuric acid (60mL). After first adding some solvent and about 10g of granular Na₂SO₄, the column is packed with the mixture and a final 7-8cm of Na₂SO₄ is added at the top [Hornstein and Crowe, Anal Chem 34 1037 1962]. Alternatively, Celite impregnated with 2,4-dinitrophenylhydrazine can be used.

With solid hydrocarbons such as naphthalene and polycyclic hydrocarbons, preliminary purification by sublimation in vacuum (or high vacuum if the substance is high melting), is followed by zone refining and finally by chromatography (e.g. on alumina) using low-boiling liquid hydrocarbon eluents. These solids can be recrystallised from alcohols, alcohol/petroleum ether or from liquid hydrocarbons (e.g. toluene) and dried below their melting points. Aromatic hydrocarbons that have been purified by zone melting include anthracene, biphenyl, fluoranthrene, naphthalene, perylene, phenanthrene, pyrene and terphenyl, among others. Some polycyclic hydrocarbons, e.g. benzpyrene, are CARCINOGENIC.

Olefinic hydrocarbons have a very strong tendency to polymerise and commercially available materials are generally stabilised, e.g. with hydroquinone. When distilling compounds such as vinylpyridine or styrene, the stabiliser remains behind and the purified olefinic material is more prone to polymerisation. The most common impurities are higher-boiling dimeric or polymeric compounds. Vacuum distillation in a nitrogen atmosphere not only separates monomeric from polymeric materials but in some cases also depolymerises the impurities. The distillation flask should be charged with a polymerisation inhibitor and the purified material should be used immediately or stored in the dark and mixed with a small amount of stabiliser (e.g. 0.1% of hydroquinone or tert-butylcatechol). It is also advisable to add to the flask a small amount (ca 5-10% by volume of liquid in the flask) of a ground mixture of Kieselguhr and NaCl which will provide nuclei for facilitating boiling and finally for cleaning the flask from insoluble polymeric residue (due to the presence of the water soluble NaCl).
IMIDES
Imides (e.g. phthalimide) can be purified by conversion to their potassium salts by reaction in ethanol with ethanolic potassium hydroxide. The imides are regenerated when the salts are hydrolysed with dilute acid. Like amides, imides readily crystallise from alcohols and, in some cases (e.g. quinolinic imide), from glacial acetic acid.

IMINO COMPOUNDS
These substances contain the -C=NH group and, because they are strong, unstable bases, they are kept as their more stable salts, such as the hydrochlorides. (The free base usually hydrolys to the corresponding oxo compound and ammonia.) Like amine hydrochlorides, the salts are purified by solution in alcohol containing a few drops of hydrochloric acid. After treatment with charcoal, and filtering, dry diethyl ether (or petroleum ether if ethanol is used) is added until crystallisation sets in. The salts are dried and kept in a vacuum desiccator.

KETONES
Ketones are more stable to oxidation than aldehydes and can be purified from oxidisable impurities by refluxing with potassium permanganate until the colour persists, followed by shaking with sodium carbonate (to remove acidic impurities) and distilling. Traces of water can be removed with type 4A Linde molecular sieves. Ketones which are solids can be purified by crystallisation from alcohol, toluene, or petroleum ether, and are usually sufficiently volatile for sublimation in vacuum. Ketones can be further purified via their bisulfite, semicarbazone or oxime derivatives (vide supra). The bisulfite addition compounds are formed only by aldehydes and methyl ketones but they are readily hydrolysed in dilute acid or alkali.

MACROMOLECULES See Chapter 6.

NITRILES
All purifications should be carried out in an efficient fume cupboard because of the TOXIC nature of these compounds.
Nitriles are usually prepared either by reacting the corresponding halide or diazonium salts with a cyanide salt or by dehydrating an amide. Hence, possible contaminants are the respective halide or alcohol (from hydrolysis), phenolic compounds, amines or amides. Small quantities of phenols can be removed by chromatography on alumina. More commonly, purification of liquid nitriles or solutions of solid nitriles in a solvent such as diethyl ether is by shaking with dilute aqueous sodium hydroxide, followed by washing successively with water, dilute acid and water. After drying with sodium sulfate, the solvent is distilled off. Liquid nitriles are best distilled from a small amount of P₂O₅ which, besides removing water, dehydrates any amide to the nitrile. About one fifth of the nitrile should remain in the distilling flask at the end of the distillation (the residue may contain some inorganic cyanide). This purification also removes alcohols and phenols. Solid nitriles can be recrystallised from ethanol, toluene or petroleum ether, or a mixture of these solvents. They can also be sublimed under vacuum. Preliminary purification by steam distillation is usually possible.
Strong alkali or heating with dilute acids may lead to hydrolysis of the nitrile, and should be avoided.

NITRO COMPOUNDS
Aliphatic nitro compounds are generally acidic. They are freed from alcohols or alkyl halides by standing for a day with concentrated sulfuric acid, then washed with water, dried with magnesium sulfate followed by calcium sulfate and distilled. The principal impurities are isomeric or homologous nitro compounds. In cases where the nitro compound was originally prepared by vapour phase nitration of the aliphatic hydrocarbon, fractional distillation should separate the nitro compound from the corresponding hydrocarbon. Fractional crystallisation is more effective than fractional distillation if the melting point of the compound is not too low.
The impurities present in aromatic nitro compounds depend on the aromatic portion of the molecule. Thus, benzene, phenols or anilines are probable impurities in nitrobenzene, nitrophenols and nitroanilines, respectively. Purification should be carried out accordingly. Isomeric compounds are likely to remain as impurities after the preliminary purifications to remove basic and acidic contaminants. For example, o-nitrophenol may be found in samples of p-nitrophenol. Usually, the o-nitro compounds are more steam volatile than the p-nitro isomers, and can be separated in this way. Polynitro impurities in mononitro compounds can be readily removed because of their relatively lower solubilities in solvents. With acidic or basic nitro compounds which cannot be separated in the above manner, advantage may be taken of their differences in pK values (see Chapter 1). The compounds can thus be purified by preliminary extractions with several sets of aqueous buffers
of known pH (see for example Table 19, Chapter 1) from a solution of the substance in a suitable solvent such as diethyl ether. This method is more satisfactory and less laborious the larger the difference between the pK value of the impurity and the desired compound. Heterocyclic nitro compounds require similar treatment to the nitroanilines. Neutral nitro compounds can be steam distilled.

NUCLEIC ACIDS  See Chapter 6.

PHENOLS
Because phenols are weak acids, they can be freed from neutral impurities by dissolution in aqueous N sodium hydroxide and extraction with a solvent such as diethyl ether, or by steam distillation to remove the non-acidic material. The phenol is recovered by acidification of the aqueous phase with 2N sulfuric acid, and either extracted with ether or steam distilled. In the second case the phenol is extracted from the steam distillate after saturating it with sodium chloride (salting out). A solvent is necessary when large quantities of liquid phenols are purified. The phenol is fractionated by distillation under reduced pressure, preferably in an atmosphere of nitrogen to minimise oxidation. Solid phenols can be crystallised from toluene, petroleum ether or a mixture of these solvents, and can be sublimed under vacuum. Purification can also be effected by fractional crystallisation or zone refining. For further purification of phenols via their acetyl or benzoyl derivatives (vide supra).

POLYPEPTIDES AND PROTEINS  See Chapter 6.

QUINONES
These are neutral compounds which are usually coloured. They can be separated from acidic or basic impurities by extraction of their solutions in organic solvents with aqueous basic or acidic solutions, respectively. Their colour is a useful property in their purification by chromatography through an alumina column with, e.g. toluene, as eluent. They are volatile enough for vacuum sublimation, although with high-melting quinones a very high vacuum is necessary. p-Quinones are stable compounds and can be recrystallised from water, ethanol, aqueous ethanol, toluene, petroleum ether or glacial acetic acid. o-Quinones, on the other hand, are readily oxidised. They should be handled in an inert atmosphere, preferably in the absence of light.

SALTS (ORGANIC)
With metal ions
Water-soluble salts are best purified by preparing a concentrated aqueous solution to which, after decolorising with charcoal and filtering, ethanol or acetone is added so that the salts crystallise. They are collected, washed with aqueous ethanol or aqueous acetone, and dried. In some cases, water-soluble salts can be recrystallised satisfactorily from alcohols. Water-insoluble salts are purified by Soxhlet extraction, first with organic solvents and then with water, to remove soluble contaminants. The purified salt is recovered from the thimble.

With organic cations
Organic salts (e.g. trimethylammonium benzoate) are usually purified by recrystallisation from polar solvents (e.g. water, ethanol or dimethyl formamide). If the salt is too soluble in a polar solvent, its concentrated solution should be treated dropwise with a miscible nonpolar, or less polar, solvent (see Table 8, Chapter 1) until crystallisation begins.

With sodium alkane sulfonates
Purified from sulfites by boiling with aqueous HBr. Purified from sulfates by adding BaBr$_2$. Sodium alkane disulfonates are finally pptd by addition of MeOH. [Pethybridge and Taba J Chem Soc Faraday Trans 1 78 1331 1982].

SULFUR COMPOUNDS
Disulfides
These can be purified by extracting acidic and basic impurities with aqueous base or acid, respectively. However, they are somewhat sensitive to strong alkali which slowly cleaves the disulfide bond. The lower-melting members can be fractionally distilled under vacuum. The high members can be recrystallised from alcohol, toluene or glacial acetic acid.

Sulfones
Sulfones are neutral and very stable compounds that can be distilled without decomposition. They are freed from acidic and basic impurities in the same way as disulfides. The low molecular weight members are quite
soluble in water but the higher members can be recrystallised from water, ethanol, aqueous ethanol or glacial acetic acid.

**Sulfoxides**
These compounds are odourless, rather unstable compounds, and should be distilled under vacuum in an inert atmosphere. They are water-soluble but can be extracted from aqueous solution with a solvent such as diethyl ether.

**Thioethers**
Thioethers are neutral stable compounds that can be freed from acidic and basic impurities as described for disulfides. They can be recrystallised from organic solvents and distilled without decomposition. They have sulfurous odours.

**Thiols**
Thiols, or mercaptans, are stronger acids than the corresponding aliphatic hydroxy or phenolic compounds, but can be purified in a similar manner. However, care must be exercised in handling thiols to avoid their oxidation to disulfides. For this reason, purification is best carried out in an inert atmosphere in the absence of oxidising agents. Similarly, thiols should be stored out of contact with air. They can be distilled without change, and the higher-melting thiols (which are usually more stable) can be crystallised, e.g. from water or dilute alcohol. They oxidise readily in alkaline solution but can be separated from the disulfide which is insoluble in this medium. They should be stored in the dark below 0°C. **All operations with thiols should be carried out in an efficient fume cupboard because of their very unpleasant odour and their TOXICITY.**

**Thiol sulfonates (disulfoxides)**
Thiol sulfonates are neutral and are somewhat light-sensitive compounds. Their most common impurities are sulfonyl chlorides (neutral) or the sulfonic acid or disulfide from which they are usually derived. The first can be removed by partial freezing or crystallisation, the second by shaking with dilute alkali, and the third by recrystallisation because of the higher solubility of the disulfide in solvents. Thiol sulfonates decompose slowly in dilute, or rapidly in strong, alkali to form disulfides and sulfonic acids. Thiol sulfonates also decompose on distillation but they can be steam distilled. The solid members can be recrystallised from water, alcohols or glacial acetic acid.
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CHARACTERISATION OF ORGANIC AND INORGANIC COMPOUNDS


METAL HYDRIDES


SPECTROSCOPY

Chemical Methods used in Purification


**TRACE METAL ANALYSIS**


CHAPTER 3

THE FUTURE OF PURIFICATION

INTRODUCTION

The essence of research is to seek answers wherever there are questions. Regardless of what the answers are the experiments to be conducted must be carried out with utmost care. For this, one must ensure that the quality of the reactants used and the products obtained are of the highest possible purity. In general terms, one can broadly categorise experimental chemistry and biological chemistry into the following areas:

- Isolation and identification of substances (natural products from nature, protein purification and characterisation, etc).
- Synthesis of substances (organic, or inorganic in nature; these substances may be known substances or new compounds).
- Analysis of substances (this is a key process in the identification of new or known chemical and biological substances. Methods of analysis include spectroscopic methods, derivatisation and sequencing methods).
- Measurements of particular properties of a compound or substance (enzyme kinetics, reaction kinetics, FACS, fluorescence-activated cell sorting, assay).

Impressive and sophisticated strategies, in the form of new reagents, catalysts and chemical transformations, are currently available for the syntheses of molecules. In recent years there is a deviation in focus from developing new synthetic routes and reactions to improving methods for carrying out reactions. In particular, traditional reactions can be carried out in new ways such that those efficiencies of reactions are greatly improved. The efficiencies of reactions can be measured in terms of the yields of the desired product(s), or in terms of the time taken to obtain the desired product(s). Some of the ‘new’ lateral ways of thinking to improve efficiencies of reactions recognise the importance of purification of products in the planning of a synthetic sequence. Thus methods such as solid phase synthesis, fluorous chemistry as well as the use of ionic liquids minimise purification procedures and thus improve the ability to rapidly access pure compounds. These techniques also contribute to the efficiencies of reactions in terms of yields. In looking ahead to synthesis in the 21st century, a brief outline of the key aspects of these techniques are presented. In time many commercially available chemicals will be prepared using methods described in this chapter, and knowledge of these now should be useful to the experimenter. Some of these compounds (e.g. peptides) have already been synthesised by such methods (e.g. SPPS, see below).

SOLID PHASE SYNTHESIS

Solid phase synthesis (SPS) has emerged as an important methodology for the rapid and efficient synthesis of molecules. The ease of work-up and purification procedures in solid phase as compared to solution phase chemistry, as well as the scope for combinatorial chemistry provides impetus for further development in this field. The earliest studies on solid phase chemistry were focused on solid phase peptide synthesis (SPPS). The concept of carrying out reactions on a polymer support as distinct to reactants in solution, was conceived by R.B. Merrifield who received the Nobel Prize in Chemistry in 1984 for his pioneering work. However since the mid 1990's, advances in solid phase chemistry have moved beyond the routine (often robotic) synthesis of small to medium peptides and oligonucleotides. SPOS (solid phase organic synthesis) has gained much prominence due to the wealth of compounds (combinatorial libraries) that can be synthesised rapidly. This is especially important for pharmaceutical companies, screening for compounds with certain biological profiles or for chemical companies, screening for new catalysts or reagents. In SPOS, it is envisaged that difficult reactions can be driven to completion by using a large excess of reagents, which are easily removed by filtration. Furthermore, expensive reagents in the form of catalysts or chiral auxiliaries may be recycled easily if supported on a polymer and hence solid phase reactions provide economy in terms of costs and labour. Another strength of SPS is the ease in purification procedures which generally involves filtration of polymer supported products (solid) from soluble
reaction components (liquid) in what is effectively a solid-liquid extraction. In the final step of the synthetic sequence, the desired product is then cleaved from the polymer support.

Despite the relative infancy in the development of solid phase reactions, a wide range of functionalised resins are commercially available. The main uses of these functionalised resins can be roughly classified as follows:

**SOLID PHASE PEPTIDE SYNTHESIS (SPPS)**

Extensive studies on the synthesis of peptides on solid phase have been carried out, so much so that the technique of SPPS can be reliably and routinely used for the synthesis of short peptides by novices in the field. A large number of resins and reagents have been developed specifically for this purpose, and much is known on problems and avoidance of racemisation, difficult couplings, compatibility of reagents and solvents. Methods for monitoring the success of coupling reactions are available. Automated synthesisers are available commercially (e.g. from Protein Technologies, Rainin Inst Inc, Tuscon AZ; protan@dakotacom.net) which can carry out as many as a dozen polypeptide syntheses simultaneously. The most satisfactory chemistry currently used is Fmoc (9-fluorenylmethoxycarbonyl) chemistry whereby the amino group of the individual amino acid residues is protected as the Fmoc. A large number of Fmoc-amino acids are commercially available as well as polymer resins to which the specific Fmoc-amino acid (which will eventually become the carboxy terminal residue of the peptide) is attached. With automated synthesisers, the solvent used is N-methylpyrrolidone and washings are carried out with dimethylformamide. Deprotection of the polypeptide is carried out with anhydrous trifluoroacetic acid (TFA). A cycle for one residue varies with the residue but can take an hour or more. This means that 70-80 mer polypeptides could take more than a week to prepare. This is not a serious drawback because several different polypeptides can be synthesised simultaneously. The success of the synthesis is dependent on the amino acid sequence since there are some twenty or more different amino acids and the facility of forming a peptide bond varies with the pair of residues involved. However, generally 70 to 80 mers are routinely prepared, and if the sequence is favourable, up to 120 mer polypeptides can be synthesised. After deprotection with TFA the polypeptide is usually purified by HPLC using a C18 column with reverse phase chromatography. There are many commercial firms that will supply custom made polypeptides at a price depending on the degree of purity required.

**SOLID PHASE DEOXYRIBONUCLEOTIDE SYNTHESIS**

The need for oligodeoxyribonucleotides mainly as primers for the preparation of deoxyribonucleic acids (DNA) and for DNA sequencing has resulted in considerable developments in oligodeoxyribonucleotide synthesis. The solid phase procedure is the method commonly used. Automated synthesisers are commercially available, but with the increase in the number of firms which will provide custom made oligodeoxyribonucleotides, it is often not economical to purchase a synthesiser to make one's own oligodeoxyribonucleotides. Unlike in polypeptide synthesis where there are some twenty different residues to "string" together, in DNA synthesis there are only four deoxyribonucleotides, consequently there is usually little difficulty in synthesising 100 mers in quantities from 10 µg to 10 milligrams of material. The deprotected deoxyribonucleic acid which is separated from the solid support is purified on an anion exchange column followed by reverse phase HPLC using C8 to C18 columns for desalting. As for the polypeptides, the cost of DNA will depend on the purification level required.

**SOLID PHASE OLIGOSACCHARIDE SYNTHESIS**

Although automated solid phase peptide and oligonucleotide synthetic procedures are well established, automated solid phase oligosaccharide synthesis is considerably more difficult. The current awareness of the importance of polysaccharides as surface recognition molecules and glycoproteins and glycolipids has prompted much interest in oligosaccharide synthesis and some progress has been made (see Kochetkov Russ Chem Rev 69 795 2000; Ito and Manabe Curr Opin Chem Biol 2 701 1998; Seeberger and Danishefsky Acc Chem Res 31 685 1998). A general method for automated oligosaccharide synthesis is not as yet available. An example of an automated synthesis of specific glycosides has been reported by Seeberger (Science 291 1523 2001; see also Houlton Chem Br 38 (4) 46 2002).

**SOLID PHASE ORGANIC SYNTHESIS (SPOS)**

At the time of writing this book, SPOS is in an area of relative infancy but has considerable potential. One of the main difficulties in SPOS lies in the lack of techniques available to monitor reactions carried out on polymer supports. Unlike reactions in solution phase, reactions on solid support cannot be monitored with relative ease and this has hindered the progress as well as the efficacy of solid supported synthesis of small non-peptidic molecules. Despite these difficulties, a large body of studies is available for SPOS. Recent reviews incorporate
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information on the types of reactions that can be carried out, as well as outline the difficulties and differences with SP (solid phase) reactions as compared with their solution phase counterparts (see bibliography). An interesting application of such procedures is the synthesis of polymeric esters (e.g. polycaprolactones, polyhydroxybutyrates, polylactates) and starch- and cellulose-like polymers using a plasticised starch support. These have been useful for making biodegradable trays and containers for foodstuffs (BenBrahim Chem Br 38(4) 40 2002).

POLYMER SUPPORTED REACTANTS

These have become of increasing importance in synthesis and a broad classification of polymer supported reactants are as follows: Polymer bound bases (e.g. dimethylaminopyridine, morpholine, piperidine); Polymer supported catalysts (e.g. Grubbs catalyst for metathesis reactions, palladium for hydrogenation reactions, tributylmethylammonium chloride for phase transfer reactions); Polymer supported condensation reagents (e.g. DEAD (diethyl azodicarboxylate) for Mitsonobu reactions, DEC [1-(3-dimethylamino-propyl)-3-ethylcarbodiimide hydrochloride] (or EDCI [1-ethyl-3-(3-di-methylaminopropyl) carbodiimide HCl]) for peptide synthesis, HOBT (1-hydroxybenzotriazole) for peptide synthesis; Polymer supported oxidizing agents (e.g. osmium tetroxide, perruthenate, pyridinium chlorochromate); Polymer supported reducing agents (e.g. borohydride, tributyltin fluoride); Polymer supported phosphines (for miscellaneous applications depending on the structure) and so on. Commercially available polymer supported reactants are identified in Chapters 4 and 5 of this book.

SCAVENGER RESINS

Though not as extensively utilised as polymer supported reactants, the use of resins to clean up reactions is gaining favour. The type of commercially available scavenger resins are electrophilic scavenger resins (e.g. benzaldehyde derivatised resins to scavenge amines; isocyanate resins to scavenge amines, anilines and hydrazines; tosyl chloride resins to scavenge nucleophiles) and nucleophilic scavenger resins (e.g. diethylenetriamine resins to scavenge acids, acid chlorides, anhydrides; sulfonyl amide resins to scavenge acids, acid chlorides, aldehydes, isocyanates and chloroformates).

RESIN SUPPORT

The common resin matrices comprise of polystyrene crosslinked with divinylbenzene, graft polymers of polystyrene-polyethylene glycol (PS-PEG) and polyethylene glycol acrylamide (PEGA) composite resins. For each type of resin matrixes, a range of functionalised polymer supports are available. In addition, a number of these resins are available with different percentage of crosslinking as well as a range of loadings of the reactive functionality. Polystyrene based resins are the most extensively used. Unfortunately these resins do not swell, i.e. do not imbibe water, in polar solvents such as water and methanol and thus cannot be used for carrying out reactions in these solvents. In contrast grafted PS-PEG resins swell in a range of solvents from toluene to water. Examples of grafted PS-PEG resins are NovaSyn® TG and NovaGel® resins. As the success of transformations to be carried out on SPOS depends in part on the swelling properties as well as the robustness of the resin, the choice of resin matrix to be used must be carefully considered. The swelling properties of a number of resin types in a variety of solvents have been documented (see NovaBiochem catalog and also Santini, Griffith and Qi Tetrahedron Lett 39 8951 1998). For example, the swelling of a polystyrene resin in DMF is 3 mL/g of resin as compared to that in dichloromethane which is 7 mL/g of resin. It is thought that swelling of resins in the order of greater than 4 mL/g constitutes a good solvent, between 2-4 mL/g a moderate solvent and that less than 2 mL/g a poor solvent choice for carrying out solid phase reactions. Lightly crosslinked resins are less robust but have greater ability to swell in appropriate solvents. Typically a 1-2% crosslinked divinyl benzene polystyrene resin is employed in organic synthesis.

An extensive list of the commercially available resins is available from Sigma-Aldrich (www.sigmaaldrich.com), Novabiochem (www.novabiochem.com), Fluka and other chemical companies. Sigma-Aldrich and Novabiochem have excellent catalogs. In addition, the Novabiochem catalog and website are a rich source of useful technical information.

CHOICE OF RESIN FOR SPOS

There is a large range of resins available for SPOS. These resins are derivatised polymer supports with a range of linkers. The roles of linkers are (i) to provide point(s) of attachment for the tethered molecule, akin to a solid supported protecting group(s), (ii) to provide distance from the polymeric backbone in order to minimise interactions with the backbone, (iii) to enable cleavage of product molecules under conditions compatible with the stability of the molecules and the reaction conditions employed for chemical transformations. Hence in order to
choose an appropriate resin for use in SPOS, one would need to consider the nature of the attachment of the reactant molecule onto the solid support (e.g. in order to tether the carboxy group in a reactant as an ester linkage on a solid support, one may choose to use a hydroxy functionalised linker), the stability of the resin under conditions employed in the chemical transformations (e.g. issues of orthogonality - will the conditions utilised cause premature cleavage of the linker or premature cleavage of the products?), the solvents and reactants needed in the transformations (e.g. will the solvents swell the resin?), conditions of cleavage of products (e.g. will this cause racemisation or rearrangement of the product?), the functionality of the resultant product after cleavage (e.g. will cleavage of the product result in a residual functionality in the molecule?) and so on. Linkers which leave no residual functionalities in the products upon cleavage are known as traceless linkers and those which need to be activated in order to be cleaved are known as safety catch linkers. A fascinating array of linkers (commercial or otherwise) is available and some excellent reviews are cited in the bibliography at the end of this chapter.

COMBINATORIAL CHEMISTRY
The major impetus for the development of solid phase synthesis centers around applications in combinatorial chemistry. The notion that new drug leads and catalysts can be discovered in a high throughput fashion has been demonstrated many times over as is evidenced from the number of publications that have arisen (see references at the end of this chapter). A number of approaches to combinatorial chemistry exist. These include the split-mix method, serial techniques and parallel methods to generate libraries of compounds. The advances in combinatorial chemistry are also accompanied by sophisticated methods in deconvolution and identification of compounds from libraries. In a number of cases, innovative hardware and software has been developed for these purposes. Depending on the size of the combinatorial library to be generated as well as the scale of the reactions to be carried out, a wide range of specialised glassware and equipment are commercially available. For example, in order to carry out parallel combinatorial synthesis, reaction stations equipped with temperature and stirring control are available from a number of sources (e.g. www.fisher.co.uk; www.radleys.com; www.sigmaaldrich.com). These reaction stations are readily adapted, using appropriate modules, for conditions under reflux or under inert atmosphere. For automated synthesis of large libraries of compounds, reactions can be carried out using reaction blocks on microtiter plates. Ready to use CombiKits™ which contain a variety of pre-weighed building blocks are available from Aldrich Chemical Company.

MONITORING SOLID PHASE REACTIONS
This remains the bane of solid phase reactions. Unlike solution phase reactions, where the progress of reactions can be monitored rapidly via TLC, GC or HPLC methods, procedures for the rapid monitoring of progress in solid phase reactions are limited. Although a number of spectroscopic methods have been developed for direct monitoring of reactions on solid supports, these methods usually require specialised equipment, not routinely available in chemical laboratories. These methods include on-bead IR analysis (e.g. Huber et al. Anal Chim Acta 393 213 1999; Yan and Gremlich J Chromatogr. B. 725 91 1999; Yan et al. J Org Chem 60 5736 1995) and solid state magic angle spinning NMR techniques (e.g. Warrass and Lippens J Org Chem 65 2946 2000; Rousselot-Pailley, Ede and Lippens J. Comb. Chem. 3 559 2001).

The most common methods for monitoring solid phase reactions utilized in normal research laboratories are:

**Infrared analysis of resin**
This is a destructive method in which the resin is ground and pelleted as a KBr disc and analysed by FT-IR analysis. This method works best for systems where distinct functional group transformations (C=O, C-OH, C=C, etc) are expected. No special equipment is needed.

**Qualitative and quantitative analyses**
There are a number of colour or UV tests which are available for monitoring the presence or absence of certain functional groups. Although some of these tests are routinely used for the quantitative analysis of functional groups in solution phase, the quantification on solid phase is less than reliable. An exception to this is the Fmoc (9-fluorenylmethoxycarbonyl) assay, which is routinely used for quantification of coupling in SPPS using Fmoc amino acids. It should also be noted that the generality of some of these colour tests on a variety of solid phase resins is not known and hence these tests serve only as a guide to functional group identification. Some (not an exhaustive list) of the reported methods of analyses are outlined below.
DETECTION OF REACTIVE GROUPS ON RESINS

Detection of hydroxy groups on resin
A method in which the resin is treated with cyanuric chloride (trichlorotriazine, TCT) in DMF followed by a nucleophlic dye (AliR or Mordant Orange 1, beads appear red in the presence of hydroxyl groups, or with fuschin, beads appear fuschia, or with fluorescein, they become fluorescent) has been reported (Attardi and Taddei Tetrahedron Lett 42 2927 2001; Attardi, Falchi and Taddei Tetrahedron Lett 41 7395 2001). Another colorimetric test for the detection of polymer supported tertiary alcohols utilizes the conversion of the alcohols to the polymer supported diphenylsilylchloride ether, followed by subsequent treatment with methyl red. The beads form a readily distinguishable orange/red colour. The test is also positive for the hydroxy Wang resin and the aminomethylpolystyrene resin [Burkett, Brown and Meloni Tetrahedron Lett 42 5773 2001]. Alternatively the conversion of polymer supported alcohols to the tosylate followed by displacement by p-nitrobenzylpyridine (PNBP) gives a strongly coloured salt upon treatment with bases such as piperidine, followed by gentle heating [Kuisle et al. Tetrahedron 55 14807 1999].

Detection of aldehyde groups on resin
The use of an acidic solution of p-anisaldehyde in ethanol to detect aldehyde functionalities on polystyrene polymer supports has been reported (beads are treated with a freshly made solution of p-anisaldehyde (2.55 mL), ethanol (88 mL), sulfuric acid (9 mL), acetic acid (1 mL) and heated at 110°C for 4 min). The colour of the beads depends on the percentage of CHO content such that at 0% of CHO groups, the beads are colourless, ~50% CHO content, the beads appear red and at 98% CHO the beads appear burgundy [Vázquez and Albericio Tetrahedron Lett 42 6691 2001]. A different approach utilises 4-amino-3-hydrazino-5-mercapto-1,2,4-triazole (Purpald) as the visualizing agent for CHO groups. Resins containing aldehyde functionalities turn dark brown to purple after a 5 min reaction followed by a 10 minute air oxidation [Courmoyer et al. J Comb Chem 4 120 2002].

Detection of carboxy groups on resin
The presence of a COOH functionality on a polystyrene resin can be detected using a 0.25% solution of malachite green-oxalate in ethanol in the presence of a drop of triethylamine. Beads with COOH functionalities are coloured dark green or appear as clear gel beads [Attardi, Porcu and Taddei Tetrahedron Lett 41 7391 2000].

Detection of amino groups on resin
The methods for the detection of amine functional groups are well established. For example the Kaiser test can be used to detect the presence of amine groups on resins (blue colour is observed). In the Kaiser test, two reagents are prepared. Reagent 1 comprises of a mixture of two solutions: A and B. A is a solution of phenol in absolute ethanol (40g of phenol in 10 mL of absolute ethanol, followed by treatment of this clear solution with 4g of Amberlite mixed bed resin MB-3 for 45 mins. The solution is then filtered.). Solution B is made up of 65 mg of KCN in 100 mL water; 2 mL of this solution is diluted to 100 mL of freshly distilled pyridine. The solution is then stirred with 4 g of Amberlite mixed-bed resin MB-3 and filtered. Solutions A and B are then mixed. Reagent 2 is a solution of ninhydrin (2.5g) in absolute ethanol (50 mL). For a qualitative Kaiser test, 6 drops of reagent 1 and 2 drops of reagent 2 are added to the well washed dried resin (2-5 mg) and mixed, followed by heating to 100°C for 4-6 min. A method for the quantitative determination of amino groups using this test has also been reported [Sarin et al. Anal Biochem 117 147 1981]. It is however known that the Kaiser test does not give a positive test with a secondary amino acid such as proline or some 'unnatural' amino acids. In addition some deprotected amino acids (Ser, Asn, Asp) do not show the expected intense blue colour typical of free primary amino groups.


Detection of thiol groups on resin
For quantitative analysis of solid supported thiol residues on free macroporous or PEG grafts, Ellman's reagent has been used [5,5'-dithio-bis-(2-nitrobenzoic acid). However only qualitative information can be gained using lightly crosslinked polystyrene resins [Badayl et al. Tetrahedron Lett 42 8531 2001].

Fmoc assay
This is a very important and well tested method for the quantitative determination of loading of Fmoc protected compounds particularly that of Fmoc (fluorenylmethoxycarbonyl) amino acids on solid support. Fmoc groups can

The Future of Purification
be readily deprotected in the presence of base. Generally, in the deprotection and quantification procedures, a known amount of resin is treated with 20% piperidine in DMF at room temperature for 30 mins. The resin is washed with more DMF and the pooled filtrates are combined in a volumetric flask and made up to an accurate volume (e.g. to 10 mL) with more DMF. The UV absorbance at 301 nm of the piperidine-dibenzofulvene adduct which is formed can then be measured against a blank solution of piperidine in DMF [Meienhofer et al. Int J Pept Protein Res 13 35 1979]. The loading L is then determined using the equation:

\[ L = \frac{(\text{Absorbance value})}{\text{Solution volume in litres}} \times 7.8 \times (\text{Weight of resin in mg}) \]

IONIC LIQUIDS

Ionic liquids are organic or inorganic salts that are liquid at room or reaction temperatures. Although ionic liquids are themselves not new discoveries (e.g. the ionic liquid [EtNH\(_2\)][NO\(_3\)] was described in 1914), the use of ionic liquids in synthesis is only recent. In particular, the potential applications of ionic liquids as solvents in synthesis and in catalysis have recently been realised. The physical properties of ionic liquids make them unique solvents for synthesis. For example, ionic liquids are good solvents for both organic and inorganic substances and hence can be used to bring reagents into the same phase for reaction. Ionic liquids are also immiscible with a number of organic solvents and thus provide a non-aqueous, polar alternative for two-phase extraction systems. As ionic liquids are non-volatile, they can be used in high vacuum systems without the possibility of loss or contaminants. In addition, this also facilitates the isolation of products as the products can be distilled from the ionic liquid or alternatively extracted with an organic solvent that is immiscible with the ionic liquid. Although ionic liquids are frequently composed of poorly coordinating ions, they are highly polar which are important characteristics in the activation of catalysts.

Commonly used ionic liquids are N-alkylpyridinium, N,N’-dialkylimidazolium, alkylammonium and alkylphosphonium salts.


FLUOROUS CHEMISTRY

This new approach to synthesis was introduced by Curran early in 1997 and involves the attachment of fluororous phase labels to substrates such that the subsequent fluorinated products can be extracted into the fluorous phase. For example in liquid-liquid extractions (typical work-up procedures), a three-phase extraction is now possible (organic, fluororous and aqueous phases). As organic and inorganic compounds have little or no tendency to dissolve in highly fluorinated solvents and compounds, phase labeling a compound as fluororous will enable successful extraction into the fluorous phase. However in order to carry out homogenous reactions with these fluorinated compounds, organic solvents with a good dissolving power for fluororous compounds or miscible organic and fluorous solvents can be used. Alternatively organic solvents with a few fluoride atoms e.g. trifluoroethanol, benzotri fluoride (‘hybrid solvents’) will dissolve both organic and fluorous compounds. A number of synthetic applications utilising fluorous chemistry have been reported in the literature. [For examples, see Schneider and Bannwarth Helv Chim Acta 84 735 2001; Galante, Lhoste and Sinou Tetrahedron Lett 42 5425 2001; Studer and Curran Tetrahedron 53 6681 1997; Studer et al. J Org Chem 62 2917 1997; Crich and Neelamkavil Tetrahedron 58 3865 2002].
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Applications to SPOS, SPPS


Monitoring SP reactions

The Future of Purification


COMBINATORIAL CHEMISTRY


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IONIC LIQUIDS


FLUOROUS CHEMISTRY


CHAPTER 4

PURIFICATION OF ORGANIC CHEMICALS

The general principles, techniques and methods of purification in Chapters 1 and 2 are applicable to this chapter. Most organic liquids and a number of solids can readily be purified by fractional distillation, usually at atmospheric pressure. Sometimes, particularly with high boiling or sensitive liquids, or when in doubt about stability, distillation or fractionation under reduced pressure should be carried out. To save space, the present chapter omits many substances for which the published purification methods involve simple distillation. Where boiling points are given, purification by distillation is another means of removing impurities. Literature references are omitted for methods which require simple recrystallisation from solution if the correct solvent can be guessed readily, and where no further information is given, e.g. spectra. Substances are listed alphabetically, usually with some criteria of purity, giving brief details of how they can be purified. Also noted are the molecular weights (to the first decimal place), melting points and/or boiling points together with the respective densities and refractive indexes for liquids, and optical rotations when the compounds are chiral. When the temperatures and/or the wavelengths are not given for the last three named properties then they should be assumed to be 20°C and the average of the wavelengths of the sodium D lines respectively; and densities are relative to water at 4°C.

The present chapter includes commercially available organic chemicals. Most of the inorganic, metalorganic, organo-bismuth, boron, phosphorus, selenium, silicon and alkali metal compounds and metal ion salts of organic acids are in Chapter 5. Naturally occurring commercially available organic compounds for use in biochemistry, molecular biology and biology are in Chapter 6. Commercially available polymer supported reagents are indicated with Q under the appropriate reagent.

Rapid purification procedures are noted for commonly used solvents and reagents which make them suitable for general use in synthetic chemistry.

Abbreviations of titles of periodicals are defined as in the Chemical Abstracts Service Source Index (CASSI). Other abbreviations are self evident (see Chapter 1, p. 30).

Ionisation constants of ionisable compounds are given as pK values (published from the literature) and refer to the pKa values at room temperature (~ 15°C to 25°C). The values at other temperatures are given as superscripts, e.g. pK25 for 25°C. Estimated values are entered as pKEst. (see Chapter 1, p. 7 for further information).

As a good general rule, all low boiling (<100°C) organic liquids should be treated as highly flammable and toxic (because they can be inhaled in large quantities) and the necessary precautions should be taken.

Benzene, which has been used as a solvent successfully and extensively in the past for reactions and purification by chromatography and crystallisation is now considered a very dangerous substance so it has to be used with extreme care. We emphasise that an alternative solvent system to benzene (e.g. toluene, toluene-petroleum ether, or a petroleum ether to name a few) should be used first. However, if no other solvent system can be found then all operations involving benzene have to be performed in an efficient fumehood and precautions must be taken to avoid inhalation and contact with skin and eyes. Whenever benzene is mentioned in the text an asterisk e.g. *C6H6 or *benzene, is inserted to remind the user that special precaution should be adopted.

80
Abietic acid [514-10-3] M 302.5, m 172-175°, [α]D25 15 -116° (c 1, EtOH), pH 5.27. Cryst by dissolving 100g of acid in 95% EtOH (700mL), adding to H2O (600mL) and cooling. Filter, dry in a vacuum (over KOH or CaSO4) store in an O2-free atmosphere. λ in EtOH nm (log e): 2343(4.3), 241(4.4), 2505(4.2), 235(4.34) and 240(4.36). [Org Synth 23 1 1952; J Am Chem Soc 35 3736 1949; Monatsh Chem 116 1345 1985.]

S-Abscisic acid [21293-29-8] M 264.3, m 160-161°, 161-163° (sublimation), [α]297 + 24,000°, [α]245 -69,000° (c 1-50μg/mL in acidified MeOH or EtOH), pKf3 3.9. Crystd from CCl4-pet.ether, EtOH + hexane and sublimes at 120°.

Acenaphthalene [208-96-8] M 152.2, m 92-93°. Dissolved in warm redistd MeOH, filtered through a sintered glass funnel and cooled to -78° to ppte the material as yellow plates [Dainton, Ivin and Walmsley Trans Faraday Soc 56 1784 1960]. Alternatively can be sublimed in vacuo.


RS-Acenaphthenol [6306-07-6] M 170.2, m 144.5-145.5°, 146°, 148°. If highly coloured (yellow), dissolve in boiling *benzene (14g in 200mL), add charcoal (0.5g), filter through a heated funnel, concentrate to 100mL and cool to give almost colourless needles. *Benzene vapour is TOXIC use an efficient fume cupboard. The acetate has b 166-168°/5mm (bath temp 180-185°). [Org Synth Col.Vol. III 3 1955.] It can also be recrystd from *C6H6 or EtOH [Fieser and Cason J Am Chem Soc 62 432 1940]. It forms a brick-red crystalline complex with 2,4,5-7-tetranitrofluoren-9-one which is recrystd from AcOH and dried in a vacuum over KOH and P2O5 at room temp, m 170-172° [Newman and Lutz J Am Chem Soc 78 2469 1956].

Acetal (acetaldehyde diethylacetal) [105-57-7] M 118.2, b 103.7-104°, d 0.831, n1 1.38054, n2 1.3682. Dried over Na to remove alcohols and water, and to polymerise aldehydes, then fractionally distd. Or, treat with alkaline H2O2 soln at 40-45° to remove aldehydes, then the soln is saturated with NaCl, separated, dried with K2CO3 and distd from Na [Vogel J Chem Soc 616 1948].

Acetaldehyde [75-07-0] M 44.1, b 20.2°, d 0.788, m 1.33113, pK 13.57 (hydrate). Usually purified by fractional distn in a glass helices-packed column under dry N2, discarding the first portion of distillate. Or, shaken for 30min with NaHCO3, dried with CaSO4 and fractionally distd at 760mm through a 70cm Vigreux column. The middle fraction was taken and further purified by standing for 2h at 0° with a small amount of hydroquinone, followed by distn [Longfield and Walters J Am Chem Soc 77 810 1955].

Acetaldehyde ammonia trimer (hexahydro-2,4,6-trimethyl-1,3,5-triazine trihydrate) [76231-37-3] M 183.3, m 94-96°, 95-97°, 97°, b 110° (partly dec). Crystd from EtOH-Et2O. When prepared it separates as the trihydrate which can be dried in a vacuum over CaCl2 at room temp to give the anhydrous compound with the same melting point. The dihydrate melts at 25-28° then resolidifies and melts again at 94-95°. IRRITATES THE EYES AND MUCOUS MEMBRANES. [J Org Chem 38 3288 1973.]

Acetaldehyde dimethyl acetel [534-15-6] M 90.1, b 63-65°, d1 0.852, nD 1.36678. Distd through a fractionating column and fraction boiling at 63.89/751mm is collected. It forms an azeotrope with MeOH. It has been purified by GLC.

Acetamide [60-35-5] M 59.1, m 81°, pK 1.4, pK 0.37. Crystd by soln in hot MeOH (0.8mL/g), distd with Et2O and allowed to stand [Wagner J Chem Educ 7 1135 1930]. Alternate crystns are from acetone, *benzene, chloroform, dioxane, methyl acetate or from *benzene-ethyl acetate mixture (3:1 and 1:1). It has also been recrystd from hot water after treating with HCl-washed activated charcoal (which had been
repeatedly washed with water until free from chloride ions), then crystallized again from hot 50% aq. EtOH and finally twice from hot 95% EtOH. Acetamide is also purified by distillation (b 221-223°) or by sublimation in vacuo. Also purified by recrystallization twice from cyclohexane containing 5% (v/v) of benzene. Needle-like crystals separated by filtration, washed with a small volume of distilled H2O and dried with a flow of dry N2. [Slebocka-Tilk et al. J Am Chem Soc 109 1286 1987.]

Acetamide hydrochloride [124-42-5] M 94.5, m 164-166°, 165-170° (dec), 174°, pK 12.4. It can be recrystallized from small volumes of EtOH. Alternatively dissolve in EtOH, filter, add Et2O, filter, and dry in a vacuum desiccator over P2O5. Acetamide is also purified by distillation (b 221-223°) or by sublimation in vacuo. Also purified by recrystallization twice from cyclohexane containing 5% (v/v) of benzene. Needle-like crystals separated by filtration, washed with a small volume of distilled H2O and dried with a flow of dry N2. [Slebocka-Tilk et al. J Am Chem Soc 109 1286 1987.]


α-Acetamidocinnamic acid [5469-45-4] M 205.2, m 185-186° (2H2O), 190-191° (anhyd), 193-195°, pKα 3.2. Recrystallized from H2O as the dihydrate and on drying at 100° it forms the anhydrous compound which is hygroscopic. Alkaline hydrolysis yields NH3 and phenylpyruvic acid. [Erlenmeyer and Früstück Justus Liebigs Ann Chem 284 47 1895.]

Z-O-(2-Acetamido-2-deoxy-D-glycopyranosylideneamino)-N-phenylcarbamate (PUGNAC) [132063-05-9] M 335.3, m 171-174° (dec), 174-180° (dec), [α]D +67.5° (c 0.2, MeOH). Purified by flash chromatography (silica gel and eluted with AcOEt-hexane 3:2) evaporated, and the foam recrystallized from AcOEt-MeOH. TLC on Merck SiO2 gel 60 F254 and detected by spraying with 0.025 M I2 in 10% aqueous H2SO4 and heat at 200° gave RF 0.21. The acetate is hydrolysed with NH2-MeOH.

2-Acetamido-5-nitrothiazole [140-40-9] M 190.2, m 219° (dec), pK1 2.3, pK2 6.6. Dissolved in water by adding one equivalent of NaOH soln (to final pH of 8-9), then acidified with HCl to ppte the free acid. Filtered with washed water.

Acetamidomethanol [625-51-4] M 89.1, m 47-50°, 54-56°, 55°. Recrystallized from freshly distilled Me2CO, wash the crystals with dry Et2O and dry in a vacuum desiccator over P2O5. RF 0.4 on paper chromatography with CHCl3-EtOH (2:8) as solvent and developed with ammoniacal AgNO3. Also crystallizes in needles from EtOAc containing a few drops of Me2CO. It is hygroscopic and should be stored under dry conditions. [J Am Chem Soc 73 1275 1951; Chem Ber 99 1204 1966; Justus Liebig Ann Chem 343 265 1905.]

Purification of Organic Chemicals

2-Acetamidophenol [614-80-2] M 151.2, m 209°, pK_{est} ~ 9.4. Recrystd from water or aqueous EtOH.

3-Acetamidophenol [621-42-1] M 151.2, m 148-149°, pK ~ 9.5. Recrystd from water or aqueous EtOH.

4-Acetamidophenol [103-90-2] M 151.2, m 169-170°, pK_{est} ~ 10.0. Recrystd from water or EtOH.

4-Acetamido-2,2,6,6-tetramethylpiperidine-1-oxyl (acetamidoTEMPO) [14691-89-5] M 213.3, m 144-145°, 146-147°. Dissolve in CHCl₃, wash with saturated K₂CO₃, then saturated aqueous NaCl, filter and evaporate. The red solid is recrystd from aqueous MeOH, m 147.5°. [Org Chem 56 6110 1991; Bull Acad Sci USSR, Div Chem Sci 15 1422 1966.]


Acetanilide [103-84-4] M 135.2, m 114°, pK ~ 0.5. Recrystd from water, aqueous EtOH, *benzene or toluene.

Acetic acid (glacial) [64-19-7] M 60.1, m 16.6°, b 118°, d 1.049, n 1.37171, n² 1.36995, pK ~ 4.76. Usual impurities are traces of acetaldehyde and other oxidisable substances and water. (Glacial acetic acid is very hygroscopic. The presence of 0.1% water lowers its m by 0.2°.) Purified by adding some acetic anhydride to react with water present, heating for 1h to just below boiling in the presence of 2g CrO₃ per 100mL and then fractionally distilling [Orton and Bradfield J Chem Soc 960 1924, 983 1927]. Instead of CrO₃, 2-5% (w/w) of KMnO₄, with boiling under reflux for 2-6h, has been used.

Traces of water have been removed by refluxing with tetraacetyl diborate (prepared by warming 1 part of boric acid with 5 parts (w/w) of acetic anhydride at 60°, cooling, and filtering off), followed by distn [Eichelberger and La Mer J Am Chem Soc 55 3633 1933].

Refluxing with acetic anhydride in the presence of 0.2g % of 2-naphthalenesulfonic acid as catalyst has also been used [Orton and Bradfield J Chem Soc 983 1927]. Other suitable drying agents include CuSO₄ and chromium triacetate: P₂O₅ converts some acetic acid to the anhydride. Azeotropic removal of water by distn with thiophene-free *benzene or with butyl acetate has been used [Birdwhistell and Griswold J Am Chem Soc 77 873 1955]. An alternative purification uses fractional freezing.

**Rapid procedure:** Add 5% acetic anhydride, and 2% of CrO₃. Reflux and fractionally distil.

Acetic anhydride [108-24-7] M 102.1, b 138°, d 1.082, n 1.3904. Adequate purification can usually be obtained by fractional distn through an efficient column. Acetic acid can be removed by prior refluxing with CaC₂ or with coarse Mg filings at 80-90° for 5days, or by distn from a large excess of quinoline (1% AcOH in quinoline) at 75mm pressure. Acetic anhydride can also be dried by standing with Na wire for up to a week, removing the Na and distilling from it under vacuum. (Na reacts vigorously with acetic anhydride at 65-70°). Dippy and Evans [J Org Chem 15 451 1950] let the anhydride (500g) stand over P₂O₅ (50g) for 3h, then decanted it and stood it with ignited K₂CO₃ for a further 3h. The supernatant liquid was distd and the fraction b 136-138°, was further dried with P₂O₅ for 12h, followed by shaking with ignited K₂CO₃, before two further distns through a five-section Young and Thomas fractionating column. The final material distd at 137.8-138.0°. Can also be purified by azeotropic distn with toluene: the azeotrope boils at 100.6°. After removal of the remaining toluene, the anhydride is distd [sample had a specific conductivity of 5 x 10⁻⁹ ohm⁻¹cm⁻¹].

**Rapid procedure:** Shake with P₂O₅, separate, shake with dry K₂CO₃ and fractionally distil.

Acetic hydrazide [1068-57-1] M 74.1, m 67°, b 127°/18mm. Cryst as needles from EtOH. Reduces NH₃/AgNO₃.

Acetoacetamide [5977-14-0] M 101.1, m 54-55°, 54-56°. Recrystallise from CHCl₃, or Me₂CO/pet ether. Crystallises from pyridine with 4mol of solvent. Slightly soluble in H₂O, EtOH and AcOH but
insoluble in Et₂O. Phenylhydrazone has $m$ 128°. [Beilstein 3, 4th Suppl, p 1545; Kato Chem Pharm Bull Jpn 15 921,923 1967; Chem Ber 35 583 1902.]

**Acetoacetanilide** [102-01-2] $M$ 177.2, $m$ 86°, $pK$ 10.68. Crystd from H₂O, aqueous EtOH or pet ether (b 60-80°).

**Acetoacetylpirperidide** [1128-87-6] $M$ 169.2, b 88.9°/0.1mm, $n^2_5$ 1.4983. Dissolved in *benzene, extracted with 0.5M HCl to remove basic impurities, washed with water, dried, and distd at 0.1mm [Wilson J Org Chem 28 314 1963].

**α-Acetobromoglucose** (2,3,4,6-tetraacetyl-α-D-glucopyranosyl bromide) [572-09-8] $M$ 411.2, $m$ 88-89°, $[^{25}D = +199.3°$ (c 3, CHCl₃). Crystd from isopropyl ether or pet ether (b 40-60°) [Org Synth 65 236 1897].

**Acetone** [67-64-1] $M$ 58.1, b 56.2°, d 0.791, n 1.35880, $pK_1$ -6.1 (basic, monoprotonated), $pK_2$ 20.0 (acidic) The commercial preparation of acetone by catalytic dehydrogenation of isopropyl alcohol gives relatively pure material. Analytical reagent quality generally contains less than 1% organic impurities but may have up to about 1% H₂O. Dry acetone is appreciably hygroscopic. The main organic impurity in acetone is mesityl oxide, formed by the aldol condensation. It can be dried with anhydrous CaSO₄, K₂CO₃ or type 4A Linde molecular sieves, and then distd. Silica gel and alumina, or mildly acidic or basic desiccants cause acetone to undergo the aldol condensation, so that its water content is increased by passage through these reagents. This also occurs to some extent when P₂O₅ or sodium amalgam is used. Anhydrous MgSO₄ is an inefficient drying agent, and CaCl₂ forms an addition compound. Drierite (anhydrous CaSO₄) offers the minimum acid and base catalysis of aldol formation and is the recommended drying agent for this solvent [Coetzee and Sao Inorg Chem 14v 2 1987; Riddick and Bunger Organic Solvents Wiley-Interscience, N.Y., 3rd edn, 1970]. Acetone was shaken with Drierite (25g/L) for several hours before it was decanted and distd from fresh Drierite (10g/L) through an efficient column, maintaining atmospheric contact through a Drierite drying tube. The equilibrium water content is about 10⁻²M. Anhydrous Mg(CIO₄)₂ should not be used as drying agent because of the risk of EXPLOSION with acetone vapour.

Organic impurities have been removed from acetone by adding 4g of AgNO₃ in 30mL of water to 1L of acetone, followed by 10mL of M NaOH, shaking for 10min, filtering, drying with anhydrous CaSO₄ and distilling [Werner Analyst (London) 58 335 1933]. Alternatively, successive small portions of KMnO₄ have been added to acetone at reflux, until the violet colour persists, followed by drying and distn. Refluxing with chromium trioxide (CrO₃) has also been used. Methanol has been removed from acetone by azeotropic distn (at 35°) with methyl bromide, and treatment with acetyl chloride.

Small amounts of acetone can be purified as the NaI addition compound, by dissolving 100g of finely powdered NaI in 400g of boiling acetone, then cooling in ice and salt to -8°. Crystals of NaI.3Me₂CO are filtered off and, on warming in a flask, acetone distils off readily. [This method is more convenient than the one using the bisulfite addition compound.] Also purified by gas chromatography on a 20% free fatty acid phthalate (on Chromosorb P) column at 100°.

For efficiency of desiccants in drying acetone see Burfield and Smithers [J Org Chem 43 3966 1978]. The water content of acetone can be determined by a modified Karl Fischer titration [Koupparis and Malmstadt Anal Chem 54 1914 1982].

**Rapid procedure:** Dry over anhydrous CaSO₄ and distil.

**Acetone cyanohydrin** [75-86-5] $M$ 85.1, b 48°/2.5mm, 68-70°/11mm, 78-82°/15mm, $d_4^0$ 0.93. Dry with Na₂SO₄ and distil as rapidly as possible under vacuum to avoid decomposition. Discard fractions boiling below 78-82°/15mm. Store in the dark. USE AN EFFICIENT FUME HOOD as HCN (POISONOUS) is always present. [Org Synth Col. Vol. II 7 1940.]


**Acetone semicarbazone** [110-20-3] $M$ 115.1, $m$ 187°, $pK_1$ 1.33. Crystd from water or from aqueous EtOH.
Acetonitrile (methyl cyanide) [75-05-8] M 41.1, b 81.60, d25 0.77683, n 1.3441, n25 1.34163. Commercial acetonitrile is a byproduct of the reaction of propylene and ammonia to acrylonitrile. The following procedure that significantly reduces the levels of acrylonitrile, allyl alcohol, acetone and benzene was used by Kiesel [Anal Chem 52 2230 1980]. Methanol (300mL) is added to 3L of acetonitrile fractionated at high reflux ratio until the boiling temperature rises from 64° to 80°, and the distillate becomes optically clear down to λ = 240nm. Add sodium hydride (1g) free from paraffin, to the liquid, reflux for 10min, and then distil rapidly until about 100mL of residue remains. Immediately pass the distillate through a column of acidic alumina, discarding the first 150mL of percolate. Add 5g of CaH2 and distil the first 50mL at a high reflux ratio. Discard this fraction, and collect the following main fraction. The best way of detecting impurities is by gas chromatography.

Usual contaminants in commercial acetonitrile include H2O, acetamide, NH4OAc and NH3. Anhydrous CaSO4 and CaCl2 are inefficient drying agents. Preliminary treatment of acetonitrile with cold, satd KOH is undesirable because of base-catalysed hydrolysis and the introduction of water. Drying by shaking with silica gel or Linde 4A molecular sieves removes most of the water in acetonitrile. Subsequent stirring with CaH2 until no further hydrogen is evolved leaves only traces of water and removes acetic acid. The acetonitrile is then fractionally distd at high reflux, taking precaution to exclude moisture by distilling over CaH2 [Coetzee Pure Appl Chem 13 429 1966]. Alternatively, 0.5-1% (w/v) P2O5 is often added to the distilling flask to remove most of the remaining water. Excess P2O5 should be avoided because it leads to the formation of an orange polymer. Traces of P2O5 can be removed by distilling from anhydrous K2CO3.

Kolthoff, Bruckenstein and Chantooni [J Am Chem Soc 83 3297 1961] removed acetic acid from 3L of acetonitrile by shaking for 24h with 200g of freshly activated alumina (which had been reactivated by heating at 250° for 4h). The decanted solvent was again shaken with activated alumina, followed by five batches of 100-150g of anhydrous CaCl2. (Water content of the solvent was then less than 0.2%). It was shaken for 1h with 10g of P2O5, twice, and distilled in a 1m x 2cm column, packed with stainless steel wool and protected from atmospheric moisture by CaCl2 tubes. The middle fraction had a water content of 0.7 to 2mM.

Traces of unsaturated nitriles can be removed by an initial refluxing with a small amount of aq KOH (1mL of 1% solution per L). Acetonitrile can be dried by azeotropic distillation with dichloromethane, benzene or trichloroethylene. Isonitrile impurities can be removed by treatment with conc HCl until the odour of isonitrile has gone, followed by drying with K2CO3 and distillation.

Acetonitrile was refluxed with, and distillate from alkaline KMnO4 and KHSO4, followed by fractional distillation from CaH2. (This was better than fractionation from molecular sieves or passage through a type H activated alumina column, or refluxing with KPH4 for 24h and fractional distillation).[Bell, Rodgers and Burrows J Chem Soc, Faraday Trans I 73 315 1977; Moore et al. J Am Chem Soc 108 2257 1986]. Material suitable for polarography was obtained by refluxing over anhydrous AlCl3 (15g/L) for 1h, distilling, refluxing over Li2CO3 (10g/L) for 1h and redistilling. It was then refluxed over CaH2 (2g/L) for 1h and fractionally distilled, retaining the middle portion. The product was not suitable for UV spectroscopy use. A better purification procedure used refluxing over anhydrous AlCl3 (15g/L) for 1h, distilling, refluxing over alkaline KMnO4 (10g KMnO4, 10g Li2CO3/L) for 15min, and distilling. A further reflux for 1h over KHSO4 (15g/L), then distilling, was followed by refluxing over CaH2 (2g/L) for 1h, and fractional distillation. The product was protected from atmospheric moisture and stored under nitrogen [Walter and Ramalay Anal Chem 45 165 1973]. Purification of "General Purity Reagent" for this purpose is not usually satisfactory because very large losses occur at the KMnO4, Li2CO3 step. For electrochemical work involving high oxidation fluorides, further reflux over P2O5 (1g/mL for 0.5h) and distilling (discarding 3% of first and last fractions) and repeating this step is necessary. The distillate is kept over molecular sieves in vac after degassing, for 24h and vac distillation onto freshly activated 3Å molecular sieves. The MeCN should have absorption at 200nm of <0.05 (H2O reference) and UV cutoff at ca 175nm. Also the working potential range of purified Et4N+ BF4- (0.1mol/dcm3 in the MeCN) should be +3.0 to -2.7V vs Ag+/Ag0. If these criteria are not realised then further impurities can be removed by treatment with activated neutral alumina (60 mesh) in vacuo before final molecular sieves treatment [Winfield J Fluorine Chem 25 91 1984].

Acetonitrile has been distillate from AgNO3, collecting the middle fraction over freshly activated Al2O3. After standing for two days, the liquid was distillate from the activated Al2O3. Specific conductivity 0.8-1.0 x 10^-8 mhos [Harkness and Daggett Can J Chem 43 1215 1965]. Acetonitrile 14C was purified by gas chromatography and is water free and distillate at 81°. [J Mol Biol 87 541 1974.]
Rapid procedure: Dry over anhydrous K$_2$CO$_3$ for 24h, followed by further drying for 24h over 3A molecular sieves or boric anhydride, followed by distillation. Alternatively, stir over P$_2$O$_5$ (5% w/v) for 24h then distill. However this last method is not suitable for use in reactions with very acid sensitive compounds.

Acetonyleacetone (2,5-hexanedione) [110-13-4] M 114.2, m -90, b 76-78°/13 mm, 88°/25mm, 188°/atm, d$_4^2$ 0.9440, n$_D^2$ 1.423, pK 18.7. Purified by dissolving in Et$_2$O, stirred with K$_2$CO$_3$ (a quarter of the wt of dione), filtered, dried over anhydrous Na$_2$SO$_4$ (not CaCl$_2$), filtered, evapd and distd in a vacuum. It is then redistd through a 30cm Vigreux column (oil bath temp 150°). It is miscible with H$_2$O and EtOH. The dioxime has m 137° (plates from C$_8$H$_8$), mono-oxime has b 130°/1 lmm, and the 2,4-dinitrophenylhydrazone has m 210-212° (red needles from EtOH). [Chem Ber 22 2100 1989; for enol content see J Org Chem 19 1960 1954.]

4-Acetophenetidine (phenacetin) [62-44-2] M 179.2, m 136°. Crystd from H$_2$O or purified by soln in cold dilute alkali and reppted by addn of acid to neutralisation point. Air-dried.

Acetophenone [98-86-2] M 120.2, m 19.6°, b 54°/2.5mm, 202°/760mm, d$_5^2$ 1.0238, n$_D^2$ 1.5322, pK 19.2. Dried by fractional distn or by standing with anhydrous CaSO$_4$ or CaCl$_2$ for several days, followed by fractional distn under reduced pressure (from P$_2$O$_5$, optional), and careful, slow and repeated partial crystns from the liquid at 0° excluding light and moisture. It can also be crystd at low temperatures from isopentane. Distn can be followed by purification using gas-liquid chromatography [Earls and Jones J Chem Soc, Faraday Trans 1 71 2186 1975.]

A commercial polystyrene supported version is available — scavanger resin (for diol substrate).

Aceto-o-toluidide [120-66-1] M 149.2, m 110°, b 296°/760mm. Crystd from H$_2$O, EtOH or aqueous EtOH.

Aceto-m-toluidide [537-92-8] M 149.2, m 65.5°, b 182-183°/14mm, 303°/760mm. Crystd from H$_2$O, EtOH or aqueous EtOH.

Aceto-p-toluidide [103-89-9] M 149.2, m 146°, b 307°/760mm. Crystd from aqueous EtOH.

Acetoxime (acetone oxime) [127-06-0] M 73.1, m 63°, b 135°/760mm, pK$_{40}$ 0.99. Crystd from pet ether (b 40-60°). Can be sublimed.

Acetoxyacetone (acetol acetone) [592-20-1] M 116.1, b 65°/11mm, 73-75°/17mm, 174-176°/atm, d$_4^2$ 1.0757, n$_D^2$ 1.4141. Distil under reduced pressure, then redistil at atm pressure. It is miscible with H$_2$O but is slowly decomposed by it. Store in dry atmosphere. The 2,4-dinitrophenylhydrazone has m 115-115.5° (from CHCl$_3$/hexane). [J Chem Soc 59 789 1891; J Org Chem 21 68 1956; Justus Liebigs Ann Chem 335 260 1904.]

4-Acetoxy-2-azetidinone [28562-53-0] M 129.1, m 38-41°. Dissolve in CHCl$_3$, dry (MgSO$_4$) concentrate at 40°/70mm, or better at room temperature to avoid decomposition. Wash and stir the residual oil with hexane by decantation and discard wash. Dry the oil at high vacuum when it should solidify, m 34°. It can be distd at high vacuum, 80-829°10°, but this results in extensive losses. The purity can be checked by TLC using Merck Silica Gel F$_{254}$ and eluting with EtOAc. The azetidinone has R$_F$ 0.38 (typical impurities have R$_F$ 0.67). The spots can be detected by the TDM spray. This is prepared from (A) 2.5g 4,4'-tetramethylidaminophenylmethane (TDM) in 10mL AcOH and diluted with 50mL of H$_2$O, (B) 5g KI in 100mL of H$_2$O and (C) 0.3g ninhydrin in 10mL of AcOH and 90mL of H$_2$O. The spray is prepared by mixing (A) and (B) with 1.5mL of (C) and stored in a brown bottle. [Justus Liebigs Ann Chem 35 206 1904.]

1-Acetoxy-1,3-butadiene (1,3-butadienyl acetate) cis-trans mixture [1515-76-0] M 112.1, b 42-43°/16mm, 51-52°/20mm, 60-61°/40mm, d$_4^2$ 0.9466, n$_D^2$ 1.4622. The commercial sample is stabilised with 0.1% of p-tert-butylcatechol. If the material contains crotonaldehyde (by IR, used in its synthesis) it should be dissolved in Et$_2$O, shaken with 40% aqueous sodium bisulfite, then 5% aqueous
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Na$_2$CO$_3$, water, dried (Na$_2$SO$_4$) and distilled several times in a vac through a Widmer (Helv Chim Acta 7 59 1924) or Vigreux column [Wicterle and Hudlicky Collect Czech Chem Commun 12 564 1947; Hagemeyer and Hull Ind Eng Chem 41 2920 1949].

1-Acetoxy-2-butoxyethane [112-07-2] M 160.2, b 61-62°/0.2mm, 75-76°/12mm, 185.5°/740mm, 188-192°/atm, d$_4^{10}$ 0.9425, n$_D^{10}$ 1.4121. Shake with anhydrous Na$_2$CO$_3$, filter and distil in a vacuum. Redistn can be then be carried out at atmospheric pressure. [J Org Chem 21 1041 1956.]

3R,4R,1'R-[4-(tert-butylmethylsilyloxy)ethyl]-2-azetinone see Chapter 5.


1-Acetoxy-2-methoxyethane [110-49-6] M 118.1, b 141°/732mm, 140144°/atm, d$_4^{14}$ 1.009, n$_D^{14}$ 1.4011. Shake with anhydrous Na$_2$CO$_3$, filter and distil in a vacuum. Redistn can be then be carried out at atmospheric pressure. [J Org Chem 21 1041 1956.]

R-(-)-a-Acetoxyphenylacetic (acetyl mandelic) acid [51019-43-3] M 194.2, m 96-98°, [al]$_D^{20}$ -153.7° (c 2.06, Me$_2$CO), [al]$_D^{18}$ -194° (c 2.4, Me$_2$CO), pK$_{a_{1}}$ -2.9 Recrysts from H$_2$O with 1mol of solvent which is removed on drying, or from solvents as for the S-isomer. [J Chem Soc 227 1943.]


S-(--)-2-Acetoxypropionyl chloride [36394-75-9] M 150.6, b 51-53°/11mm, d$_4^{18}$ 1.19, n$_D^{18}$ 1.423, [al]$_D^{20}$ -33° (c 2, CHCl$_3$), [al]$_D^{18}$ -28° (c 13, Ac$_2$O). It is moisture sensitive and is hydrolysed to the corresponding acid. Check the IR spectrum. If the OH band above 3000cm$^{-1}$ is too large and broad then the mixture should be refluxed with pure acetyl chloride for 1h, evapd and distd under reduced pressure.


Acetylacetone (2,4-pentanedione) [123-56-6] M 100.1, b 45°/30mm, d$_{30}^{20}$ 0.9630, n$_{18.5}^{18.5}$ 1.45178, pK$_{1}^{25}$ -5.0 (enol), -6.6 (keto), pK$_{1}^{25}$ 8.95 Small amounts of acetic acid were removed by shaking with small portions of 2M NaOH until the aqueous phase remained faintly alkaline. The sample, after washing with water, was dried with anhydrous Na$_2$SO$_4$, and distd through a modified Vigreux column [Cartledge J Am Chem Soc 73 4416 1951]. An additional purification step is fractional crystn from the liquid. Alternatively, there is less loss of acetylacetone if it is dissolved in four volumes of benzene and the soln is shaken three times with an equal volume of distd water (to extract acetic acid): the benzene is then removed by distn at 43-53° and 20-30mm through a helices-packed column. It is then refluxed over P$_2$O$_5$ (10g/L) and fractionally distd under reduced pressure. The distillate (sp conductivity 4 x 10$^{-8}$ ohm$^{-1}$cm$^{-1}$) was suitable for polarography [Fujinaga and Lee Talanta 24 395 1977]. To recover used acetylacetone, metal ions were stripped from the soln at pH 1 (using 100mL 0.1M H$_2$SO$_4$/L of acetylacetone). The acetylacetone was washed with
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(i:10) ammonia soln (100mL/L) and with distd water (100mL/L, twice), then treated as above. It complexes with Al, Be, Ca, Cd, Ce, Cu, Fe$^{2+}$, Fe$^{3+}$, Mn, Mg, Ni, Pb and Zn.


**N-Acetylanthranilic acid** [89-52-1] M 179.1, m 182-184°, 185-186°, 190°(dec), pK$_{25}$ 3.61. Wash with distilled H$_2$O and recrystallise from aqueous AcOH, dry and recrystallise again from EtOAc. Also recryst from water or EtOH. [J Chem Soc 2495 1931; J Am Chem Soc 77 6698 1955.]

**2-Acetylbenzoic acid** [577-56-0] M 164.2, m 115-116°, 116-118°, pK$_{25}$ 4.16. Recrystallises from *C$_6$H$_6$ and H$_2$O (15g/100mL). The oxime has m 156-157°, and the 2,4-dinitrophenylhydrazone has m 185-186°(needles from EtOH). [J Am Chem Soc 69 1547 1947.]

**4-Acetylbenzoic acid** [586-89-0] M 164.2, m 207.5-209.5°, 208.6-209.4°, pK$_{25}$ 3.70, 5.10 (EtOH). Dissolve in 5% aqueous NaOH, extract with Et$_2$O, and acidify the aqueous soh. Collect the ppt, and recrystallise from boiling H$_2$O (100 parts) using decolorising charcoal [J Org Chem 24 504 1959; J Chem Soc 265 1957; J Am Chem Soc 72 2882 1050, 74 1058 1952].


**4-Acetyl-5-bromosalicylic acid** [1503-53-3] M 259.1, m 168-169°, pK$_{m}$ ~3.0. Crystd from EtOH.

**4-Acetyl-biphenyl** [92-91-1] M 196.3, m 120-121°, b 325-327°/760mm. See 4'-phenyl-acetophenone on p. 327.

**Acetyl-5-bromosalicylic acid** [1503-53-3] M 259.1, m 168-169°, pK$_{m}$ ~3.0. Crystd from EtOH.

**2-Acetylbutyrolactone** [517-23-7] M 128.1, b 105°/5mm, 120-123°/11mm, 142-143°/30mm, d$_2^0$ 1.1846, n$_D^0$ 1.459. Purified by distillation, which will convert any free acid to the lactone, alternatively dissolve in Et$_2$O, wash well with 0.5N HCl, dry the organic layer and distil. The solubility in H$_2$O is 20% v/v. The 2,4-dinitrophenylhydrazone forms orange needles from MeOH, m 146°. The lactone hydrolyses in mineral acid to 2-acetyl-4-hydroxybutyric acid which can be converted to the di-n-propylamine salt with m 68-70°. The lactone is a SKIN IRRITANT. [Yakugaku Zasshi (*J Pharm Soc Japan*) 62 417(439) 1942; Helv Chim Acta 35 2401 1952.]

**Acetyl chloride** [75-36-5] M 78.5, b 52°, d 1.1051, n 1.38976. Refluxed with PCl$_5$ for several hours to remove traces of acetic acid, then distd. Redistd from one-tenth volume of dimethylaniline or quinoline to remove free HCl. A.R. quality is freed from HCl by pumping it for 1h at -78° and distg into a trap at -196°.
Acetyl bromide \([506-96-7]\) M 123.0, b 76-77\(^\circ\), d 1.65. Boiled with PB\(_3\)/AC\(_2\)O for 1\(h\) then distd off and redistd. Store dry. [Burton and Degering *J Am Chem Soc* 62 227 1940.] LACHRYMATORY.

Acetylcyclohexane (cyclohexyl methylketone) \([823-76-7]\) M 126.2, b 64\(^\circ/\)11\(^{mm}\), 76.2-77\(^\circ/\)25\(^{mm}\), d\(_4\) 0.9178, n\(_D\) 1.4519. Dissolve in Et\(_2\)O, shake with H\(_2\)O, dry, evaporate and fractionate under reduced pressure. [UV: *J Am Chem Soc* 74 518 1952; enol content: *J Org Chem* 19 1960 1954.] The semicarbazone has m 174\(^\circ\), the 2,4-dinitrophenylydrazone has m 139-140\(^\circ\) [Helv Chim Acta 39 1290 1956].

2-Acetylcyclohexanone \([874-23-7]\) M 140.2, m -11\(^\circ\), b 62-64\(^\circ/\)2.5\(^{mm}\), 95-98\(^\circ/\)10\(^{mm}\), 111-112\(^\circ/\)18\(^{mm}\), d\(_2\) 1.08, n\(_D\) 1.51. Dissolve in ligroin (b 30-60\(^\circ\)), wash with saturated aqueous NaHCO\(_3\) dry over Drierite and fractionate in a vacuum. [UV: *J Am Chem Soc* 75 626, 5030 1953; *Chem Ber* 87 108 1954.] It forms a *Cu salt* which crystallises in green leaflets from EtOH, m 162-163\(^\circ\) [UV: *J Chem Soc* 4419 1957].

2-Acetylcyclopentanone \([1670-46-8]\) M 126.2, b 72-75\(^\circ/\)8\(^{mm}\), 82-86\(^\circ/\)12\(^{mm}\), 88\(^\circ/\)18\(^{mm}\), d\(_4\) 1.043, n\(_D\) 1.490. Dissolve in pet ether (b 30-60\(^\circ\)), wash with satd aq NaHCO\(_3\), dry over Drierite and fractionate in a vacuum. It gives a violet colour with ethanolic FeCl\(_3\) and is only slowly hydrolysed by 10% aq KOH but rapidly on boiling to yield 6-oxoheptanoic acid. [J Am Chem Soc 75 5030 1953; J Chem Soc 4232 1956; UV: *J Am Chem Soc* 81 2342 1959.] It gives a gray green *Cu salt* from EtOH-pentane, m 237-238\(^\circ\) [J Am Chem Soc 79 1488 1957].

Acetyldigitoxin-\(\alpha\) \([25395-32-8]\) M 807.0, m 217-221\(^\circ\), [\(\alpha\)]\(_{20}\) +5.0 (c 0.7, pyridine). Cryst from MeOH as plates.

Acetylene \([74-86-2]\) M 26.0, m -80.8\(^\circ\), b -84\(^\circ\), pK -25. If very impure it should be purified by successive passage through spiral wash bottles containing, in this order, satd aq NaHCO\(_3\), H\(_2\)O, 0.2M iodine in aq KI (two bottles), sodium thiosulfate soln (two bottles), alkaline sodium hydrosulfite with sodium anthraquinone-2-sulfonate as indicator (two bottles), and 10% aqueous KOH soln (two bottles). The gas was then passed through a Dry-ice trap and two drying tubes, the first containing CaC\(_2\), and the second, Dehydrite (Mg(ClO\(_4\))\(_2\)) [Conn, Kistiakowsky and Smith *J Am Chem Soc* 61 1868 1939]. Acetone vapour can be removed from acetylene by passage through H\(_2\)O, then concd H\(_2\)SO\(_4\), or by passage through two gas traps at -65\(^\circ\) and -80\(^\circ\), concd H\(_2\)SO\(_4\) and a soda lime tower, a tower of 1-mesh A\(_2\)O\(_3\) then into H\(_2\)SO\(_4\) [Org Synth Coll Vol I 229 1941, 3 853 1955; 4 793 1963]. Sometimes it contains acetone and air. These can be removed by a series of bulb-to-bulb distns, e.g. a train consisting of a conc H\(_2\)SO\(_4\) trap and a cold EtOH trap (-73\(^\circ\)), or passage through H\(_2\)O and H\(_2\)SO\(_4\), then over KOH and CaCl\(_2\). [See Brandsma Preparative Acetylenic Chemistry, 1st Edn Elsevier 1971, for pK p15, ISBN 0444409475; 2nd Edn Elsevier 1988, ISBN 0444429603, and Chapter 5 for sodium acetylide.] It is also available commercially as 10ppm in helium, and several concentrations in N\(_2\) for instrument calibration.

*Sodium acetylide* \([1066-26-8]\) M 48.0, was prepd by dissolving Na (23g) in liquid NH\(_3\) (1L) and bubbling acetylene until the blue color was discharged (ca 30min) and evapd to dryness [Saunders *Org Synth Coll* Vol III 416 1955]; and is available commercially as a suspension in xylene/light mineral oil. [See entry in Chapter 5.]

Acetylenedicarboxamide \([543-21-5]\) M 112.1, m 294\(^\circ\) (dec). Cryst from MeOH.

Acetylenedicarboxylic acid \([142-45-0]\) M 114.1, m 179\(^{\circ}\) (anhydrous), pK\(_1\) 1.04, pK\(_2\) 2.50. Cryst from aqueous ether as dipicrate. For mono K salt see entry in Chapter 5.

*N-Acetylenediamine* \([1001-53-2]\) M 102.1, m 50-51\(^\circ\), 51\(^\circ\), b 128\(^\circ/\)3\(^{mm}\), 125-130\(^\circ/\)5\(^{mm}\), 133-139\(^\circ/\)27\(^{mm}\), pK\(_{19}\) 9.28. It has been fractionated under reduced pressure and fraction b 125-130/5\(^{mm}\) was refractionated; fraction c 132-135/4\(^{mm}\) was collected and solidified. It is a low melting hygroscopic solid which can be recrystd from dioxane- Et\(_2\)O. It is soluble in H\(_2\)O, Et\(_2\)O and \(\text{C}_6\text{H}_6\). The \(p\)-toluenesulfonate salt can be recrystd from EtOH-EtOAc 1:8, has m 125-126\(^\circ\) but the free base cannot be recovered from it by basifying and extracting with CH\(_2\)Cl\(_2\). The *picrate* has m 175\(^\circ\) (from EtOH) [J Am Chem Soc 63 853 1941, 78 2570 1956].

2-Acetylfluorene \([781-73-7]\) M 208.3, m 132\(^\circ\). Cryst from EtOH.

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\( \text{N-Acetyl-D-galactosamine [14215-68-0]} \) M 221.2, m 160-161°, \( \left[ \alpha \right]_{\text{D}}^{546} +102^\circ \) (c 1, H\(_2\)O). Crystd from MeOH/\( \text{Et}_2\)O.

\( \text{N-Acetyl-D-glucosamine [7512-17-6]} \) M 221.2, m \( \text{ca} \) 215°, \( \left[ \alpha \right]_{\text{D}}^{546} +49^\circ \) after 2h (c 2, H\(_2\)O). Crystd from MeOH/\( \text{Et}_2\)O.

\( \text{N-Acetylglutamic acid [1188-37-0]} \) M 189.2, m 185° (RS); 201° (S), \( \left[ \alpha \right]_{\text{D}}^{25} -16.6^\circ \) (in H\(_2\)O), \( \text{pK}^e_1 \approx 3.4, \text{pK}^e_2 \approx 4.3 \). Likely impurity is glutamic acid. Crystd from boiling water.

\( \text{N-Acetylglycinamide [2620-63-5]} \) M 116.1, m 139-139.5°. Repeated crystn from EtOH/\( \text{Et}_2\)O. Dried in a vacuum desiccator over KOH.

\( \text{N-Acetylglycine [543-24-8]} \) M 117.1, m 206-208°, \( \text{pK}^e_1 - 1.92, \text{pK}^e_2 3.69 \). Treated with acid-washed charcoal and recrystd three times from water or EtOH/\( \text{Et}_2\)O and dried in \text{vacuo} over KOH [King and King J Am Chem Soc 78 1089 1956].

\( \text{N-Acetylglycyl-L-alaninamide [34017-20-4]} \) M 175.2. Repeated crystn from EtOH/\( \text{Et}_2\)O. Dried in a vacuum desiccator over KOH.

\( \text{N-Acetylglycylglycinamide [35455-24-4]} \) M 230.2, m 253-255°. Repeated crystn from \( \text{EtOHEt}_2\)O. Dried in a vacuum desiccator over KOH.

\( \text{N-Acetylglycylglycylglycinamide} \) M 230.2, m 253-255°. Repeated crystn from \( \text{EtOHEt}_2\)O. Dried in a vacuum desiccator over KOH.

\( \text{N-Acetylhistidine (H\(_2\)O) [39145-52-3]} \) M 171.2, m 148° (RS); 169° (S) \( \left[ \alpha \right]_{\text{D}}^{25} +46.2^\circ \) (H\(_2\)O). Likely impurity is histidine. Crystd from water, then 4:1 acetone:water.

\( \text{N-Acetyll-homocysteine thiolactone (Citiolone) [1195-16-0]} \) M 159.2, m 110°, 109-111°, 115-112.5°. Dry in a vacuum desiccator and recrystallise from toluene as needles. It is a ninhydrin -ve substance which gives a "slow" nitroprusside test. \( \text{hmax} \) 238nm (E 4,400 M\(^{-1}\)cm\(^{-1}\)), v (nujol) 1789s and 851ms cm\(^{-1}\). [J Am Chem Soc 78 1597 1956; J Chem Soc 2758 1963].

\( \text{N-Acetyl imidazole [2466-76-4]} \) M 110.1, m 101.5-102.5°, \( \text{pK}^{25} 3.6 \). Cryst from isopropenyl acetate. Dried in a vacuum over P\(_2\)O\(_5\).

\( \text{3-Acetylindole [703-80-0]} \) M 159.2, m 188-190°, 191-193°, 194°, \( \text{pK}^{25} 12.99 \) (acidic). Recryst from MeOH or \( *\text{C}_6\text{H}_6 \) containing a little EtOH. The \text{phenylureido} derivative has m 154°. [J Chem Soc 461 1946].

\( \text{Acetyl iodide [507-02-8]} \) M 170.0, b 108°/760mm. Purified by fractional distn.

\( \text{N-Acetyl-L-leucinamide [28529-34-2]} \) M 177.2, m 133-134°. Recrystd from CHCl\(_3\) and pet ether (b 40-60°).

\( \text{3-(S-Acetylmercapto)isobutyric acid [RS 33325-40-5]} \) M 162.2, m 40-40.5°, b \( \text{ca} \) 120°/1.25mm, \( \text{pK}^e_{\text{Et}_2}\) = -4.0. Distil under vacuum and recryst from \( *\text{C}_6\text{H}_6 \). [Chem Abstr 38 3616 1944].

\( \text{Acetyl methanesulfonate [5539-53-7]} \) M 170.2, b <120°/<0.01mm. The main impurity is methanesulfonic acid. Reflux with redistd acetyl chloride for 6-10h, i.e. until no further HCl is absorbed in a trap, and exclude moisture. Dist off excess of AcCl and carefully dist below 0.001mm with the bath temp below 120° to give the anhydride as a pale yellow oil which solidifies below 0°. Below ~130° it decom to the
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disulfonic anhydride and above -130° polymers are formed. It is used for cleaving ethers [Prep, IR, NMR: Karger and Mazur J Org Chem 36 528, 532 1971].


N-Acetyl-A½-methyl-L-alaninamide [19701-83-8] M 144.2. Crystd from EtOAcEt2O, then from EtOH and Et2O.

4-Acetyl-1-methyl-1-cyclohexene [6090-09-1] M 138.2, b 73-75°/7.5mm, 85-86°/13mm, 94-94.7°/20mm, 204.5-206°/747mm, d20 1.0238, nD 1.469. Purified by distillation under reduced pressure in vacuo, and when almost pure it can be distilled at atmospheric pressure, preferably in an inert atm. Forms two semicarbazones one of which is more soluble in C6H6, and both can be recryst from EtOH, more soluble has m 149°(151°), and the less soluble has m 172-175°(191°). 4-Nitrophenyldihydrazone has m 166-167° and the 2,4-dinitrophenylhydrazone has m 114-115°. [Helv Chim Acta 17 129, 140 1934; Justus Liebigs Ann Chem 564 109 1949.]


1-Acetylnaphthalene [94-1-98-0] M 170.1, m 10.5°, b 93-95°/0.1mm, 167°/12mm, 302°/atm, d20 1.1.2, pK 6.22 (H2 scale, aq H2SO4). If the NMR spectrum indicates the presence of impurities, probably 2-acetylnaphthalene, convert the substance to its picrate by dissolving in benzene or EtOH and adding excess of satd-picric acid in these solvents until separation of picrates is complete. Recryst the picrate till m is 118°. Decompose the picrate with dil NaOH and extract with Et2O. Dry the extract (Na2SO4), filter, evap and dist. The 2,4-dinitrophenylhydrazone crystals from EtOH and has m 259°. [Justus Liebigs Ann Chem 380 95 1911; J Am Chem Soc 61 3438 1939.]

2-Acetylnaphthalene (2-acetonaphthone, β-Acetonaphthone, 2-acetonaphthalene, methyl-2-naphthylketone) [93-08-3] M 170.2, m 52-53°, 55°, 55.8°, b 164-166°/8mm, 171-173°/17mm, 301-303°/atm, pK 6.16 (H2 scale, aq H2SO4). Separated from the 1-isomer by fractional cryst of the picrate in EtOH (see entry for the 1-isomer above) m 82°. Decomposition of the picrate with dil NaOH and extraction with Et2O then evaporation gives purer 2-acetylnaphthalene. If this residue solidifies it can be recrystd from pet ether, EtOH or acetic acid; otherwise it should be distilld in a vac and the solid distillate is recryst [Gorman and Rodgers J Am Chem Soc 108 5074 1986; Levanon et al. J Phys Chem 91 14 1987]. Purity should be checked by high field NMR spectroscopy. Oxime has m 145° dec, and the semicarbazone has m 235°. [Justus Liebigs Ann Chem 380 95 1911; J Am Chem Soc 72 753 and 5626 1950, J Org Chem 5 512 1940.]

N-Acetyl-D-penicillamine [15537-71-0] M 191.3, m 189-190° (dec), [α]1D +18° (c 1, in 50% EtOH). See N-acetyl penicillamine on p. 507 in Chapter 6.

N-Acetyl-L-phenylalanine [2018-61-3] M 207.2, m 170-171°, [α]1D +41° (c 1, EtOH), (DL) m 152.5-153°, pK 3.5. Crystd from CHCl3 and stored at 4°. (DL)-isomer crystd from water or acetone.

1-Acetyl-2-phenylhydrazine [13889-98-0] M 128.2, m 124-128°/0.2mm, 218°/760mm, d4° 1.1444, nD 1.5023. Purified by fractional distn through a short Vigreux column (15mm). The 2,4-dinitrophenylhydrazone has m 212-213° (from EtOH). It is freely soluble in H2O but insoluble in Et2O. [J Am Chem Soc 75 816 1953.]

1-Acetyl-4-piperidone [32161-06-1] M 141.2, b 124-125°/0.2mm, 215°/760mm, ai5 1.1444, ni' 1.5023. Purified by fractional distn through a short Vigreux column (15mm). The 2,4-dinitrophenylhydrazone has m 212-213° (from EtOH). It is freely soluble in H2O but insoluble in Et2O. [J Am Chem Soc 75 816 1953.]

Acetylsalicylic acid (Aspirin) [50-78-2] M 180.2, m 133.5-135°, pK 4.06, (pK 4.56). Crystd twice from toluene, washed with cyclohexane and dried at 60° under vacuum for several hours [Davis and Hetzer J Res Nat Bur Stand 60 569 1958]. Has also been recrystd from isopropanol and from diethyl ether/pet ether (b 40-60°).

3-Acetylsalicyloyl chloride [5538-51-2] M 198.6, m 45°, 46-49°, 48-52°, b 107-110°/0.1mm, 135°/12mm, d4° 1.1065, nD 1.5023. Check first the IR to see if an OH frequency is present. If so then some free acid is present. Then reflux with acetyl chloride for 2-3h and fractionate at high vac. The distillate should crystallise. It can be recryst from hexane. [J Chem Soc 89 1318 1906.]

O-Acetylsalicyloyl chloride [530-75-5] M 300.3, m 159°. Crystd from dilute acetic acid.


2-Acetylthiazole [24295-03-2] M 127.2, b 89-91° (90-95°)/12mm, 95-105°/15mm, d7° 1.23, nD 1.55. Check NMR spectrum, if not too bad, distil through an efficient column in a vacuum. The oxime sublimes at 140-145°, m 159° (cryst from H2O) has m 163-165.5° [Helv Chim Acta 31 1142 1948; J Am Chem Soc 79 4524 1957; Helv Chim Acta 40 554 1957].

2-Acetylthiophene (methyl 2-thienyl ketone) [88-15-3] M 126.2, m 9.2-10.5°, 10.45°, 10-11°, b 77°/4mm, 89-91°/9mm, 94.5-96.5°/13mm, 213-214°/atm, d2° 1.17, nD 1.5666. Fractionally distd through a 12 plate column and fraction b 77°/4mm was collected. Also wet the acetylthiophene in order to remove and free thiophene which forms an azeotrope with H2O, b 68°. Store in a brown bottle and the clear colourless liquid remains thus for extended periods. [Org Synth 28 1 1948; J Am Chem Soc 69 3093 1947.] The red 4-nitrophenylhydrazone crystallizes from EtOH, m 181-182°.
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3-Acetylthiophene (methyl 3-thienyl ketone) [1468-83-3] M 126.2, m 57°, 60-63°, b 106-107°/25 mm, 208-210°/748 mm. Recrystd from pet ether (b 30-60°) or EtOH. 2,4-dinitrophenylhydrazone crystallises from CHCl₃, m 265°, and the semicarbazone crystallises from EtOH, m 174-175°. [J Am Chem Soc 70 1555 1948.]

N-Acetylthiouria [591-08-2] M 118.2, m 164-165°, 165-169°. Recrystd from AcOH, the solid is washed with Et₂O and dried in air then at 110°. [Collect Czech Chem Commun 24 3678 1959.]

Acetyl p-toluene sulfonate [26908-82-7] M 214.2, m 54-56°. The most likely impurity is p-toluenesulfonic acid (could be up to 10%). This can be removed by dissolving in dry Et₂O and cooling until the anhydride crystallises out. It decomp on heating; below -130° it gives the disulfonic anhydride and above -130° polymers are formed. It is used for cleaving ethers [Prep, IR, NMR: Karger and Mazur J Org Chem 36 528, 532 1971].


N-Acetyl-L-valine amide [37933-88-3] M 158.2, m 275°. Recrystd from CH₃OH/Et₂O.


trans-Aconitic acid (1,2,3-propenetricarboxylic acid) [4023-65-8] M 174.1, m 195°(dec), m 198-199°(dec), 204-205°(dec), pKₐ 2.81, pKₐ 4.46. Purified by dissolving in AcOH (77g/150 mL), filtering and cooling. The acid separates (55g) as colourless needles. A further quantity (10g) can be obtained by reducing the vol of the filtrate. The acid is dried in air then in a vacuum desiccator over NaOH. The acid can be recrystd from Me₂CO-CHCl₃. The highest m is obtained with the very dry acid. The m (209°) is obtained on a Dennis bar [J Am Chem Soc 52 3128 1930, Org Synth Coll Vol II 12 1943].

cis-Aconitic anhydride [6318-55-4] M 156.1, m 75°, 76-78°, 78-78.5°. Reflux in xylene (7.5 parts) for 1 h, then evaporate and recrystallise the residue from *C₆H₆. Alternatively, reflux in Ac₂O, evaporate and recrystallise from *C₆H₆. It is sensitive to moisture. [IR: Acta Chem Scand 21 291 1967, Chem Ber 61 2523 1928; NMR: Biochemistry 5 2335 1966.]


Aconitine hydrobromide [6034-57-7] M 726.7, m 207°. Crystd from water or EtOH/ether.

Acridine (2,3-benzoquinoline) [260-94-6] M 179.2, m 111° (sublimes), b 346°, pK 5.58 (pK15 of excited state 10.65). Crystd twice from benzene/cyclohexane, or from aqueous EtOH, then sublimed, removing and discarding the first 25% of the sublimate. The remainder was again crystd and sublimed, discarding the first 10-15% [Wolf and Anderson J Am Chem Soc 77 1608 1955]. Acridine can also be purified by crystn from n-heptane and then from ethanol/water after pre-treatment with activated charcoal, or by chromatography on alumina with pet ether in a darkened room. Alternatively, acridine can be ppted as the hydrochloride from benzene by adding HCl, after which the base is regenerated, dried at 110°/50 mm, and crystd to constant melting point from pet ether [Cumper, Ginman and Vogel J Chem Soc 4518 1962]. The regenerated free base may be recryst, chromatographed on basic alumina, then vac-sublimed and zone-refined. [Williams and Clarke, J Chem Soc, Faraday Trans 1 73 514 1977; Albert, The Acridines
Arnold Press 1966]. It can exist in five crystalline forms and is steam volatile. It is a strong IRRITANT to skin and mucous membranes and can become a chronic irritant—handle with CARE.

Acridine Orange [494-38-2] M 349.94, m 181-182° (free base). The double salt with ZnCl₂ (6g) was dissolved in water (200mL) and stirred with four successive portions (12g each) of Dowex-50 ion-exchange resin (K⁺ form) to remove the zinc. The soln was then concentrated in vacuum to 20mL, and 100mL of ethanol was added to ppted KCl which was removed. Ether (160mL) was added to the soln from which, on chilling, the dye crystallises as its chloride. It was separated by centrifuging, washed with chilled ethanol and ether, and dried under vac, before being recryst from ethanol (100mL) by adding ether (50mL), and chilling. Yield 1g. [Pal and Schubert J Am Chem Soc 84 4384 1962].

It was recrystd twice as the free base from ethanol or methanol/water by dropwise addition of NaOH (less than 0.1M). The ppted was washed with water and dried under vac, before being recryst from ethanol (100mL) by adding ether (50mL), and chilling. Yield 1g. [Pal and Schubert J Am Chem Soc 84 4384 1962].


Acridone [578-95-0] M 195.2, m >300°, pk₁ -0.32 (basic), pk₂ 14 (acidic). Dissolve ~1g in ca 1% NaOH (100mL), add 3M HCl to pH 4 when acridone separates as a pale yellow solid with m just above 350° (sharp). It can be recrystd from large vols of H₂O to give a few mg. It is soluble in 160 parts of boiling EtOH (540 parts at 22°) [J Chem Soc 1294 1956]. A few decigrams are best crystallised as the hydrochloride from 400 parts of 10N HCl (90% recovery) from which the free base is obtained by washing the salt with H₂O. A small quantity can be recrystd (as the neutral species) from boiling AcOH. Larger quantities are best recrystallised from a mixture of 5 parts of freshly distd aniline and 12.5 parts of glacial acetic acid. Acridone distils unchanged from atmospheric pressure, but the boiling point was not recorded, and some sublimation occurs below 350°. It has UV: \(\lambda_{\text{max}}\) 399nm. [see Albert, The Acridines Arnold Press pp. 201, 372 1966.]

N-(9-Acridinyl)maleimide (NAM) [49759-20-8] M 274.3, m 248°, 255-258°. Purified by chromatography on silica gel using CH₂Cl₂ as eluant. Evaporation of pooled fractions that gave the correct NMR spectra gave a solid which was recrystd from Me₂CO as pale yellow prisms. IR v (nujol): 1710 (imide); UV (MeOH): \(\lambda_{\text{max}}\) (nm), (ε M⁻¹cm⁻¹): 251 (159 500), 343 shoulder (7 700), 360 (12 400) and 382shoulder (47 000). [Chem Pharm Bull Jpn 26 596 1978; Eur J Biochem 25 64 1972.]

Acriflavine [8048-52-0] M 196.2, pk >12. Treated twice with freshly ppted AgOH to remove proflavine, then recryst from absolute methanol [Wen and Hsu J Phys Chem 66 1353 1962].

Acriflavine Mixture (Euflavin, 3,6-diamino-10-methylacridinium chloride) [8063-24-9] M 259.7, m 179-181°. Purified by dissolving in 50 parts of H₂O, shake with a small excess of freshly ppted and washed Ag₂O. The mixture is set aside overnight at 0° and filtered. The cake is not washed. The pH of the filtrate is adjusted to 7.0 with HCl and evaporated to dryness. The residue is then crystd twice from MeOH, twice from H₂O and dried at 120°. \(\lambda_{\text{max}}\) at 452nm has a logε value of 4.67. It is a red powder which readily absorbs H₂O. The solubility is increased in the presence of proflavine. The dihydrochloride is a deep red crysts powder. It is available as a mixture of 3,6-diaminoacridinium chloride (35%) and its 10-metho-chloride (65%). [see Albert, The Acridines Arnold Press p. 346 1966; Chem Ber 45 1787 1912.]

Acrolein (acraldehyde) [107-02-8] M 56.1, b 52.1°, n 1.3992, d 0.839. Purified by fractional distn. under nitrogen, drying with anhydrous CaSO₄ and then distilling under vac. Blacet, Young and Roof [J Am Chem Soc 59 608 1937] distd under nitrogen through a 90cm column packed with glass rings. To avoid formation of diacryl, the vapour was passed through an ice-cooled condenser into a receiver cooled in an ice-salt mixture and containing 0.5g catechol. The acrolein was then distd twice from anhydrous CuSO₄ at low pressure, catechol being placed in the distilling flask and the receiver to avoid polymerization. [Alternatively, hydroquinone (1% of the final soln) can be used.]
Acrolein diacetyl acetal (1,1-diacetoxy-2-propene). [869-29-4] M 158.2, b 75°/10 mm, 184°/atm, d₂¹⁰ 1.08, nD¹⁰ 1.4203. Check the NMR spectrum. If it is not satisfactory then add Ac₂O and a drop of conc H₂SO₄ and heat at 50° for 10 min. Then add anhydrous NaOAc (ca 3 g/100 g of liquid) and fractionate. Note that it forms an azeotrope with H₂O, so do not add H₂O at any time. It is a highly flammable and TOXIC liquid, keep away from the skin. [J Am Chem Soc 73 5282 1951.]

Acrolein diethyl acetal [3054-95-3] M 130.2, b 120-125°/atm, nD¹⁰ 1.398-1.407. Add Na₂CO₃ (ca 3.5%) and distil using an efficient column, or better a spinning band column. [Org Synth 25 1 1945.]

Acrolein dimethyl acetal (1,1-dimethoxy-2-propene) [6044-68-4] M 102.1, b 87.5-88°/750 mm, 89-90°/760 mm, d₂¹⁰ 0.86, nD¹⁰ 1.3962. Fractionally distil (after adding 0.5 g of hydroquinone) under reduced press through an all glass column (40 cm x 2.5 cm) packed with glass helices and provided with a heated jacket and a total reflux variable take-off head. Stainless steel Lessing rings (1/8 x 1/8 in) or gauze have been used as packing. It is a highly flammable and TOXIC liquid, keep away from the skin. [J Chem Soc 2657 1955.]


Acrylamide [79-06-1] M 71.1, m 84°, b 125°/25 mm. Crystd from acetone, chloroform, ethyl acetate, methanol or *benzene/chloroform mixture, then vac dried and kept in the dark under vac. Recryst from CHCl₃ (200 g dissolved in 1 L heated to boiling and filtered without suction in a warmed funnel through Whatman 541 filter paper. Allowed to cool to room temp and kept at -15° overnight). Crystals were collected with suction in a cooled funnel and washed with 300 mL of cold MeOH. Crystals were air-dried in a warm oven. [Dawson et al. Data for Biochemical Research, Oxford Press 1986 p. 449.]

CAUTION: Acrylamide is extremely TOXIC and precautions must be taken to avoid skin contact or inhalation. Use gloves and handle in a well ventilated fume cupboard.

Acrylic acid [79-10-7] M 72.1, m 13°, b 30°/3 mm, d 1.051, pK₂¹⁰ 4.25. Can be purified by steam distn, or vacuum distn through a column packed with copper gauze to inhibit polymerisation. (This treatment also removes inhibitors such as methylene blue that may be present.) Azeotropic distn of the water with *benzene converts aqueous acrylic acid to the anhydrous material.

Acrylonitrile [107-13-1] M 53.1, b 78°, d 0.806, nD¹⁰ 1.3886. Washed with dilute H₂SO₄ or dilute H₃PO₄, then with dilute Na₂CO₃ and water. Dried with Na₂SO₄, CaCl₂ or (better) by shaking with molecular sieves. Fractionally distill under nitrogen. Can be stabilised by adding 10 ppm tert-butyl catechol. Immediately before use, the stabilizer can be removed by passage through a column of activated alumina (or by washing with 1% NaOH soln if traces of water are permissible in the final material), followed by distn. Alternatively, shaken with 10% (w/v) NaOH to extract inhibitor, and then washed in turn with 10% H₂SO₄, 20% Na₂CO₃ and distilled water. Dried for 24 h over CaCl₂ and fractionally distill under N₂ taking the fraction boiling at 75.0 to 75.5°C (at 734 mm Hg). Stored with 10 ppm tert-butyl catechol. Acrylonitrile is distilled off as required. [Burton et al, J Chem Soc, Faraday Trans I 75 1050 1979.]

Acryloyl chloride [814-68-6] M 90.5, b 72-74°/740 mm, 74°/760 mm, d₂¹⁰ 1.1127, nD²⁰ 1.4337. Distill rapidly through an efficient 25 cm column after adding 0.5 g of hydroquinone/200 g of chloride, and then redistill carefully at atmospheric pressure preferably in a stream of dry N₂. [J Am Chem Soc 72 72, 2299 1950.]

The liquid is an irritant and is TOXIC.

Actarit (p-acetamidophenylacetic acid) [18699-02-0] M 193.2, m 174-175°. Crystd from MeOH + Me₂CO or aq BOH.


Adamantane was also purified by dissolving in n-heptane (ca 10 mL/g of adamantane) on a hot plate, adding activated charcoal (2 g/100 g of adamantane), and boiling for 30 min, filtering the hot soln through a filter paper, concentrating the filtrate until crystals just start, adding one quarter of the original volume n-heptane and...
allowing to cool slowly over a period of hours. The supernatant was decanted off and the crystals were dried on a vacuum line at room temperature. [Walter et al. J Am Chem Soc 107 793 1985.]


1-Adamantane carboxylic acid [828-51-3] M 180.3, m 175-176.5°, 177°, pK<sub>Est</sub> -4.9. Possible impurities are trimethylacetic acid and C9 and C13 acids. Dissolve 15g of acid in CCl<sub>4</sub> (300mL) and shake with 1 lOmL of 15N aqueous NH<sub>3</sub> and the ammonium salt separates and is collected. Acid impurities form soluble ammonium salts. The salt is washed with cold Me<sub>2</sub>CO (20mL) and suspended in H<sub>2</sub>O (250mL). This is treated with 12N HCl and extracted with CHCl<sub>3</sub> (100mL). The dried (Na<sub>2</sub>SO<sub>4</sub>) is evaporated and the residue recryst from a mixture of MeOH (30mL) and H<sub>2</sub>O (ca 10mL) to give the pure acid (10-1 lg). [Org Synth Coll Vol V 20 1973. Also recrystd from absolute EtOH and dried under vacuum at 1W.]

1,3-Adamantane diamine dihydrochloride [26562-81-2] M 239.2, m >310°, pK<sub>Est</sub>(1) -8.1, pK<sub>Est</sub>(2) -10.1. Dissolve in boiling conc HCl (400mg in 15mL) and evaporate to dryness. Dissolve in absolute EtOH and add dry Et<sub>2</sub>0 to crystallise the dihydrochloride. [Chem Ber 93 1366 1960.]

1,3-Adamantane dicarboxylic acid [39269-10-8] M 224.3, m 276°, 276-278°, 279°, pK<sub>Est</sub>(1) ~4.9, pK<sub>Est</sub>(2) 5.9. Dissolve in aq NaOH, treat with charcoal, filter and acidify with dilute HCl. Recryst from MeOH. [Chem Ber 93 1366 1960.]

1-Adamantanol (1-hydroxyadamantane) [768-95-6] M 152.4, m 288.5-290°. If 2-adamantanol is a suspected impurity then dissolve substance (log) in acetone (1OOmL) and Jones's reagent (CrO<sub>3</sub> (10.3g) in H<sub>2</sub>O (30mL)) and conc H<sub>2</sub>S0<sub>4</sub> (8.7mL) is added dropwise (turns green in colour) until excess reagent is present (slight red colour). Allow to stir overnight, decant the acetone soln from the Cr salts and adamantan-2-one, and dry (Na<sub>2</sub>SO<sub>4</sub>) and evaporate to dryness. The residue (ca 7g) is chromatographed through A1<sub>2</sub>0<sub>3</sub> (250g) and washed with 50% *benzene-pet ether (b 40-60°), then 100% Et<sub>2</sub>0 (to remove any adamantan-2-one present) and the 1-adamantanol is then eluted with 5% MeOH in Et<sub>2</sub>0. The eluate is evaporated, and the residue is recryst from pet ether (b 30-60°) at -70°, m 287.2-288.5°. It has characteristic IR, v 3640, 11 14, 1086, 982 and 930cm<sup>-1</sup>. [J Am Chem Soc 83 182 1961.] Alternatively, if free from the 2-isomer, dissolve in tetrahydrofuran, dilute with H<sub>2</sub>O to ppte the alcohol. Collect, dry and sublimate in a vacuum at 130°. [Chem Ber 92 1629 1959.]

2-Adamantanol (2-hydroxyadamantane) [700-57-2] M 152.4, m 288.5-290°. Can be purified by chromatography as for the 1-isomer. It crystallises from cyclohexane and has characteristic IR, v 3600, 1053, 1029 and 992cm<sup>-1</sup>. [J Am Chem Soc 83 182 1961.]


N-(1-Adamantyl)acetamide [880-52-4] M 193.3, m 149°. Wash well with H<sub>2</sub>O, dry and recrystallise from cyclohexane. It is an irritant. [Chem Ber 92 1629 1959.]

1-Adamantylamine hydrochloride [665-66-7] M 187.7, m 360° (dec). Dissolve in dry EtOH, add a few drops of dry EtOH saturated with HCl gas, followed by dry Et2O to crystallise the hydrochloride. Dry the salt in vacuum. [Chem Ber 93 226 1960.]

2-Adamantylamine hydrochloride [10523-68-9] M 187.7, m >300°, pK6.5 ~10.4. The free amine in Et2O, liberated by the action of alkali in H2O, is dried over KOH, filtered, evap and sublimed at 110°/12Tor, m 230-236°. The base is dissolved in EtOH and crystd by the addition of Et2O, and dried in vac. [Justus Liebigs Ann Chem 658 151 1962.]


1-Adamantyl chloride [935-56-8] M 170.7, m 164.3-165.6°. Crystd from aqueous MeOH and sublimed at 100°/12Tor. Also cryst from MeOH at -70°. [Chem Ber 92 1629 1959; J Am Chem Soc 83 2700 1961.]

1-Adamantyl fluoride (1-fluoroadamantane) [768-92-3] M 154.2, m 210-212° (dec), 259-260° (dec). Dissolve in Et2O, dry over Na2SO4, evaporate the dryness and sublime the residue at 90-100°/12mm. Recryst sublimate from MeOH, m 259-260°. [Zh Org Khim 30 1609 1965.] To remove 1-hydroxyadamantane impurity, dissolve in cyclohexane cool for many hours, filter off the hydroxyadamantane, and evaporate to dryness. Recrystallise the residue from pet ether at -77° and sublime in vacuum, m 210-212° dec (sealed tube). [J Org Chem 30 1789 1965.]

1-Adamantyl iodide (1-iodoadamantane) [768-93-4] M 262.1, m 75.3-76.4°. Dissolve in Et2O, shake with aqueous NaHSO3, aqueous K2CO3, and H2O, dry (Na2SO4), evaporate and recrystallise from MeOH at -70° (to avoid alcoholysis) giving white crystals. [J Am Chem Soc 83 2700 1961; lit m of 151-152.5° is incorrect.] Also purified by recryst from pet ether (40-60°C) followed by rigorous drying and repeated sublimation.

1-Adamantyl isocyanate [4411-25-0] M 177.3, m 144-145°. Recryst from n-hexane and sublime. Irritant. [Chem Ber 95 2302 1962.]

1-Adamantyl isothiocyanate [4411-26-1] M 198.2, m 31-32°. Dissolve in n-hexane (ca 10g in 150 mL) and keep at 0° for 24h. Any 1-adamantanol present will separate. Filter and evaporate to dryness. Crystalline residue has m 31-32° (v 1242, 1824 and 2340 cm-1). There should be no OH str band above 2500 cm-1. [Z Phys Chem 357 1647 1976; Haas et al. J Am Chem Soc 88 1988 1966.]

1-Adamantyl iodide (1-iodoadamantane) [768-93-4] M 262.1, m 75.3-76.4°. Dissolve in Et2O, shake with aqueous NaHSO3, aqueous K2CO3, and H2O, dry (Na2SO4), evaporate and recrystallise from MeOH at -70° (to avoid alcoholysis) giving white crystals. [J Am Chem Soc 83 2700 1961; lit m of 151-152.5° is incorrect.] Also purified by recryst from pet ether (40-60°C) followed by rigorous drying and repeated sublimation.

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1-Adamantyl isothiocyanate [4411-26-1] M 198.2, m 31-32°. Dissolve in n-hexane (ca 10g in 150 mL) and keep at 0° for 24h. Any 1-adamantanol present will separate. Filter and evaporate to dryness. Crystalline residue has m 31-32° (v 1242, 1824 and 2340 cm-1). There should be no OH str band above 2500 cm-1. [Z Phys Chem 357 1647 1976; Haas et al. J Am Chem Soc 88 1988 1966.]

1-Adamantyl iodide (1-iodoadamantane) [768-93-4] M 262.1, m 75.3-76.4°. Dissolve in Et2O, shake with aqueous NaHSO3, aqueous K2CO3, and H2O, dry (Na2SO4), evaporate and recrystallise from MeOH at -70° (to avoid alcoholysis) giving white crystals. [J Am Chem Soc 83 2700 1961; lit m of 151-152.5° is incorrect.] Also purified by recryst from pet ether (40-60°C) followed by rigorous drying and repeated sublimation.


Adipic acid [124-04-9] M 146.1, m 154°, pK₁ 4.44, pK₂ 5.45. For use as a volumetric standard, adipic acid was crystd once from hot water with the addition of a little animal charcoal, dried at 120° for 2h, then recrystd from acetone and again dried at 120° for 2h. Other purification procedures include crystn from ethyl acetate and from acetone/petroleum ether, fusion followed by filtration and crystn from the melt, and preliminary distn under vac.

Adiponitrile (1,4-dicyanobutane) [111-69-3] M 188.14, m 2.4°, b 123°/0.5mm, 153°/6mm, 175°/26mm, 184°/30mm, 295°/atm, d₄ 0.9396, nD 1.4371. Reflux over P₂O₅ and POCl₃, and fractionally distil, then fractionate through an efficient column. The liquid is TOXIC and is an IRRITANT. [Chem Ber 67 1770 1934; Justus Liebig's Ann Chem 596 127 1955; Can J Chem 34 1662 1956; J Am Chem Soc 62 228 1940.]

Adonitol (Ribitol) [488-81-3] M 152.2, m 102°. Crystallise from EtOH by addition of diethyl ether.

Adrenalin see epinephrine.

Adrenochrome [54-06-8] M 179.2, m 125-130°. Crystd from MeOH/formic acid, as hemihydrate, and stored in a vacuum desiccator.

Adrenosterone (Reichstein's G) [382-45-6] M 300.4, m 220-224°. Crystd from EtOH. Can be sublimed under high vacuum.

Agaricic acid [1-(n-hexadecyl)citric acid] [666-99-9] M 416.6, m 142°(dec), [α]₇ 9.8° (in NaOH), pKₑₐ 1, pKₑₐ 2, pKₑₐ 3. Crystd from EtOH.

Agmatine sulfate [5-guanidinopent-1-ylamine sulfate] [2482-00-0] M 228.3, m 231°, pKₑₐ 1 9.1, pKₑₐ 2 13.0. Crystd from aqueous MeOH.


Ajmalicine [483-04-5] M 352.4, m 250-252°(dec), [α]₅₄₆ -76° (c 0.5, CHCl₃), pKₑₐ ~7.4. Crystd from MeOH.

Ajmalicine hydrochloride [4373-34-6] M 388.9, m 290°(dec), [α]₀ -17° (c 0.5, MeOH). Crystd from EtOH.

Ajmaline [γ-yohimbine] [4360-12-7] M 326.4, m 160° (MeOH), 205-206° (anhyd), [α]₀ 144° (c 0.8, CHCl₃), pKₑₐ ~7.5. Crystd from MeOH.


Alanine (RS) [302-72-7] M 89.1, m 295-296°, (S) [56-41-7] m 297°(dec), [α]₀ 15° +14.7° (in 1M HCl), pK₁ 2.34, pK₂ 9.87. Crystd from water or aqueous EtOH, e.g. crystd from 25% EtOH in water, recrystd from 62.5% EtOH, washed with EtOH and dried to constant weight in a vacuum desiccator over P₂O₅. [Gutter and Kegeles J Am Chem Soc 75 3893 1953.] 2,2'-Iminodipropionic acid is a likely impurity.

β-Alanine [107-95-9] M 89.1, m 205°(dec), pK₁ 3.55, pK₂ 10.24. Crystd from filtered hot saturated aqueous soln by adding four volumes of absolute EtOH and cooling in an ice-bath. Recrystd in the same way and then finally, crystd from a warm saturated soln in 50% EtOH by adding four volumes of absolute
EtOH cooled in an ice bath. Crystals were dried in a vacuum desiccator over P₂O₅. [Donovan and Kegeles J Am Chem Soc 83 255 1961.]

S-Alaninol [S-2-Aminopropan-1-ol] [2749-11-3] M 75.1, b 167-169°/760mm, d₂⁰ 0.961, nD₁ 1.456, [α]₃₄₆ +26.0° (c 2, EtOH), pKₐ 9.43. Purification as for S-2-amino-3-methylbutan-1-ol

Aldol (3-hydroxybutanal) [107-89-1] M 88.1, b 80-81°/20mm. An ethereal soln was washed with a saturated aqueous soln of NaHCO₃, then with water. The non-aqueous layer was dried with anhydrous CaCl₂ and distd immediately before use. The fraction, b 80-81°/20mm, was collected, [Mason, Wade and Pouncy J Am Chem Soc 76 2255 1954].

Aldosterone [52-39-1] M 360.5, m 105-112°(hydrate), 164°(anhydr), [α]₂⁵ +14.0° (c 1, CHCl₃). Crystd from aqueous acetone.

Aldrin [309-00-2] M 354.9, m 103-104.5°C. Crystd from MeOH. POISONOUS

Aleuritie acid [RS-c~ythro-9,10,16-trihydroxyhexadecanoic acid] [533-87-9] M 490.1, m 100-101°C. Crystd from aqueous EtOH. Hydrazide cryst from EtOH has m 139-140°C (c 0.7, CHCl₃)

Alginic acid [9005-32-7] M 48,000-186,000. To 5g in 550mL water containing 2.8g KHCO₃, were added 0.3mL acetic acid and 5g potassium acetate. EtOH to make the soln 25% (v/v) in EtOH was added and any insoluble material was discarded. Further addition of EtOH, to 37% (v/v), ppted alginic acid. [Pal and Schubert J Am Chem Soc 84 4384 1962].

Aliquat 336 (methyltricaprylylammonium chloride, tri-n-octylmethylammonium chloride) [5137-55-3] M 404.2, d 0.884. An 30% (v/v) soln in benzene was washed twice with an equal volume of 1.5M HBr. [Petrow and Allen, Anal Chem 33 1303 1961.] Purified by dissolving 50g in CHCl₃ (100mL) and shaking with 20% NaOH soln (200mL) for 10min, and then with 20% NaCl (200mL) for 10min. Washed with small amount of H₂O and filtered through a dry filter paper [Adam and Pribil Tuhta 18 733 1971].

Alizarin 1,2-dihydroxyanthraquinone) [72-48-0] M 240.2, m 290°C, d 0.884, pKₐ 7.45, pKₐ 11.80. Crystd from glacial acetic acid or 95% EtOH. Can also be sublimed at 110°C/2mm.

Alizarin-3-methyliminodiacetic acid (Alizarin Complexone) (2H₂O) [3952-78-1] M 421.4, m 189°(dec), pKₐ 4.9, pKₐ 7.5. Purified by suspending in 0.1M NaOH (1g in 50mL), filtering the solution and extracting alizarin with 5 successive portions of CH₂Cl₂. Then add HCl dropwise to precipitate the reagent, stirring the solution in a bath. Filter ppte on glass filter, wash with cold water and dry in a vacuum desiccator over KOH [Ingman Talanta 20 135 1973].

Alizarin Yellow R [5-(4-nitrophenylazoalicylic acid), Mordant Orange] [2243-76-7] M 287-2, m 253-254°(dec), >300°, pKₐ 11.17. The free acid is ppted by adding HCl to an aq soln of the Na salt. After 2 recrystns from aq AcOH, it has m 253-254°(dec); [m 253-254° dec was reported J Chem Soc 79 49 1901]. The free acid can be recrystd from dilute AcOH as orange brown needles. The Na salt changes colour from yellow to red when the pH is increased from 10.2 to 12.0. [J Am Chem Soc 75 5838 1953.]


n-Alkyltrimethylammonium bromide n=10,12,16. Recrystd from an EtOH/Et₂O mixture. [Hashimoto and Thomas J Am Chem Soc 107 4655 1985.]

Allantoin [97-59-6] M 158.1, m 238°(dec). Crystd from water or EtOH.
Allene (prodiene) [463-49-0] M 40.1, m -146°, b -32°. Frozen in liquid nitrogen, evacuated, then thawed out. This cycle was repeated several times, then the allene was frozen in a methyl cyclohexane-liquid nitrogen bath and pumped for some time. Also purified by HPLC. [Cripps and Kiefer Org Synth 42 1962.]


neo-Alloisomene (te-2,6-dimethyl-2,4,6-octatriene) [7216-56-0] M 136.2, b 80°/13mm, 196-198°/atm, d25 0.8161, nD 25 1.5437. Fractionally distd through an efficient column and stabilised with ca 0.1% of hydroquinone. UV: Amax nm (e M -1cm -1) 290 (32 500), 279 (41 900) and 270 (32 600). [Justus Liebigs Ann Chem 609 1 1957; Anal Chem 26 1726 1954.]

5α-Allopregnane-3α,20α-diol [566-58-5] M 320.5, m 248-248.5°, [α]D+17° (c 0.15, EtOH). Crystd from EtOH.


Alloxan [2,4,5,6(1H,3H]pyrimidine, tetrone) [50-71-5] M 142.0, m -170°/dec. pK 6.64. Cryst from water gives the tetrahydrate. Anhydrous crystals are obtained by cryst from acetone, glacial acetic acid or by sublimation in vacuo.

Alloxan monohydrate [2244-11-3] M 160.1, m 255°/dec, pK 6.64. Recryst from H2O as the tetrahydrate in large prisms or rhombs. On heating at 100°, or on exposure to air, this is converted to the monohydrate. Dissolve it in its own weight of boiling H2O and cool for several days below 0° [the tetrahydrate crystallises from soln much more slowly when free from HNO3. It is less sol in HCO3 solns than in H2O]. Drying the solid over H2SO4 yields the monohydrate. The anhydrous crystals can be obtained by recryst from dry Me2CO or AcOH followed by washing with dry Et2O or by sublimation in a vacuum. On heating it turns pink at 230° and decomposes at ca 256°. It is acidic to litmus. [Org Synth Coll Vol III 37 1955.] It forms a compound with urea which crystallises from H2O in yellow needles that become red at 170° and dec at 185-186°.


Allyl acetate [591-87-7] M 100.1, b 103°, d 0.928, nD 0.41488, nD 27 1.4004. Freed from peroxides by standing with crystalline ferrous ammonium sulfate, then washed with 5% NaHCO3, followed by saturated Na2SO4 and fractionally distd in an all-glass apparatus.

Allylacetic acid (pent-4-enoic acid) [591-80-0] M 100.1, m -22.5°, b 83-84°/12mm, 90°/15mm, d20 0.9877, nD 20 1.4280, pK 4.68. Distil through an efficient column (allyl alcohol has b 95-97°). It is characterised as the S-benzyl isothiouronium salt m 155-158° (96% EtOH, aq EtOH) [Acta Chem Scand 9 1425 1955], 4-bromophenacyl ester m 59.5-60.5° (from 90% EtOH). Solubility at 18°: in pyridine (57%), AcOH (7.3%), MeOH (5.4%), Me2CO (3.2%), MeOAc (2.8%), EtOH (5.4%), H2O (1.8%), PrOH (1.6%), isoPrOH (0.27%). [J Am Chem Soc 74 1894 1952.]

Allyl alcohol [107-18-6] M 58.1, b 98°, d4 0.857, nD 1.4134. Can be dried with K2CO3 or CaSO4, or by azeotropic distn with *benzene followed by distn under nitrogen. It is difficult to obtain peroxide free. Also reflux with magnesiam and fractionally distd [Hands and Norman Ind Chem 21 307 1945].
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1-Allyl-6-amine-3-ethyluracil [642-44-4] M 195.2, m 143-144° (anhydr). Crystd from water (as monohydrate).

Allyl bromide [106-95-6] M 121, b 70°, d 1.398, n 1.46924. Washed with NaHCO3, soln then distd water, dried (CaCl2 or MgSO4), and fractionally distd. Protect from strong light. LACHRYMATOR, HIGHLY TOXIC and FLAMMABLE.

Allyl butyl ether [3739-64-8] M 114.2, b 64-65°/120mm, 117.8-118°/763mm, d20 1.4057, nD 0.7829. Check the IR for the presence of OH str vibrations, if so then wash well with H2O, dry with CaCl2 and distil through a good fractionating column. The liquid is an irritant. [J Org Chem 23 1666 1958; J Am Chem Soc 73 3528 1951].

Allyl chloride [107-05-1] M 76.5, b 45.1°, d 0.939, n 1.4130. Likely impurities include 2-chloropropene, propyl chloride, i-propyl chloride, 3,3-dichloropropane, 1,2-dichloropropane and 1,3-dichloropropane. Purified by washing with conc HCl, then with Na2CO3 soln, drying with CaCl2, and distn through an efficient column [Oae and Vanderwerf J Am Chem Soc 75 2724 1953]. LACHRYMATOR, TOXIC.

Allyl chloroformate [2937-50-0] M 120.5, b 64°/1.0mm, 2.9°/5 mm, 14.1°/5mm, 26.6°/20mm, 48.8°/60mm, 60.2°/100mm, 98°/400mm, 119°/760mm, d20 0.8341, nD 1.406. Wash several times with cold H2O to remove alcohol and HCl and dry over CaCl2. It is important to dry well before distilling in vacuo. Note that the receiver should be cooled in ice to avoid loss of distillate into the trap and vacuum pump. The liquid is HIGHLY TOXIC and flammable. [J Am Chem Soc 72 1254 1950].

Allyl cyanide (3-butene nitrile) [109-75-11 M 67.1, b -19.6°/1.0mm, 2.9°/5 mm, 14.1°/5mm, 26.6°/20mm, 48.8°/60mm, 60.2°/100mm, 98°/400mm, 119°/760mm, d20 0.8341, nD 1.406. It should be redistil at atmospheric pressure then distilled under a vacuum to remove final traces of HCN from the residue. Note that the residue from the first distillation may be difficult to remove from the flask and should be treated with conc HNO3 then H2O and finally hot EtOH (CARE). Allyl cyanide has an onion-like odour and is stable to heat. It forms a complex with AlCl3 (2:2) m 41°, and (3:2) m 120°. All operations should be done in an efficient fume hood as the liquid is flammable and HIGHLY TOXIC. [Org Synth Coll Vol I 46 1941].

Allyl disulfide (diallyl disulfide) [2179-57-9] M 146.3, b 58-59°/5mm, 79-81°/20mm, 138-139°/atm, d20 1.01, nD 1.541. Purified by fractional distillation until their molar refractivities are uniformly good agreement with the calculated values [J Am Chem Soc 69 1710 1947]. Also purified by gas chromatography [retention times: J Org Chem 24 175 1959; UV: J Chem Soc 395 1949].

RS-α-Allylglycine (2-aminopent-4-enolic acid). [7685-44-1] M 115.1, m 250-255°(dec), pKb1 9.6. Dissolve in absolute EtOH and ppe with pyridine, then recrystallise from aqueous EtOH [RF in BuOH:EtOH:H2O (4:4:1:1) 0.37]. The hydrobromide has m 136-140° (from EtOAc) and the phenylureido derivative has m 159-161°. [Monatsh Chem 89 377 1958].

1-N-Allyl-3-hydroxymorphinan [152-02-3] M 283.4, m 180-182°. Crystd from aqueous EtOH.

Allyl iodide (3-iodopropene) [556-56-9] M 167.7, b 103°, d12 1.848. Purified in a dark room by washing with aq Na2SO3 to remove free iodine, then drying with MgSO4 and distilling at 21 mm pressure, to give a very pale yellow liquid. (This material, dissolved in hexane, was stored in a light-tight container at -5° for up to three months before free iodine could be detected, by its colour in the soln) [Sibbett and Noyes J Am Chem Soc 75 761 1953].
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5-Allyl-5-isobutylbarbituric acid [77-26-9] M 224.3, m 139°, 139-140°, 140-142°, pK3 12.36. It can be recrystallised from H₂O or dilute EtOH, and sublimes at 100-120°/8-12mm. It is soluble in "C₆H₆, cyclohexane, tetralin and pet ether at 20°. [J Am Chem Soc 77 1486 1955.]

Allylisocyanate [1476-23-9] M 83.1, b 84°/atm, 87-89°/atm, d₄ 0.94, nD 1.417. Purify as for allylisothiocyanate.

Allylisothiocyanate [57-06-7] M 99.2, m -80°, b 84-85°/80mm, 150°/760mm, 151°/atm, d₄ 1.017, nD 1.5268. Fractionate using an efficient column, preferably in a vacuum. It is a yellow pungent irritating and TOXIC (suspected CARCINOGEN) liquid. Store in a sealed tube under N₂.

Allyl Phenyl sulfide [5296-64-0] M 150.2, b 59-60°/1.5mm, 79-80°/3mm, 114-114.3°/23.5mm, 225-226°/740mm, 215-218°/750mm, d₄ 1.0275, nD 1.5760. Dissolve in Et₂O, wash with alkali, H₂O, dry over CaCl₂, evaporate and fractionally distil, preferably under vacuum. It should not give a ppt with an alcoholic soln of Pb(OAc)₂. [J Am Chem Soc 52 3356 1930, 74 48 1952.]

N-Allylthiourea (thiosinamine) [109-57-9] M 116.2, m 70-73°, 78°. Recrystd from H₂O. Soluble in 30 parts of cold H₂O, soluble in EtOH but insoluble in "C₆H₆. Also recrystd from acetone, EtOH or ethyl acetate, after decolorising with charcoal. The white crystals have a bitter taste with a slight garlic odour and are TOXIC. [Anal Chem 21 421 1949.]

N-Allylurea [557-11-9] M 100.1, m 85°. Cryst from EtOH, EtOH/ether, EtOH/chloroform or EtOH/toluene.

Aloin [10-glucopyranosyl-1,8-dihydroxy-3-(hydroxymethyl)-9(1O-)anthracenone, Barbaloin] [8015-61-0] M 418.4, m 148-148.5°, 148-150°. Lemon yellow crystals from H₂O (450g/lSL) as the monohydrate which has a lower m (70-80°). [J Chem Soc 2573 1932, 3141 1956.]

D-Altrose [1990-29-0] M 180.2, m 103-105°, [α]25 46 +35° (c 7.6, H₂O). Cryst from aq EtOH.

Amberlite IRA-904 Anion exchange resin (Rohm and Haas) [9050-98-0]. Washed with 1M HCl, CH₃OH (1:10) and then rinsed successively for 24h in a Soxhlet apparatus with MeOH, "benzene and cyclohexane [Shue and Yan Anal Chem 53 2081 1981]. Strongly basic resin also used for base catalysis [Fieser & Fieser Reagents for Org Synth 1 1511, Wiley 1967].

Aminoacetaldehyde dimethyl acetal (2,2-dimethoxyethylamine) [22483-09-6] M 105.1, m <78°, b 139.5°/768mm, 137-139°/atm, d₄ 0.9676, nD 1.4144. Dry over KOH pellets and distil through a 30cm vac jacketed Vigreux column. [J Am Chem Soc 75 3398 1953, 77 6640 1955.]


Aminoacetic acid (Glycine) [56-40-6] M 75.1, m 262° (dec, goes brown at 226°, sublimes at 200°/0.1mm), pKₐ 2.35, pKₐ 9.78. Cryst from distilled water by dissolving at 90-95°, filtering, cooling to about -5°, and draining the crystals centrifugally. Alternatively, crystall from distilled water by addition of MeOH or EtOH (e.g. 50g dissolved in 100mL of warm water, and 400mL of MeOH added). The crystals can be washed with MeOH or EtOH, then with diethyl ether. Likely impurities are ammonium glycinate, iminodiacetic acid, nitrilotriacetic acid, ammonium chloride.

Aminoacetonitrile bisulfate [151-63-3] M 154.1, m 188°(dec) Cryst from aqueous EtOH.

Aminoacetonitrile hydrochloride [6011-14-9] M 92.5, m 166-167°, 172-174°, pKₐ 5.34. Recrystd from dil EtOH hygroscopic leaflets. Best to crystallise from absolute EtOH-E₂O (1:1) and then recryst from absolute EtOH. The m recorded range from 144° to 174°. The free base has b 58°/15mm with
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p-Aminoacetophenone [99-92-3] M 135.2, m 104-106°, 105-107°, b 293°/atm, pK25 2.19 Recryst from CHCl3, *C6H6 or H2O. Soluble in hot H2O. UV (EtOH) has lmax 403nm (log ε 4.42) [J Am Chem Soc 75 2720 1953]. [Anal Chem 26 726 1954.] The 2,4-dinitrophenylhydrazone has m 266-267° (from CHCl3 or EtOH), and the semicarbazone has m 193-194°(dec)(from MeOH) and the hydrochloride has m 98°(dec)(from H2O).

α-Amino acids see Chapter 6.

9-Aminoacridine [9-acridineamine] [90-45-9] M 194.2, m 241°, pK20 9.95. Crystd from EtOH or acetone and sublimes at 170-180°/0.04mm [Albert and Ritchie Org Synth Coll Vol III 53 1955; for hydrochloride see Chapter 6.]


2-Amino-4-anilinos-triazine [537-17-7] M 168.2, m 235-236°, pKEst ~5.5. Crystd from dioxane or 50% aqueous EtOH.


p-Aminobenzene (p-phenylazobenzene) [60-09-3] M 197.2, m 126°, pK25 ~2.82. Crystd from EtOH, CCl4, pet ether/*benzene, or a MeOH/water mixture.

o-Aminobenzoxotoluene (Fast Garnet GBC base, 4'-amino-2,3'dimethylazobenzene) [97-56-3] M 225.3, m 101.4-102.6°, CI 11160, pKEst ~2.8. Crystd twice from EtOH, once from *benzene, then dried in an Abderhalden drying apparatus [Cilento J Am Chem Soc 74 968 1952]. CARCINOGENIC.


4-Aminobenzamide hydrochloride [59855-11-7] M 199.6, m 284-285°, pKEst ~1.7. Recrystd from EtOH.

p-Aminobenzeneazodimethylaniline [539-17-3] M 240.3, m 182-183°. Crystd from aqueous EtOH.

o-Aminobenzoic acid (anthranilic acid) [118-92-3] M 137.1, m 145°, pK125 2.94, pK225 4.72. Crystd from water (charcoal). Has also been crystd from 50% aqueous acetic acid. Can be vacuum sublimed.
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m-Aminobenzoic acid [99-05-8] M 137.1, m 174°, pK\textsubscript{1} 25 3.29, pK\textsubscript{2} 25 5.10. Crystd from water.

p-Aminobenzoic acid [150-13-0] M 137.1, m 187-188°, pK\textsubscript{1} 25 2.45, pK\textsubscript{2} 25 4.85. Purified by dissolving in 4-5% aqueous HCl at 50-60°, decolorising with charcoal and carefully precipitating with 30% Na\textsubscript{2}CO\textsubscript{3} to pH 3.5-4 in the presence of ascorbic acid. It can be crystd from water, EtOH or EtOH/water mixtures.


4-Aminobenzophenone [I 137-41-3] M 197.2, m 123-124°, pK 25 2.17. Dissolved in aq acetic acid, filtered and ppted with ammonia. Process repeated several times, then recrystd from aqueous EtOH.


6-Aminobenzothiazole [533-30-2] M 150.2, m 87°, pK\textsubscript{est} 3. Crystd from aqueous EtOH.

N-(p-Aminobenzoyl)-L-glutamic acid [4271-30-1] M 266.3, m 173° (L-form), [a]\textsubscript{D} 546 -17.5° (c 2, 0.1m HCl); 197° (DL), pK\textsubscript{Ehm}(1) 1.7, pK\textsubscript{Ehm}(2) 3.4, pK\textsubscript{Ehm}(3) 4.3. Crystd from H\textsubscript{2}O.

3-o-Aminobenzyl-4-methylthiazolium chloride hydrochloride [534-94-1] M 277.4, m 213°(dec). Crystd from aqueous EtOH.

4-Amino-1-benzylpiperidine [50541-93-0] M 190.3, b -180°/20mm, d 0.933, n\textsubscript{D} 1.543, pK\textsubscript{est}(1) 8.3 pK\textsubscript{est}(2) 10.4. Purified by distn in vacuo, and stored under N\textsubscript{2} because it absorbs CO\textsubscript{2}. The dihydrochloride salt [1205-72-7] has m 270-273° (255°) after recrystn from MeOH + EtOAc or EtOH. [J Chem Soc 3165, 3172 1957.] The 4-methyllumino-1-benzylpiperidine derivative has m 168-172°/17mm, n 1.5367 [J Am Chem Soc 70 4009 1948]. The 1-(1-benzyl-4-piperidinyl)-3-cyano-2-methylisothiourea derivative has m 160° from CHCl\textsubscript{3}/Et\textsubscript{2}O [Prepn, IR, NMR: Ried et al. Chem Ber 116 1547 1983].

o-Aminobiphenyl [90-41-5] M 169.2, m 49.0°, pK\textsubscript{1} 3.83. Crystd from aqueous EtOH (charcoal).

p-Aminobiphenyl [92-67-1] M 169.2, m 53°, b 191°/16mm, pK\textsubscript{1} 4.38. Crystd from water or EtOH. CARCINOGENIC.

2-Amino-5-bromotoluene [583-75-5] M 186.1, m 59°, pK\textsubscript{25} 3.58. Steam distd, and crystd from EtOH.

RS-2-Aminobutyric acid [2835-81-6] M 103.1, m 303°(dec), pK\textsubscript{1} 25 2.29, pK\textsubscript{2} 25 9.83. Crystd from water.

S-2-Aminobutyric acid [1492-24-6] M 103.1, m 292°(dec), [a]\textsubscript{D} 20.4° (c 2, 2.5N HCl). Crystd from aqueous EtOH.

3-Aminobutyric acid [2835-82-7] M 103.1, m 193-194°, pK\textsubscript{Ehm}(1) 3.5, pK\textsubscript{Ehm}(2) 10.3. Crystd form aqueous EtOH or MeOH + Et\textsubscript{2}O.

4-Aminobutyric acid (GABA) [56-12-2] M 103.1, m 202°(dec), pK\textsubscript{1} 25 4.14, pK\textsubscript{2} 10 5.5. Crystd form aqueous EtOH or MeOH + Et\textsubscript{2}O.

2-Amino-5-chlorobenzoic acid [635-21-1] M 171.6, m 100°, pK\textsubscript{1} 25 1.69, pK\textsubscript{2} 25 4.35. Crystd from water, EtOH or chloroform.
3-Amino-4-chlorobenzoic acid [2840-28-0] M 171.6, m 216-217°, pK_{Est(1)} -2.7, pK_{Est(2)} -2.9. Crystd from water.


2-Amino-4-chloro-6-methylpyrimidine [5600-21-5] M 143.6, m 184-186°, pK_{Est} -1.0. Crystd from EtOH.

2-Amino-5-chloropyridine [1072-98-6] M 128.6, m 135-136°, pK 4.38. Crystd from pet ether, sublimes at 50°/0.5mm.

1-Amino-1-cyclopentanecarboxylic acid (cycloleucine) [52-52-8] M 129.2, m 330°(dec), pK_{Est(1)} -2.5 pK_{Est(2)} -10.3. Crystd from aq EtOH.

2-Amino-3,5-dibromopyridine [35486-42-1] M 251.9, m 103-104°, pK_{Est} -2.4. Steam distd and crystd from aqueous EtOH or pet ether.


3-Amino-2,6-dichloropyridine [62476-56-6] M 164.0, m 119°, b 110°/0.3mm, pK_{Est} -2.0. Crystd from water.


4-Amino-3,5-diiodobenzoic acid [2122-61-4] M 388.9, m >350°, pK_{Est(1)} 0.4, pK_{Est(2)} -1.6. Purified by soln in dilute NaOH and pptn with dilute HCl. Air dried.

2-Amino-4,6-dimethylpyridine [5407-87-4] M 122.2, m 69-70.5°, pK 7.84. Crystd from hexane, ether/pet ether or *benzene. Residual *benzene was removed over paraffin-wax chips in an evacuated desiccator.


2-Aminodiphenylamine [534-85-0] M 184.2, m 79-80°, pK_{Est(1)} -3.8 (NH₂), pK_{Est(2)} <0. Cryst from H₂O.

2-Aminodiphenylamine [101-54-2] M 184.2, b 155°/0.26mm, pK 5.20. Crystn from EtOH gives m 66°, and crystn from ligrois gives m 75°.

2-Amino-1,2-diphenylethanol [530-36-9] M 213.3, m 165°, pK_{Est(1)} -7.5. Crystd from EtOH.

2-Aminodiphenylmethane [28059-64-5] M 183.3, m 52°, b 172°/12mm and 190°/22mm, pK_{Est(1)} -4.2. Crystd from ether.

2-Aminooethanethiol see cysteamine in Chapter 6.

2-Aminooethanol (ethanolamine) [141-43-5] M 61.1, f 10.5°, b 72-73°/12 mm, 171.1°/760mm, d 1.012, n 1.14539, pK 9.51. Decomposes slightly when distd at atmospheric pressure, with the formation of conducting impurities. Fractional distn at about 12mm pressure is satisfactory. After distn, 2-aminooethanol was further purified by repeated washing with ether and crystn from EtOH (at low temperature). After fractional distn in the absence of CO₂, it was twice crystd by cooling, followed by distn.
Hygroscopic. [Reitmeier, Silvertz and Tartar J Am Chem Soc 62 1943 1940.] It can be dried by azeotropic distn with dry benzene.

2-Aminoethanol hydrochloride [2002-24-6] M 97.6, m 75-77°. Crystd from EtOH. It is deliquescent.


S-(2-Aminoethyl)isothiouronium bromide hydrobromide [56-10-0] M 281.0, m 194-195°. Crystd from absolute EtOH/ethyl acetate. It is hygroscopic.

(2-Aminoethyl)trimethylammonium chloride hydrochloride (chloramine chloride hydrochloride) [3399-67-5] M 175.1, m 260°(dec). Crystd from EtOH. (Material is very soluble in H2O).

2-Aminofluorene [153-78-6] M 181.2, m 127.8-128.8°, 132-133°, pK<sub>2</sub> 4.64. Wash well with H2O and recrystd from EtOH or 50% aqueous EtOH (25g with 400mL), and dry in a vacuum. Store in the dark. [Org Synth Coll Vol II 447 1943; Coll Vol V 30 1973].

4-Amino hippuric acid [61-78-9] M 194.2, m 198-199°, pK<sub>Est(1)</sub> 1.7(NH<sub>2</sub>), pK<sub>Est(2)</sub> ~3.4(CO<sub>2</sub>H). Crystd from H2O.

4-Amino-3-hydrazino-5-mercapto-1,2,4-triazole (Purpald) [116-85-8] M 119.1, m 225°(dec), pK<sub>1</sub> 3.80 (CO<sub>2</sub>H), pK<sub>2</sub> -9.3. Crystd from H2O or aqueous EtOH.

5-Amino-8-hydroxyquinoline hydrochloride [3881-33-2] M 196.7, pK<sub>1</sub> 5.67, pK<sub>2</sub> 11.24. Dissolved in minimum of MeOH, then Et<sub>2</sub>O was added to initiate pptn. Ppte was filtered off and dried [Lovell et al. J Phys Chem 88 1885 1984].

6-Amino-3-hydroxytoluene [95-84-1] M 123.2, m 137-138°, pK<sub>Est(1)</sub> 4.7(NH<sub>2</sub>), pK<sub>Est(2)</sub> 9.6(OH). Crystd from H2O or toluene.

4-Aminoimidazole-5-carboxamide hydrochloride (AICAR HCl) [72-40-2] M 162.6, m 255-256°(dec), pK<sub>Est(1)</sub> 3.5, pK<sub>Est(2)</sub> 9.4. Recrystd from EtOH.

5-Aminoisindane [24425-40-9] M 133.2, m 37-38°, b 131°/15mm, 146-147°/25mm, 247-249°/745mm, pK<sub>1</sub> 5.31. Distd and then crystd from pet ether.

2-Amino-5-iodotoluene [13194-68-8] M 233.0, m 87°, pKEm -3.6. Crystd from 50% EtOH.


RS- p-Aminoisobutyric acid (α-methyl-P-alanine) [10569-72-9] M 103.1, m 176-178°, 178-180°, 181-182°, R (-)- isomer [144-90-11 m 183°, [α]D +210 (c 0.43, H2O), pKEst(1) - 3.7, pKEst(2) - 10.2. Colorless prisms from hot H2O, were powdered and dried in vacuo.

The purity is checked by paper chromatography (Whatman 1) using ninhydrin spray to visualise the amino acid; RF values in 95% MeOH and n-PrOH 5N HCOOH (8:2) are 0.36 and 0.50 respectively. [Kupiecki and Coon Biochem Prep 7 20 1960; Pollack J Am Chem Soc 65 1335 1943. The R-enantiomer, isolated from iris bulbs or human urine was crystd from H2O and sublimed in vacuo [Asen et al. J Biol Chem 234 343 1959].

5-Aminolaevulinic acid hydrochloride [5451-09-2] M 167.6, m 156-158°(dec), pK2 4.05, pK8 8.90. Dried in a vacuum desiccator over P2O5 overnight then crystd by dissolving in cold EtOH and adding dry Et2O.

Aminomalononitrile toluene-4-sulfonate [5098-14-6] M 253.4, m 168-170°, 172°(dec), pKEm ~ 1.3. Colourless crystals on recryst from MeCN (1.8g in 100mL) using activated charcoal. Wash the crystals with dry Et2O and dry at 110/1 mm. Recovery of ~80%. [Ferris et al. Org Synth Coll Vol V 32 1973.]

3-Amino-5-mercapto-1,2,4-triazole [I 6691 -43-3] M 116.1, m 298°, pKEm(1) - 3.0, pKEm(2) - 9. Recrystd from H2O and dried in vacuo. The acetyl derivative has m 325° (dec) after recrystn from H2O. [Beilage 26, 3rd/4th Suppl p. 1351. Also recrystd from EtOH/H2O (3:1, lg in 50 mL, 50% recovery), m 300-302° dec subject to heating rate (λmax 265nm, log ε 4.12), and S-Benzyl derivative when crystd from *C6H&tOH (20: l), or CHCl3Et2O has m 109-110° [Godfrey and Kruzer J Chem Soc 3437 1960].

4-Aminomethylbenzenesulfonamide [90-52-8] M 260.8, NH2), pK8 10.23 (SONH2). Crystd from dilute HCl and dried in a vacuum at 100°. Purified by TLC on silica gel plates using toluene/acetone (3:1) as eluent. The main band was scraped off and extracted with MeOH. The solvent was evaporated and the residue dried in a drying pistol [Land, McAlpine, Sinclair and Truscott J Chem Soc, Faraday Trans I 72 2091 1976].

5-2-Amino-3-methyl-1-butanol (S-valinol) [2026-48-4] M 103.2, m 31-32°, b 88°/11mm, d 0.92, [α]D +16.5° (c 6.32, l = 2 H2O), [α]D + 15.6° (EtOH), pKEm ~ 10.4. Purified by vacuum distn using short Vigreux column. Alternatively it is purified by steam distn. The steam distillate is acidified with HCl, the aq layer is collected and evapd. The residue is dissolved in butan-1-ol, filtered and dry Et2O added to cryst the hydrochloride salt (hygroscopic), m 113°. The free base can be obtained by suspending the salt in Et2O adding small vols of satd K2CO3 until effervescence is complete and the mixture is distinctly alkaline. At this stage the aqueous layer should appear as a white sludge. The mixture is heated to boiling and refluxed for 30 min (more Et2O is added if necessary). The Et2O is decanted off from the white sludge, the
sludge is extracted twice with Et_2O (by boiling for a few minutes), the combined organic layers are dried (KOH pellets), evapd and the residue distd in a vacuum.

7-Amino-4-methylcoumarin \([26093-31-2]\) M 175.2, m 221-442\(^\circ\) (dec), \(pK_{\text{Est}} \sim 3.2\). Dissolved in 5% HCl, filtered and basified with 2M ammonia. The ppte is dried in a vacuum, and crystd from dilute EtOH. It yields a blue soln and is light sensitive.

4-Amino-2-methyl-1-naphthol hydrochloride \([130-24-5]\) M 209.6, m 283\(^\circ\) (dec), \(pK_{\text{Est(1)}} \sim 5.6\) (NH_2), \(pK_{\text{Est(2)}} \sim 10.4\) (OH). Crystd from dilute HCl.

2-Amino-2-methyl-1,3-propanediol \([115-69-5]\) M 105.1, m 111\(^\circ\), b 151-152\(^\circ\)/10mm, \(pK_{2}^{25} 8.80\). Crystd three times from MeOH, dried in a stream of dry N_2 at room temp, then in a vacuum oven at 55\(^\circ\). Stored over CaCl_2 [Hetzer and Bates \textit{J Phys Chem} 66 308 1962].

2-Amino-2-methyl-1-propanol (β-aminoisobutanol) \([124-68-5]\) M 99.4, m 24\(^\circ\), 31\(^\circ\), b 67\(^\circ\)/10mm, 164-166\(^\circ\)/760mm, d 0.935, n 1.45, \(pK_{2}^{25} 9.71\). Purified by distn and fractional freezing. The hydrochloride has m 204\(^\circ/-206\(^\circ\).

2-Amino-3-methylpyridine \([1603-40-3]\) M 108.1, m 33.2\(^\circ\), b 221-222\(^\circ\), \(pK_{2}^{25} 7.24\). Crystd three times from *benzene, most of the residual *benzene being removed from the crystals over paraffin wax chips in an evacuated desiccator. The amine, transferred to a separating funnel under N_2, was left in contact with NaOH pellets for 3h with occasional shaking. It was then placed in a vacuum distilling flask where it was refluxed gently in a stream of dry N_2 before being fractionally distd [Mod, Magne and Skau \textit{J Phys Chem} 60 1651 1956].

2-Amino-4-methylpyridine \([695-34-1]\) M 108.1, m 99.2\(^\circ\), b 230\(^\circ\), \(pK_{2}^{25} 7.48\). Crystd from EtOH or a 2:1 *benzene/acetone mixture, and dried under vacuum.

2-Amino-5-methylpyridine \([1603-41-4]\) M 108.1, m 76.5\(^\circ\), b 227\(^\circ\), \(pK_{2}^{25} 7.22\). Crystd from acetone.

2-Amino-6-methylpyridine \([1824-81-3]\) M 108.1, m 44.2\(^\circ\), b 208-209\(^\circ\), \(pK_{2}^{25} 7.41\). Crystd three times from acetone, dried under vacuum at ca 45\(^\circ\). After leaving in contact with NaOH pellets for 3h, with occasional shaking, it was decanted and fractionally distd [Mod, Magne and Skau \textit{J Phys Chem} 60 1651 1956]. Also recrystd from CH_2Cl_2 by addition of pet ether. [Marzilli et al. \textit{J Am Chem Soc} 108 4830 1986.]

2-Amino-5-methylpyrimidine \([50840-23-8]\) M 109.1, m 193.5\(^\circ\), \(pK_{\text{Est}} \sim 4.0\). Crystd from water and *benzene. Sublimes at 50\(^\circ\)/0.5mm.

4-Amino-2-methylquinoline \([6628-04-2]\) M 158.2, m 168\(^\circ\), b 333\(^\circ\)/760mm, \(pK_{2}^{26} 9.42\). Crystd from *benzene/pet ether.

2-Aminonaphthalene (6-naphthylamine) \([91-59-8]\) M 143.2, m 111-113\(^\circ\), \(pK_{2}^{25} 4.20\). See entry on p. 306.

3-Amino-2-naphthoic acid \([5959-52-4]\) M 187.2, m 214\(^\circ\) (dec), \(pK_{\text{Est(1)}} \sim 1.5\) \(pK_{\text{Est(2)}} \sim 4.0\). Crystd from aqueous EtOH.

4-Amino-5-naphthol-2,7-disulfonic acid \([90-20-0]\) M 320.3, \(pK_{2}^{25} 3.63\), \(pK_{2}^{25} 8.83\). Sufficient Na_2CO_3 (ca 22g) to make the soln slightly alkaline to litmus was added to a soln of 100g of the dry acid in 750mL of hot distd water, followed by 5g of activated charcoal and 5g of Celite. The suspension was stirred for 10min and filtered by suction. The acid was ppted by adding ca 40mL of conc HCl (soln blue to Congo Red), then filtered by suction through sharkskin filter circular sheet (or hardened filter paper) and washed with 100mL of distd water. The purification process was repeated. The acid was dried overnight in an oven at 60\(^\circ\) and stored in a dark bottle [Post and Moore \textit{Anal Chem} 31 1872 1959].

1-Amino-2-naphthol-4-sulfonic acid [116-63-2] M 239.3, m 295°(dec), pK_{Est(1)}^-<0, pK_{Est(2)}^-2.8 (NH_2), pK_{Est(2)}^-8.8. Purified by warming 15g of the acid, 150g of NaHSO_3 and 5g of Na_2SO_3 (anhydrous) with 1L of water to ca 90°, shaking until most of the solid had dissolved, then filtering hot. The precipitate obtained by adding 10mL of conc HCl to the cooled filtrate was collected, washed with 95% EtOH until the washings were colourless, and dried under vacuum over CaCl_2. It was stored in a dark coloured bottle, in the cold [Chanley, Gindler and Sobotka J Am Chem Soc 74 4347 1952].

6-Aminonicotinic acid [3167-49-5] M 138.1, m 312°(dec), pK_{Est(1)}^-2.2 (CO_2H), pK_{Est(2)}^-6.5. Crystd from aq acetic acid.

2-Amino-4-nitrobenzoic acid [619-17-0] M 182.1, m 269°(dec), pK_{i}^-0.65, pK_{f}^-3.7. Crystd from water or aq EtOH.

5-Amino-2-nitrobenzoic acid [13280-60-9] M 182.1, m 235°(dec), pK_{Est(1)}^-1.1, pK_{Est(2)}^-1.2. Crystd from water.

1-Amino-4-nitronaphthalene [776-34-1] M 188.2, m 195°, pK_{20}^-0.54. Crystd from EtOH or ethyl acetate.

2-Amino-4-nitrophenol [99-57-0] M 154.1, m 80-90° (hydrate), 142-143° (anhydrr), pK_{Est(1)}^-3.9 (NH_2), pK_{Est(2)}^-9.2. Crystd from water.

2-Amino-5-nitrophenol [121-88-0] M 154.1, m 207-208°, pK_{Est(1)}^-3.8, pK_{Est(2)}^-9.3. Crystd from water.

6-Aminopenicillanic acid [551-16-6] M 216.2, m 208-209°, [α]_{546}^{20} +327° (in 0.1M HCl), pK_{i}^-2.30, pK_{f}^-4.90. Crystd from water.

2-Aminoperimidine hydrobromide [40835-96-9] M 264.1, m 299°, pK_{Est}^-7.9 (free base). Purified by boiling a saturated aqueous soln with charcoal, filtering and leaving the salt to crystallise. Stored in a cool, dark place.

2-Aminophenol [95-55-6] M 109.1, m 175-176°, pK_{i}^-4.65, pK_{f}^-9.75. Purified by soln in hot water, decolorised with activated charcoal, filtered and cooled to induce crystn. Maintain an atmosphere of N_2 over the hot phenol soln to prevent its oxidation [Charles and Freiser J Am Chem Soc 74 1385 1952]. Can also be crystd from EtOH.


4-Aminophenol [123-30-8] M 109.1, m 190° (under N_2), pK_{i}^-5.38, pK_{f}^-10.4. Crystd from EtOH, then water, excluding oxygen. Can be sublimed at 110°/0.3mm. Has been purified by chromatography on alumina with a 1:4 (v/v) mixture of absolute EtOH/benzene as eluent.

4-Aminophenol hydrochloride [51-78-5] M 145.6, m 306°(dec). Purified by treating an aqueous soln with saturated Na_2S_2O_3, filtering under an inert atmosphere, then recrystd from 50% EtOH twice and once from absolute EtOH [Livingston and Ke J Am Chem Soc 72 909 1950].

4-Aminophenylacetic acid [1197-55-3] M 151.2, m 199-200°(dec), pK_{i}^-3.60, pK_{f}^-5.26. Crystd from hot water (60-70mL/g).

S-(−)-2-Amino-3-phenyl-1-propanol (L-phenylalaninol) [3182-95-4] M 151.2, m 95°. See phenylalaninol on p. 327.

N-Aminophthalimide [1875-48-5] M 162.2, m 200-202°, pK_{Et} = 0. It has been recrystd from 96% EtOH (sol ~2% at boiling temperature) to form a yellow solution. It sublimes in vacuo at ca 150°. Resolidifies after melting, and remelts at 338-341°.

4-Aminopropiophenone [70-69-9] M 163.1, m 140°, pK_{Et} = 2.2. Crystd from water or EtOH.


1-Aminopyrene [1606-67-3] M 217.3, m 117-118°, pK_{1} = 2.91 (50% aq EtOH), pK_{2} = 2.77 (50% aq EtOH). Crystd from hexane.

2-Aminopyridine [504-29-0] M 94.1, m 58°, b 204-210°, pK_{1} = 7.6, pK_{2} = 6.71. Crystd from benzene/pet ether (b 40-60°) or CHCl₃/pet ether.

3-Aminopyridine [504-24-5] M 94.1, m 64°, b 248°, pK_{1} = 1.5, pK_{2} = 6.03. Crystd from benzene, CHCl₃/pet ether (b 60-70°), or benzene/pet ether (4:1).

4-Aminopyridine [591-54-8] M 95.1, m 160°, b 180°/12-13mm, pK_{1} = 5.65, pK_{2} = 9.11 (9.18). Crystd from benzene/EtOH, then recrystd twice from water, crushed and dried for 4h at 105° [Bates and Hetzer J Res Nat Bur Stand 64A 427 1960]. Has also been crystd from EtOH, benzene, benzene/pet ether, toluene and sublimes in vacuum.

2-Aminopyrimidine [109-12-6] M 95.1, m 126-127.5°, pK = 3.45. Crystd from C₆H₆, EtOH or H₂O.

4-Aminopyrimidine [591-54-8] M 95.1, m 149-151°, 154-156°, pK = 5.69. Recryst 10.6g from hot EtOAc (200mL). 7.4g colorless needles, first crop, evap to 25mL gave 1.7g of second crop. The Hydroiodide has m 180°. Picrate has m 225°. [Brown J Soc Chem Ind (London) 69 353 1950.]

5-Aminopyrimidine [591-55-9] M 95.1, m 171-172° (with sublimation), pK = 2.52. Purified by conversion to the MgCl₂ complex in a small vol of H₂O. The complex (~ 5g) is dissolved in the minimum vol of hot H₂O, passed through a column of activated AI₂O₃ (200g) and the column washed with EtOH. Evapn of the EtOH gives a colorless residue of the aminopyrimidine which is recrystd from C₆H₆ (toluene could also be used) which forms needles at first then prisms. It melts with sublimation. Acetylation yields 5-acetamidopyrimidine which crysts from C₆H₆, m 148-149°. [Whittaker J Chem Soc 1565 1951.]

Aminopyrine (4-dimethylaminoantipyrene) [58-15-1] M 231.3, m 107-109°, pK_{1} = 2.22, pK_{2} = 4.94. Crystd from pet ether.


5-Aminoquinoline [611-34-7] M 144.2, m 110°, b 184°/10mm, 310°/760mm, pK_{1} = 0.97, pK_{2} = 5.42. Crystd from pentane, then from benzene or EtOH.
6-Aminoquinoline \([580-15-4]\) M 144.2, m 117-119\(^\circ\), \(pK_{1}^{a} 1.63, pK_{2}^{a} 5.59\). Purified by column chromatography on a SiO\(_2\) column using CHCl\(_3\)/MeOH (4:1) as eluent. It is an irritant.

8-Aminoquinoline \([578-66-5]\) M 144.2, m 70\(^\circ\), \(pK_{1}^{a} 5.95\). Crystd from EtOH or ligroin.

4-Aminosalicylic acid \([65-49-6]\) M 153.1, m 150-151\(^\circ\)(dec), \(pK_{1}^{a} 1.78\) (CO\(_2\)H), \(pK_{2}^{a} 3.63\) (NH\(_2\)), \(pK^{b} 13.74\) (OH). Cryst from EtOH.

5-Aminosalicylic acid (5-amino-2-hydroxybenzoic acid) \([89-57-6]\) M 153.1, m 276-280\(^\circ\), 283\(^\circ\)(dec), \(pK_{1}^{a} 2.74\) (CO\(_2\)H), \(pK_{2}^{a} 5.84\) (NH\(_2\)). Cryst as needles from H\(_2\)O containing a little NaHSO\(_3\) to avoid aerial oxidation to the quinone-imine. The Me ester gives needles from C\(_6\)H\(_6\), m 96\(^\circ\), and the hydrazide has m 180-182\(^\circ\)(From H\(_2\)O). [Fallab et al. Helv Chim Acta 34 26 1951, Shave1 J Amer Pharm Assoc 42 402 1953.]

2-Amino-5-sulfanilylthiazole \([473-30-3]\) M 238.3, m 219-221\(^\circ\)(dec), \(pK_{1}^{a} -4.5\) (OH). Crystd from EtOH.

4-Amino-2-sulfobenzoic acid \([527-76-4]\) M 217.1. Crystd from water.

2-Aminothiazole \([96-50-4]\) M 108.1, m 93\(^\circ\), b 140\(^{\circ}\)/11mm, \(pK_{1}^{a} 5.36\). Cryst from pet ether (b 100-120\(^\circ\)), or EtOH.

1-Amino-1,2,4-triazole \([24994-60-3]\) M 84.1, m 91-93\(^\circ\), \(pK_{1}^{a} -2\). Crystd from water. [Barszcz et al. J Chem Soc, Dalton Trans 2025 1986.]

3-Amino-1,2,4-triazole \([61-82-5]\) M 84.1, m 159\(^\circ\), \(pK_{1}^{a} 4.04, pK_{2}^{a} 11.08\). Crystd from EtOH (charcoal), then three times from dioxane [Williams, McEwan and Henry J Phys Chem 61 261 1957].

4-Amino-1,2,4-triazole \([584-13-4]\) M 84.1, m 80-81\(^\circ\), \(pK 3.23\). Cryst from water. [Barszcz et al. J Chem Soc, Dalton Trans 2025 1986.]

7-Amino-4-(trifluoromethyl)coumarin, \([53518-15-3]\) M 229.1, m 222\(^\circ\), \(pK_{1}^{a} -3.1\). Purified by column chromatography on a C\(_18\) column, eluted with acetonitrile/0.01M aq HCl (1:1), and crystd from isopropanol. Alternatively, it is eluted from a silica gel column with CH\(_2\)Cl\(_2\), or by extracting a CH\(_2\)Cl\(_2\) solution (4gL) with 1M aq NaOH (3 x 0.1L), followed by drying (MgSO\(_4\)), filtration and evaporation. [Bissell J Org Chem 45 2283 1980.]

9-Aminotriptycene \([793-41-9]\) M 269.3, m 223.5-224.5\(^\circ\). Recrystd from ligroin [Imashiro et al. J Am Chem Soc 109 729 1987].

5-Amino-n-valeric acid (5-aminopentanoic acid) \([660-88-8]\) M 117.2, m 157-158\(^\circ\), \(pK_{1}^{a} 4.25, pK_{2}^{a} 10.66\). Crystd by dissolving in H\(_2\)O and adding EtOH.

5-Amino-n-valeric acid hydrochloride \([627-95-2]\) M 153.6, m 103-104\(^\circ\). Crystd from CHCl\(_3\).

Amodiaquin \([4-(3-dimethylaminomethyl-4-hydroxyanilino)-7-chloroquinoline]\) \([86-42-0]\) M 287.5, m 208\(^\circ\). Crystd from 2-ethoxyethanol.

D-Amygdalin \([29883-15-6]\) M 457.4, m 214-216\(^\circ\), [\(\alpha\)]\(_D^{22}\) -38\(^\circ\) (c 1.2, H\(_2\)O). Crystd from water.

\(n\)-Amyl acetate \([628-63-7]\) M 130.2, b 149.2\(^\circ\), d 0.876, n 1.40228. Shaken with saturated NaHCO\(_3\) soln until neutral, washed with water, dried with MgSO\(_4\) and distd.

\(n\)-Amyl alcohol (1-pentanol) \([71-41-0]\) M 88.2, b 138.1\(^\circ\), d\(_{15}\) 0.818, n 1.4100. Dried with anhydrous K\(_2\)CO\(_3\) or CaSO\(_4\), filtered and fractionally distd. Has also been treated with 1-2% of sodium and
heated at reflux for 15h to remove water and chlorides. Traces of water can be removed from the near-dry alcohol by refluxing with a small amount of sodium in the presence of 2-3% n-amyl phthalate or succinate followed by distn (see ethanol).

Small amounts of amyl alcohol have been purified by esterifying with p-hydroxybenzoic acid, recrystallising the ester from CS₂, saponifying with ethanolic-KOH, drying with CaSO₄ and fractionally distilling [Olivier Recr Trav Chim Pays-Bas 55 1027 1936].

tert-Amyl alcohol [75-85-4] M 88.2, b 102.3°, d₁⁵ 0.8135, n 1.4058. Refluxed with anhydrous K₂CO₃, CaH₂, CaO or sodium, then fractionally distd. Near-dry alcohol can be further dried by refluxing with magnesium activated with iodine, as described for ethanol. Further purification is possible using fractional crystall, zone refining or preparative gas chromatography.


n-Amyl bromide (n-pentylbromide) [110-53-2] M 151.1, b 129.7°, d 1.218, n 1.445. Washed with conc H₂SO₄, then water, 10% Na₂CO₃ soln, again with water, dried with CaCl₂ or K₂CO₃, and fractionally distd just before use.

n-Amyl chloride [543-59-9] M 106.6, b 107.8°, d 0.882, n 1.41177. Same as sec-amyl chloride.

sec-Amyl chloride (1-chloro-2-methylbutane) [616-13-7] M 106.6, b 96-97°. Purified by stirring vigorously with 95% H₂SO₄, replacing the acid when it became coloured, until the layer remained colourless after 12h stirring. The amyl chloride was then washed with satd Na₂CO₃ soln, then distd water, and dried with anhydrous MgSO₄, followed by filtration, and distn through a 10-in Vigreux column. Alternatively a stream of oxygen containing 5% ozone was passed through the amyl chloride for three times as long as it took to cause the first coloration of starch iodide paper by the exit gas. Washing the liquid with NaHCO₃ hydrolyzed ozonides and removed organic acids prior to drying and fractional distn [Chien and Willard J Am Chem Soc 75 6160 1953].

tert-Amyl chloride [594-36-5] M 106.6, b 86°, d 0.866. Methods of purification commonly used for other alkyl chlorides lead to decomposition. Unsatd materials were removed by chlorination with a small amount of chlorine in bright light, followed by distn [Chien and Willard J Am Chem Soc 75 6160 1953].

Amyl ether [693-65-2] M 158.3, b 186.8°, d 0.785, n 1.41195. Repeatedly refluxed over sodium and distd.

p-tert-Amylphenol [80-46-6] M 146.3, m 93.5-94.2°, pKₑₑₐₚₐ₁₀-2. Purified via its benzoate, as for phenol. After evaporating the solvent from its soln in ether, the material was crystd (from the melt) to constant melting point [Berliner, Berliner and Nelidow J Am Chem Soc 76 507 1954].

2-n-Amylpyridine [2294-76-0] M 149.2, b 63.0°/2mm, n²⁶ 1.4861, pK₂⁵ 6.00. Dried with NaOH for several days, then distd from CaO under reduced pressure, taking the middle fraction and redistilling it.

4-n-Amylpyridine [2961-50-4] M 149.2, b 78.0°/2.5mm, n 1.4908, pKₑₑₐₚₐ-6.1. Dried with NaOH for several days, then distd from CaO under reduced pressure, taking the middle fraction and redistilling it.

α-Amyrin [638-95-9] M 426.7, m 186°. Crystd from EtOH.

β-Amyrin [508-04-3] M 426.7, m 197-197.5°. Crystd from pet ether or EtOH.

Androstane [24887-75-0] M 260.5, m 50-50.5°. Crystd from acetone/MeOH.

epi-Androsterone [481-29-8] M 290.4, m 172-173°, [α]₅₄₆ +115° (c 1, MeOH). Crystd from aq EtOH.
cis-Androsterone [53-41-8] M 290.4, m 185-185.5°. Crystd from acetone/Et₂O.

Angelic acid [565-63-9] M 100.1, m 45°, pK \(18 \cdot 4.29\). Steam distd, then crystd from H₂O.

Aniline [62-53-3] M 93.1, f -6.0°, b 68.3/10mm, 184.4°/760mm, d 1.0220, n 1.585, n² 1.5832, pK² 4.60. Aniline is hygroscopic. It can be dried with KOH or CaH₂, and distd at reduced pressure. Treatment with stannous chloride removes sulfur-containing impurities, reducing the tendency to become coloured by aerial oxidn. Can be crystd from Et₂O at low temps. More extensive purifications involve preparation of derivatives, such as the double salt of aniline hydrochloride and cuprous chloride or zinc chloride, or N-acetylaniline (m 114°) which can be recrystd from water.

Recrystd aniline was dropped slowly into an aqueous soln of recrystd oxalic acid. Aniline oxalate was filtered off, washed several times with water and recrystd three times from 95% EtOH. Treatment with satd Na₂CO₃ soln, regenerated aniline which was distd from the soln, dried and redistd under reduced pressure [Knowles Ind Eng Chem 12 881 1920].

After refluxing with 10% acetone for 10h, aniline was acidified with HCl (Congo Red as indicator) and extracted with Et₂O until colourless. The hydrochloride was purified by repeated crystn before aniline was liberated by addition of alkali, then dried with solid KOH, and distd. The product was sulfur-free and remained colourless in air [Hantzsch and Freese Chem Ber 27 2529, 2966 1894].

Non-basic materials, including nitro compounds were removed from aniline in 40% H₂SO₄ by passing steam through the soln for 1h. Pellets of KOH were added to liberate the aniline which was steam distd, dried with KOH, distd twice from zinc dust at 20mm, dried with freshly prepared BaO, and finally distd from BaO in an all-glass apparatus [Few and Smith J Chem Soc 753 1949]. Aniline is absorbed by skin and is TOXIC.

Aniline hydrobromide [542-11-0] M 174.0, m 286°. Crystd from water or EtOH and dried at 5mm over P₂O₅. Crystd four times from MeOH containing a few drops of conc HCl by addition of pet ether (b 60-70°), then dried to constant weight over paraffin chips, under vacuum [Gutbezahl and Grunwald JAm Chem Soc 75 559 1953]. It was ppted from EtOH soln by addition of Et₂O, and the filtered solid was recrystd from EtOH and dried in vacuo. [Buchanan et al. J Am Chem Soc 108 1537 1986].

Aniline hydroiodide [45497-73-2] M 220.0, m dec on heating. Same as aniline HBr above.

Aniline hydroiodide [45497-73-2] M 220.0, m dec on heating. Same as aniline HBr, store in the dark.

m-Anisaldehyde [591-31-1] M 136.2, b 143°/50mm, d 1.119. Washed with saturated aq NaHCO₃, then H₂O, dried with anhydrous MgSO₄ and distd at reduced pressure under N₂. Stored under N₂ in glass sealed ampoules.

p-Anisaldehyde (p-methoxybenzaldehyde) [122-11-5] M 136.2, m -1°, b 249°/atm, 89-90°/2mm, d 1.119, n 1.576. Washed with saturated aq NaHCO₃, then H₂O, steam distd, extracted distillate with Et₂O, dried (MgSO₄) and distd under vac and N₂. Store in glass ampules under N₂ in the dark.

o-Anisidine [2-methoxyaniline] [90-04-0] M 123.2, m -5°, b 109°/17mm, 119°/21mm, 225°/atm, d 1.096, n 1.575, pK² 4.52. It is separated from the m- and p- isomers by steam distn. It is also separated from its usual synthetic precusor o-nitroanisole by dissolving in dil HCl (pH <2.0) extracting the nitro impurity with Et₂O, adjusting the pH to ~8.0 with NaOH extracting the amine in Et₂O or steam distg. Extract the distillate with Et₂O, dry extract (Na₂SO₄), evaporate and fractionate the residual oil. Protect the almost colorless oil from light which turns it yellow in color. [Biggs and Robinson J Chem Soc 3881961; Nodzu et al. Yakugaku Zasshi (J Pharm Soc Japan) 71 713, 715 1951.]

m-Anisidine [3-methoxyaniline] [536-90-3] M 123.2, m -5°, b 79°/1mm, 128°/17mm, 251°/atm, d 1.101, n 1.583, pK² 4.20. o-Isomer impurity can be removed by steam distn. Possible impurity is the precursor 3-nitroanisole which can be removed as for the preceding o-isomer and fractionated using an efficient column. Yellow liquid. [Gilman and Kyle J Am Chem Soc 74 3027 1952; Bryson J Am Chem Soc 82 4858 1960; Kadaba and Massie J Org Chem 22 333 1957.]
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Anisole \([100-66-3]\) M 108.1, f -37.5°, b 43°/11mm, 153.8°/760mm, d\textsubscript{15} 0.9988, n\textsubscript{25} 1.5143, pK\textsubscript{0} -6.61 (aq H\textsubscript{2}SO\textsubscript{4}). Shaken with half volume of 2M NaOH, and emulsion allowed to separate. Repeated 3 times, then washed twice with water, dried over CaCl\textsubscript{2}, filtered, dried over sodium wire and finally distd from fresh sodium under N\textsubscript{2}, using a Dean-Stark trap, samples in the trap being rejected until free from turbidity [Caldin, Parbov, Walker and Wilson \textit{J Chem Soc, Faraday Trans I} \textbf{72} 1856 1976]. Dried with CaSO\textsubscript{4} or CaCl\textsubscript{2}, or by refluxing with sodium or BaO with crystalline FeSO\textsubscript{4} or by passage through an alumina column. Traces of phenols have been removed by prior shaking with 2M NaOH, followed by washing with water. Can be purified by zone refining.

2-p-Anisyl-1,3-indanone \([117-37-3]\) M 252.3, m 156-157°, pK\textsubscript{20} 4.09. Crystd from acetic acid or EtOH.

Anserine \([N,\beta\text–alanyl-1-methylhistidine] \([584-85-0]\) M 240.3, m 238-239°, [\(\alpha\)]\textsubscript{D} +11.3° (H\textsubscript{2}O), pK\textsubscript{1} \textsuperscript{25} 2.64, pK\textsubscript{2} \textsuperscript{5} 7.04, pK\textsubscript{3} \textsuperscript{5} 9.49. Crystd from aqueous EtOH. It is hygroscopic.

S-Anserine nitrate \([5937-77-9]\) M 303.3, m 225°(dec), [\(\alpha\)]\textsubscript{D} \textsuperscript{190} +12.2°. Likely impurities: 1-methylimidazol-5-alanine, histidine. Crystd from aqueous MeOH.

Antheraxanthin \([68831-78-7]\) M 584.8, m 205°, \(\lambda_{\text{max}}\) 460.5, 490.5nm, in CHCl\textsubscript{3}. Likely impurities: violaxanthin and mutatoxanthin. Purified by chromatography on columns of Ca(OH)\textsubscript{2} and of ZnCO\textsubscript{3}. Crystd from \(\text{C}_{6}\text{H}_{12}\text{OH}\) as needles or thin plates. Stored in the dark, in an inert atmosphere, at -20°.

Anthracene \([120-12-7]\) M 178.2, m 218°, pK -7.4 (aq H\textsubscript{2}SO\textsubscript{4}). Likely impurities are anthraquinone, anthrone, carbazole, fluorene, 9,10-dihydroanthracene, tetracene and bianthryl. Carbazole is removed by continuous-adsorption chromatography [see Sangster and Irvine \textit{J Phys Chem} \textbf{24} 670 1956] using a neutral alumina column and passing n-hexane. [Sherwood in \textit{Purification of Inorganic and Organic Materials}, Zief (ed), Marcel Dekker, New York, 1969.] The solvent is evaporated and anthracene is sublimed under vacuum, then purified by zone refining, under N\textsubscript{2} in darkness or non-actinic light. Has been purified by co-distillation with ethylene glycol (boils at 197.5°), from which it can be recovered by additin of water, followed by cryst from 95% EtOH, *benzene, toluene, a mixture of *benzene/xylene (4:1), or Et\textsubscript{2}O. It has also been chromatographed on alumina with pet ether in a dark room (to avoid photo-oxidation of adsorbed anthracene to anthraquinone). Other purification methods include sublimation in a N\textsubscript{2} atmosphere (in some cases after refluxing with sodium), and recrystd from toluene [Gorman et al. \textit{J Am Chem Soc} \textbf{107} 4404 1985; Saltiel \textit{J Am Chem Soc} \textbf{108} 2674 1986; Massori et al. \textit{J Am Chem Soc} \textbf{108} 1126 1986.]

Alternatively, it was recrystd from cyclohexane, chromatographed on alumina with n-hexane as eluent, and recrystd two more times [Saltiel et al. \textit{J Am Chem Soc} \textbf{109} 1209 1987]. Anthracene has also been crystd from EtOH, chromatographed through alumina in hot *benzene (fume hood) and then vac sublimed in a pyrex tube that has been cleaned and baked at 100°. (For further details see Craig and Rajikan \textit{J Chem Soc, Faraday Trans I} \textbf{74} 292 1978; and Williams and Zboinski \textit{J Chem Soc, Faraday Trans I} \textbf{74} 611 1978.) It has been chromatographed on alumina, recrystd from n-hexane and sublimed under reduced pressure. [Saltiel \textit{J Am Chem Soc} \textbf{108} 2674 1986; Massori et al. \textit{J Am Chem Soc} \textbf{108} 1126 1986.]

Anthracene-9-carboxylic acid \([723-62-6]\) M 222.2, m 214°(dec), pK\textsubscript{20} 3.65. Crystd from EtOH.


Anthranol \([529-86-2]\) M 196.2, m 160-170°(dec). Crystd from glacial acetic acid or aqueous EtOH.
Anthranthrone \([641-13-4]\) M 306.3, m 300°, pK -7.9 (aq H\(_2\)SO\(_4\)). Crystd from chlorobenzene or nitrobenzene.

Anthraquinone \([84-65-1]\) M 208.2, m 286°, pK\textsuperscript{2} -8.27 (aq H\(_2\)SO\(_4\)). Crystd from CHCl\(_3\) (38mL/g), *benzene, or boiling acetic acid, washing with a little EtOH and drying under vacuum over P\(_2\)O\(_5\).

Anthrarufin \([1,5\text{-dihydroxy}-9,10\text{-anthraquinone}]\) \(M 240.1, m 280°(dec), pK\textsuperscript{2} 9.90, pK\textsuperscript{1} 11.05\). Purified by column chromatography on silica gel with CHCl\(_3\)/Et\(_2\)O as eluent, followed by recryst from acetone. Alternatively recryst from glacial acetic acid [Flom and Barbara J Phys Chem 89 4489 1985].

1,8,9-Anthratriol \([480-22-8]\) M 226.2, m 176-181°, pK\textsubscript{est} -9.5. Crystd from pet ether.

Anthrimide \([1,1\text{-imino-bis-anthraquinone}]\) \(M 429.4, m >250°(dec)\). Crystd from chlorobenzene (red needles) or nitrobenzene (red rhombs)

Anthrone \([90-44-8]\) M 194.2, m 155°, pK -5.5 (aq H\(_2\)SO\(_4\)). Crystd from a 3:1 mixture of *benzene/pet ether (b 60-80°)(10-12mL/g), or successively from *benzene then EtOH. Dried under vacuum.

Antipyrine \([2,3\text{-dihydro-1,5-dimethyl-3-oxo-2-phenylpyrazole}]\) \(M 188.2, m 114°, b 319°, pK\textsuperscript{2} 1.45\). Crystd from EtOH/water mixture, *benzene, *benzene/pet ether or hot water (charcoal), and dried under vacuum.

β-Apo-4'-carotenal, β-Apo-8'-carotenal, β-Apo-8'-carotenoic acid ethyl ester, β-Apo-8'-carotenoic acid methyl ester, Apocodeine, Apomorphine see entries in Chapter 6.

β-L-Arabinose (natural) \([87-72-9]\) M 150.1, m 158°, [α]\(_D\) +104° (c 4, H\(_2\)O after 24h). Crystd slowly twice from 80% aq EtOH, then dried under vacuum over P\(_2\)O\(_5\).

D-Arabinose \([10323-20-3, 28697-53-2 (pyranoside)]\) M 150.1, m 164°, [α]\(_{546}\) -123° (c 10, H\(_2\)O after 24h), pK\textsuperscript{2} 12.54. Crystd three times from EtOH, vacuum dried at 60° for 24h and stored in a vacuum desiccator.

L-Arabitol \([7643-75-6]\) M 152.2, m 102°, [α]\(_{546}\) -16° (c 5, 8% borax soln). Crystd from 90% EtOH.

DL-Arabitol \([2152-56-9]\) M 152.2, m 105-106°. Crystd from 90% EtOH.

Arachidic (eicosanoic C\(_{20}\)) acid \([506-30-9]\) M 312.5, m 77°, pK\textsubscript{est} ~5.0. Crystd from abs EtOH.

Arachidic alcohol (1-eicosanol) \([629-96-9]\) M 298.6, m 65.5° (71°), b 200°/3mm. Crystd from *benzene or *benzene/pet ether.

p-Arbutin \([497-76-7]\) M 272.3, m 163-164°. Crystd from water.

S-Arginine \([74-79-3]\) M 174.2, m 207°(dec), [α]\(_D\) +26.5° (c 5, in 5M HCl), [α]\(_{546}\) +32° (c 5, in 5M HCl), pK\textsuperscript{1} 2.18, pK\textsuperscript{2} 9.36, pK\textsuperscript{3} 11.5. Crystd from 66% EtOH.

S-Arginine hydrochloride \([1119-34-2]\) M 210.7, m 217°(dec), [α]\(_D\)\textsuperscript{20} +26.9° (c 6, M HCl). Likely impurity is ornithine. Crystd from water at pH 5-7, by adding EtOH to 80% (v/v).

S-Argininosuccinic acid \([2387-71-5]\) M 290.3, [α]\(_D\)\textsuperscript{14} +16.4° (H\(_2\)O). Likely impurity is fumaric acid. In neutral or alkaline soln it readily undergoes ring closure to the 'anhydride'. Crystd from water by adding 1.5 vols of EtOH. Barium salt is stable at 0-5° if dry. [Westfall Biochem J 77 135 1960.]
S-Argininosuccinic anhydride [28643-94-9] M 272.3, [α]D23 -10° (H2O for anhydride formed at neutral pH). Crystd from water by adding two volumes of EtOH. An isomeric anhydride is formed if the free acid is allowed to stand at acid pH. In soln, the mixture of anhydrides and free acid is formed [see above entry].


S-Asparagine [70-47-3] M 150.1, m 234-235°, (monohydrate) [5799-13-8] [α]D 32.6° (0.1M HCl), pK1 1.98, pK2 5.84. Likely impurities are aspartic acid and tyrosine. Crystd from H2O or aqueous EtOH. Slowly effloresces in dry air.

Aspartic acid M 133.1, m 338-339° (RS, [617-45-8]); m 271° (S, requires heating in a sealed tube [56-84-8]), [α]D25 +25.4° (3M HCl), pK1 1.99, pK2 3.90. Likely impurities are glutamic acid, cystine and asparagine. Crystd from water by adding 4 volumes of EtOH and dried at 110°.


Aspergillic acid [490-02-8] M 224.3, m 97-99°, pK 5.5. Sublimed at 80°/10-3mm. Crystd from MeOH.

Astacin (β,β-carotene-3,3',4,4'-tetraone) [514-76-1] M 592.8, m 228°, 240-243°(evacuated tube), 550,000 at 498nm (pyridine). Probable impurity is astaxanthin. Purified by chromatography on alumina/fibrous clay (1:4) or sucrose, or by partition between pet ether and MeOH (alkaline). Crystd from pyridine/water. Stored in the dark under N2 at -20°. [Davis and Weedon J Chem Soc 182 1960.]

Atrolactic acid (0.5H2O) (2-hydroxy-2-phenylpropionic acid) [515-30-0] M 166.2, m 94.5° (anhydr), 88-91° (0.5H2O), pK1 3.53. Crystd from water and dried at 55°/0.5mm.


Aurin tricarboxylic acid [4431-00-9] M 422.4, m 300°. The acid is dissolved in aqueous NaOH, NaHSO3 solution is added until the colour is discharged and then the tricarboxylic acid is pptd with HCl [Org Synth Coll Vol 1 54 1947]. Do not extract the acid with hot water because it softens forming a viscous mass. Make a solution by dissolving in aqueous NH3. See Aluminon for the ammonium salt.


2-Azacyclotridecanone (laurolactam) [947-04-6] M 197.3, m 152°. Crystd from CHCl3, stored over P2O5 in a vacuum desiccator.


1-Azaindolizine \([274-76-0]\) \(M \) 118.1, \(b \) 72-73\(^\circ\)/1mm, \(pK^20 \) 1.43. Purified by distn or gas chromatography.

Azaserine \([115-02-6]\) \(M \) 173.1, \(m \) 146-162\(^\circ\)(dec), \(\alpha^2D^27.5 -0.5^\circ \) (c 8.5, \(H_2O\), \(pH \) 5.2), \(pK_{\text{est}(1)} \) 4.53, \(pK_{\text{est}(2)} \) 5.40. Crystd from 90\% EtOH.

8-Azapurine \((1H-1,2,3-triazol[4,5-d]pyrimidine, 1,2,3,4,6[3H]penta-azaindene) \([273-40-5]\) \(M \) 121.1, \(m \) 174-175\(^\circ\) (effervescence, \(m \) depends on heating rate), \(pK^\text{i}^2 \) 2.05 (equilib with covalent hydrate), \(pK^\text{ii}^2 \) 4.84. Sublimed at 120-130\(^\circ\)/0.01mm and recryst from 3 parts of EtOH. [Albert \(J\) \(Chm\) \(Soc(B)\) 427 1966.]

Azelaic acid \([123-99-9]\) \(M \) 188.2, \(m \) 105-106\(^\circ\). Crystd from \(H_2O\) (charcoal) or thiophene-free \(*\text{benzene. The material cryst from } H_2O \text{ was dried by azeotropic distn in toluene, the residual toluene soln was cooled and filtered, the ppt} \text{ being dried in a vacuum oven. Also purified by zone refining or by sublimation onto a cold finger at } 10^{-3} \text{ torr.}

Azetidine \((\text{trimethyleneimine}) \([503-29-7]\) \(M \) 57.1, \(b \) 61-62\(^\circ\), \(d \) 0.846, \(n \) 1.432, \(pK_{25} \) 11.29. It is a flammable, hygroscopic liquid smelling of ammonia, which absorbs \(CO_2\) from air and should be kept under Argon. Purified by drying over solid KOH and distd through a short Vigreux column at atm pressure (under Argon) and keeping the pot temp below 210\(^\circ\). [Searles et al. \(J\) \(Am\) \(Chem\) \(Soc\) 78 4917 1956.]

Aziridine \((\text{ethyleneimine}) \([151-56-4]\) \(M \) 43.1, \(b \) 55-56\(^\circ/756\text{mm}, 56\(^\circ/760\text{mm}, \ d_{24}^2 \) 0.8321, \(pK^\text{ii}^2 \) 8.00. Redistd in an Ar or \(N_2\) atmosphere in a fume hood, and stored over KOH in sealed bottles in a refrigerator. Commercial aziridine has been dried over sodium and distd from the metal through an efficient column before use [Jackson and Edwards \(J\) \(Am\) \(Chem\) \(Soc\) 83 355 1961; Wenker \(J\) \(Am\) \(Chem\) \(Soc\) 57 2328 1935]. It is a weaker base than \(\text{Me}_2\text{NH} \) \((pK 10.87)\) but is caustic to the skin. It should not be inhaled, causes inflammation of the eyes, nose and throat and one may become sensitised. It is sol in \(H_2O\) and has an ammoniacal smell and reacts with \(CO_2\). Pure aziridine is comparatively stable but polymerises in the presence of traces of \(H_2O\) and is occasionally explosive in the presence of acids. \(CO_2\) is sufficiently acidic to cause polymerisation (forms linear polymers) which is not free radical promoted. It is stable in the presence of bases. The violet 2:1 \(Cu\) complex crystd from \(EtOH\) containing a few drops of Aziridine and adding \(Et_2O\) has \(m \) 142\(^\circ\) (decomp). The picrate has \(m \) 142\(^\circ\). [O'Rourke et al. \(J\) \(Am\) \(Chem\) \(Soc\) 78 2159 1956.] It has also been dried with BaO, and distd from sodium under nitrogen. TOXIC.

Azobenzene \([103-33-3]\) \(M \) 182.2, \(m \) 68\(^\circ\), \(pK^25 \) 2.48. Ordinary azobenzene is nearly all in the trans-form. It is partly converted into the cis-form on exposure to light [for isolation see Hartley \(J\) \(Chem\) \(Soc\) 633 1938, and for spectra of cis- and trans-azobenzenes, see Winkel and Siebert \(Chm\) \(Ber\) 74B 6701941]. trans-Azobenzene is obtained by chromatography on alumina using 1:4 \(*\text{benzene/heptane or pet ether, and crystd from EtOH (after refluxing for several hours) or hexane. All operations should be carried out in diffuse red light or in the dark.}

1,1'-Azobis(cyclohexane carbonitrile) \([2094-98-6]\) \(M \) 244.3, \(m \) 114-114.5\(^\circ\), \(\epsilon_{350nm} \) 16.0. Crystd from EtOH.

\(\alpha,\alpha'\)-Azobis(isobutyronitrile) \((\text{AIBN}) \([78-61-1]\) \(M \) 164.2, \(m \) 103\(^\circ\)(dec). Crystd from acetone, \(Et_2O\), \(CHCl_3\), \(aq\) EtOH or MeOH. Has also been crystd from abs EtOH below 40\(^\circ\) in subdued light. Dried under vacuum at room temp over \(P_2O_5\) and stored under vacuum in the dark at <10\(^\circ\) until used. Also crystd from \(CHCl_3\) soln by addn of pet ether (b <40\(^\circ\)). [Askham et al. \(J\) \(Am\) \(Chem\) \(Soc\) 107 7423 1985; Ennis et al. \(J\) \(Chem\) \(Soc\), \(Dalton\) \(Trans\) 2485 1986; Inoue and Anson \(J\) \(Phys\) \(Chem\) 91 1519 1987; Tanner \(J\) \(Org\) \(Chem\) 52 2142 1987].

Azolitmin B \([1395-18-2]\) \(M \) ~3300, \(m \geq 250\(^\circ\)(dec). Crystd from water as dark violet scales, or ppted from \(H_2O\) by addn of EtOH as a red powder. It is an indicator which is red at \(pH \) 4.5 and blue at \(pH \) 8.3.
Azomethane [503-28-6] M 58.1, m -78°, b 1.5°. Purified by vacuum distn and stored in the dark at -80°. Can be EXPLOSIVE.

\( p,p'-\text{Azoxynisole (4,4'-dimethoxyazoxoxybenzene)} \) [1562-94-3] M 258.3, transition temps: 118.1-118.8°, 135.6-136.0°, \( pK^2' = 5.23 \) (20% aq EtOH + 80% aq \( \text{H}_2\text{SO}_4 \)). Crystd from absolute or 95% EtOH, or acetone, and dried by heating under vacuum or sublimed in a vac onto a cold finger.

Azoxynisole (4,4'-dimethoxyazoxybenzene) [495-48-7] M 198.2, m 36°, \( pK^2 = -6.16 \) (20% aq EtOH + 80% aq \( \text{H}_2\text{SO}_4 \)). Crystd from EtOH or MeOH, and dried for 4h at 25° and 10^-3 mm. Sublimed before use.

\( p,p'-\text{Azoxyanisole (4,4'-dimethoxyazoxybenzene)} \) [1562-94-3] M 258.3, transition temps: 118.1-118.8°, 135.6-136.0°, \( pK^2' = -5.23 \) (20% aq EtOH + 80% aq \( \text{H}_2\text{SO}_4 \)). Crystd from absolute or 95% EtOH, or acetone, and dried by heating under vacuum or sublimed in a vac onto a cold finger.

Benzalacetone (trans-4-phenyl-3-buten-2-one) [122-57-6] M 146.2, m 42°. Crystd from pet ether (b 40-60°), or distd (b 137-142° /16mm).

\( \text{Batyl alcohol} \) [544-62-7] M 344.6, m 70.5-71°. Crystd from aq Me\(_2\text{CO}, \text{EtOH}\) or pet ether (b 40-60°).

\( \text{Bathophenanthroline (4,7-diphenyl-1,10-phenanthroline)} \) [1662-01-7] M 332.4, m 215-216°, 218-220°, \( pK^2 = 4.67 \). Best purified by recryst from *C\(_6\text{H}_6* or toluene. Its solubility (per L): \( H\text{H}_2O \) (1mg), M \( \text{HCl} \) (20mg), heptane (110mg), Et\(_2\text{O} \) (530mg), Me\(_2\text{CO} \) (2.3g), dioxane (3.4g), MeOH (6.0g), Et\(_2\text{OH} \) (10.5g), isoPrOH (10.0g), n-pentanol (18.7g), *C\(_6\text{H}_6* (12.2g), pyridine (33g), nitrobenzene (44.7g), CHCl\(_3\) (78g) and AcOH (450.4g). [UV: Bull Soc Chim Fr 371 1972.] For di-Na salt 3H\(_2\)O see entry in Chapter 5.

Benzalacetone (trans-4-phenyl-3-buten-2-one) [122-57-6] M 146.2, m 42°. Crystd from pet ether (b 40-60°), or distd (b 137-142° /16mm).
**Benzalacetophenone (Chalcone)** [94-41-7] M 208.3, m 56-58°, b 208°/25mm, pK^2^ -5.73 (aq H_2SO_4). Crystd from EtOH warmed to 50° (about 5mL/g), iso-octane, or toluene/pet ether, or recrystd from MeOH, and then twice from hexane. SKIN IRRITANT.

**Benzaldehyde** [100-52-7] M 106.1, f -26°, b 62° (58°)/10mm, 179.0°/760mm, d 1.044, n 1.5455, pK^2^ -7.1 (aq H_2SO_4). To diminish its rate of oxidation, benzaldehyde usually contains additives such as hydroquinone or catechol. It can be purified via its bisulfite addition compound but usually distn (under nitrogen at reduced pressure) is sufficient. Prior to distn it is washed with NaOH or 10% Na_2CO_3 (until no more CO_2 is evolved), then with satd Na_2SO_3 and H_2O, followed by drying with CaSO_4, MgSO_4 or CaCl_2.

**anti-Benzaldoxime** [932-90-1] M 121.1, m 33-34°. Crystd from diethyl ether by adding pet ether (b 60-80°). The syn-isomer [622-32-2] has b 121-124°/12mm, m 34-36°.

**Benzamide** [55-21-0] M 121.1, m 129.5°, pK^2^ -2.16 (aq H_2SO_4). Crystd from hot water (about 5mL/g), EtOH or 1,2-dichloroethane, and air dried. Crystd from dilute aqueous ammonia, water, acetone and then *benzene (using a Soxhlet extractor). Dried in an oven at 110° for 8h and stored in a desiccator over 99% H_2SO_4. [Bates and Hobbs *J Am Chem Soc* 73 2151 1951.]


**Benzanilide** [93-98-1] M 197.2, m 164°, pK^5^ 1.26. Crystd from pet ether (b 70-90°) using a Soxhlet extractor, and dried overnight at 120°. Also crystd from EtOH.

**Benz[a]anthracene** [56-55-3] M 228.3, m 159-160°. Crystd from MeOH, EtOH or *benzene (charcoal), then chromatographed on alumina from sodium-dried *benzene (twice), using vacuum distn to remove *benzene. Final purification was by vacuum sublimation.

**Benz[a]anthracene-7,12-dione** [2498-66-0] M 258.3, m 169.5-170.5°. Crystd from MeOH (charcoal).

**Benzanthrone** [82-05-3] M 230.3, m 170°, pK^2^ -3.2 (aq H_2SO_4). Crystd from EtOH or xylene.

**Benzene** [71-43-2] M 78.1, f 5.5°, b 80.1°, d 0.874, n 1.50110, n^2^ 1.49790. For most purposes, *benzene can be purified sufficiently by shaking with conc H_2SO_4 until free from thiophene, then with H_2O, dilute NaOH and water, followed by drying (with P_2O_5, sodium, LiAlH_4, CaH_2, 4X Linde molecular sieve, or CaSO_4, or by passage through a column of silica gel, for a preliminary drying, CaCl_2 is suitable), and distn. A further purification step to remove thiophene, acetic acid and propionic acid, is by partial freezing. The usual contaminants in dry thiophene-free *benzene are non-benzenoid hydrocarbons such as cyclohexane, methycyclohexane, and heptanes, together with naphthenic hydrocarbons and traces of toluene.

Carbonyl-containing impurities can be removed by percolation through a Celite column impregnated with 2,4-dinitrophenylhydrazine, phosphoric acid and H_2O. (Prepared by dissolving 0.5g DNPH in 6mL of 85% H_3PO_4 by grinding together, then adding and mixing 4mL of dist H_2O and 10g Celite.) [Schwartz and Parker *Anal Chem* 33 1396 1961.]

*Benzened has been freed from thiophene by refluxing with 10% (w/v) of Raney nickel for 15min, after which the nickel was removed by filtration or centrifugation. Dry *benzene was obtained by distinctly distilling high purity *benzene from a soln containing the blue ketyl formed by the reaction of sodium-potassium alloy with a small amount of benzophenone.

Thiophene has been removed from *benzene (absence of bluish-green coloration when 3mL of *benzene is shaken with a soln of isatin in 10mL of conc H_2SO_4) by refluxing the *benzene (1Kg) for several hours with 40g HgO (freshly pptd) dissolved in 40mL of glacial acetic acid and 100mL of water. The ppt was filtered off, the aq phase was removed and the *benzene was washed twice with H_2O, dried and distd. Alternatively, *benzene dried with CaCl_2 has been shaken vigorously for half an hour with anhydrous AlCl_3 (12g/L) at 25-35°, then decanted, washed with 10% NaOH, and water, dried and distd. The process was repeated, giving thiophene-free *benzene. [Holmes and Beeman *Ind Eng Chem* 26 172 1934.]
After shaking successively for about an hour with conc H\textsubscript{2}SO\textsubscript{4}, distd water (twice), 6M NaOH, and distd water (twice), *benzene was distd through a 3-ft glass column to remove most of the water. Abs EtOH was added and the *benzene-alcohol azeotrope was distd. (This low-boiling distillation leaves any non-azeotrope-forming impurities behind.) The middle fraction was shaken with distd water to remove EtOH, and again redistd. Final slow and very careful fractional distillation from sodium, then LiAlH\textsubscript{4} under N\textsubscript{2}, removed traces of water and peroxides.

*Benzene liquid and vapour are very TOXIC and HIGHLY FLAMMABLE, and all operations should be carried out in an efficient fume cupboard and in the absence of naked flames in the vicinity.

Rapid purification: To dry benzene, alumina, CaH\textsubscript{2} or 4A molecular sieves (3% w/v) may be used (dry for 6h). Then benzene is distilled, discarding the first 5% of distillate, and stored over molecular sieves (3A, 4A) or Na wire.

**[2H\textsubscript{6}]**Benzene (*benzene-d\textsubscript{6}) \[1076-43-3\] M 84.2, b 80°/773.6mm, 70°/562mm, 60°/399mm, 40°/186.3mm, 20°/77.1mm, 10°/49.9mm, 0°/27.5mm, d 0.9488, d\textsubscript{40} 0.9257, n 1.4991, n\textsubscript{40} 1.4865. Hexadeuteriobenzene of 99.5% purity is refluxed over and distiled from CaH\textsubscript{2} onto Linde type 5A sieves under N\textsubscript{2}.

**Benzeneazodiphenylamine** (4-phenylazodiphenylamine) \[28110-26-1\] M 273.3, m 82°, pK\textsubscript{a} 1.52. Purified by chromatography on neutral alumina using anhydrous *C\textsubscript{6}H\textsubscript{6} with 1% anhydrous MeOH. The major component, which gave a stationary band, was cut out and eluted with EtOH or MeOH. [Högfeldt and Bigeleisen J Am Chem Soc 82 15 1960.] Crystd from pet ether or EtOH. See Sudan I.

**1-Benzeneazo-2-naphthol** \[842-07-9\] M 248.3, m 134°, pK\textsubscript{Est} ~9.5 (OH). Crystd from EtOH.

**1-Benzeneazo-2-naphthylamine** (Yellow AB) \[85-84-7\] M 247.3, m 102-104°, pK\textsubscript{Est} ~4.1. Crystd from glacial acetic acid, acetic acid/water or ethanol.

**1,2-Benzenedimethanol** (1,2-bis(hydroxymethyl)benzene) \[612-14-6\] M 138.2, m 61-64°, 63-64°, 64-65°, 65-66.5°, b 145°/3mm. Recrystd from *C\textsubscript{6}H\textsubscript{6}, H\textsubscript{2}O, pet ether or pentane. It has been extracted in a Soxhlet with Et\textsubscript{2}O, evaporated and recrystd from hot pet ether. Also dissolve in Et\textsubscript{2}O, allow to evaporate till crystals are formed, filter off and wash the colourless crystals with warm pet ether or pentane. The diacetate has m 35°, 35-36°. [J Am Chem Soc 69 1197 1947, IR and UV: J Am Chem Soc 74 441 1952.]

**m-Benzenedisulfonyl chloride** \[585-47-7\] M 238.2, pK\textsubscript{Est} <0. Freed from H\textsubscript{2}SO\textsubscript{4} by conversion to the calcium or barium salts (using Ca(OH)\textsubscript{2} or Ba(OH)\textsubscript{2}, and filtering). The calcium salt was then converted to the potassium salt, using K\textsubscript{2}CO\textsubscript{3}. Both the potassium and the barium salts were recrystd from H\textsubscript{2}O, and the acid was regenerated by passing through the H\textsuperscript{+} form of a strong cation exchange resin. The acid was recrystd twice from conductivity water and dried over CaCl\textsubscript{2} at 25°. [Atkinson, Yokoi and Hallada J Am Chem Soc 83 1570 1961.] It has also been crystd from Et\textsubscript{2}O and dried in a vacuum oven.

**m-Benzenedisulfonyl chloride** \[585-47-7\] M 275.1, m 63°. Crystd from CHCl\textsubscript{3} (EtOH free, by passing through an alumina column) and dried at 20mm pressure.

**Benzenesulfinic acid** \[618-41-7\] M 142.2, m 84°, pK\textsubscript{a} 2.16 (2.74). The acid is purified by dissolving the Na salt in H\textsubscript{2}O, acidifying to Congo Red paper with HCl and adding a concentrated soln of FeCl\textsubscript{3} whereby Fe sulfinate ppts. Collect the salt, wash with a little H\textsubscript{2}O, drain, suspend in H\textsubscript{2}O and add a slight excess of 1.5M aq NaOH. The Fe(OH)\textsubscript{3} ppts, it is filtered off, the sulfinic acid in the aq soln is extracted with
Et₂O, the extract is dried (Na₂SO₄) and evapd to give colorless crysts of benzenesulfinic acid m 84° which are stored under N₂ in the dark, as it slowly oxides in air to the sulfonic acid [see Org Synth 42 62 1966].

Benzenesulfonic acid [98-11-3] M 158.2, m 43-44°, 50-55° (anhydrous), 65-66°, pK₂ 2.7, 0.70 (2.53°) Purified by dissolving in a small volume of distd H₂O and stirring with slightly less than the theoretical amount of BaCO₃. When effervescence is complete and the solution is still acidic, filter off the insoluble barium benzenesulfonate. The salt is collected and dried to constant weight in vacuo, then suspended in H₂O and stirred with a little less than the equivalent (half mol.) of sulfuric acid. The insoluble BaSO₄ (containing a little barium benzenesulfonate) is filtd off and the filtrate containing the free acid is evapd in a high vacuum. The oily residue will eventually crystallise when completely anhydrous. A 32% commercial acid was caused to fractionally crys at room temp over P₂O₅ in a vac desiccator giving finally colorless deliquescent plates m 52.5°. The anhydrous crys acid is deliquescent and should be stored over anhyd Na₂SO₄ in the dark and should be used in subdued sunlight as it darkens under sunlight. The main impurity is Fe which readily separates as the Fe salt in the early fractions [Taylor and Vincent J Chem Soc 3210 1952]. It is an IRRITANT to the skin and eyes. [see Org Synth Coll Vol I 84 1948; Michael and Adair Chem Ber 10 5 1877.]


Benzenesulfonyl chloride [98-09-9] M 176.6, m 14.5°, b 120°/10mm, 251.2°/760mm(dec), d 1.384. Distd, then treated with 3mole % each of toluene and AlCl₃, and allowed to stand overnight. The free benzenesulfonyl chloride was distd off at 1mm pressure, and then carefully fractionally distd at 10mm in an all-glass column. [Jensen and Brown J Am Chem Soc 80 4042 1958.]

Benzene-1,2,4,5-tetracarboxylic (pyromellitic) acid [89-05-4] M 254.2, m 281-284°, pK₁ 1.87, pK₂ 2.72, pK₃ 4.30, pK₄ 5.52. See entry on p. 345.

Benzene-1,2,3-tricarboxylic (hemimellitic) acid (H₂O) [36362-97-7] M 210.1, m 190°(dec), pK₁ 2.62, pK₂ 3.82, pK₃ 5.51. Crystd from water.

Benzene-1,3,5-tricarboxylic (trimesic or trimellitic) acid [554-95-0] M 210.1, m 360°(dec), pK₁ 2.64, pK₂ 3.71, pK₃ 5.01. Crystd from water.

1,2,4-Benzenetetrol [533-73-3] M 126.1, m 141°, pK₁ 9.08, pK₂ 11.82. Crystd from Et₂O.

Benzethonium chloride [121-54-0] M 448.1, m 164-166°. Crystd from 1:9 MeOH/ Et₂O mixture.

Benzhydrol (diphenylmethanol) [91-01-0] M 184.2, m 69°, b 297°/748mm, 180°/20mm. Crystd from hot H₂O or pet ether (b 60-70°), pet ether containing a little *benzene, from CCl₄, or EtOH (1.3mL/g). An additional purification step is passage of a *benzene soln through an activated alumina column. Sublimes in a vacuum. Also crystd three times from MeOH/H₂O [Naguib J Am Chem Soc 108 128 1986]. § A commercial polystyrene supported version is available.

Benzidine (4,4'-diaminobiphenyl) [92-87-5] M 184.2, m 128-129°, pK₁ 3.85, pK₂ 4.95. Its soln in *benzene was decolorized by percolation through two 2-cm columns of activated alumina, then concentrated until benzidine crystd on cooling. Recrystd alternatively from EtOH and *benzene to constant absorption spectrum [Carlin, Nelb and Odioso J Am Chem Soc 73 1002 1951]. Has also been crystd from hot water (charcoal) and from diethyl ether. Dried under vac in an Abderhalden pistol. Stored in the dark in a stoppered container. CARCINOGENIC.

Benzidine dihydrochloride [531-85-1] M 257.2, m >250°(dec). Crystd by soln in hot H₂O, with addition of conc HCl to the slightly cooled soln. CARCINOGENIC.

Benzil [134-81-6] M 210.2, m 96-96.5°. Crystd from *benzene after washing with alkali. (Crysn from EtOH did not free benzil from material reacting with alkali.) [Hine and Howarth J Am Chem Soc 80 2274
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1958.] Has also been crystd from CCl₄, diethyl ether or EtOH [Inoue et al. J Chem Soc, Faraday Trans I 82 523 1986].

Benzilic acid (diphenylglycollic acid) [76-93-7] M 228.3, m 150°, pK18 3.06. Crystd from benzene (ca 6mL/g), or hot H₂O.

Benzil monohydrazone [5433-88-7] M 224.3, m 151°. Crystd from EtOH.

α-Benzil monoxime [14090-77-8], [E, 574-15-2], [Z, 574-16-3] M 105.1, m 140°. Crystd from C₆H₆ (must not use animal charcoal).

Benzimidazole [51-17-2] M 118.1, m 172-173°, pKf5 5.53, pKf11 11.70. Crystd from water or aqueous EtOH (charcoal), and dried at 100° for 12h.

2-Benzimidazolylacetonitrile [4414-88-4] M 157.2, m 200-205° dec, 209.7-210.7° (corrected), 210°. Recrystd from aqueous EtOH. It has been recrystd from hot H₂O using charcoal, and finally from aqueous EtOH. [J Am Chem Soc 65 1072 1943].


Benzofurazan [273-09-6] M 120.1, m 55°. Purified by crystn from EtOH and sublimed.

Benzoic acid [65-85-0] M 122.1, m 122.6-123.1°, pK25 4.12. For use as a volumetric standard, analytical reagent grade benzoic acid should be carefully fused to ca 130° (to dry it) in a platinum crucible, and then powdered in an agate mortar. Benzoic acid has been crystd from boiling water (charcoal), acetic acid, glacial acetic acid, *C₆H₅CO₂Et, pet ether (b 60-80°), and from EtOH soln by adding water. It is readily purified by fractional crystn from its melt and by sublimation in a vacuum at 80°.

o-Benzoinic acid sulfinamide (saccharin, 1,2-benzisothiazol-3(2H)-one 1,1-dioxide) [81-07-2] M 183.2, m 227-229°, 229°, 228.8-229.7°, pK25 1.31, pK25 12.8. Purified by recrystn from Me₂CO [solubility 7.14% at 0°, 14.4% at 50°], or aqueous isopROH to give a fluorescent soln. [Am J Pharm 41 17 1952.]

Benzoic anhydride [93-97-0] M 226.2, m 42°. Freed from benzoic acid by washing with NaHCO₃, then water, and drying. Crystd from benzene (0.5mL/g) by adding just enough pet ether (b 40-60°), to cause cloudiness, then cooling in ice. Can be distd at 210-220°/20mm.
(±)-Benzoin (2-hydroxy-2-phenylacetophenone) [119-53-9] M 212.3, m 137°. Crystd from 
CCl₄, hot EtOH (8mL/g), or 50% acetic acid. Crystd from high purity *benzene, then twice from high purity 


Benzonitrile [100-47-0] M 103.1, f -12.9°, b 191.1°, d 1.010, n 1.528. 
Dried with CaSO₄, CaCl₂, MgSO₄ or K₂CO₃, and distd from P₂O₅ in an all-glass apparatus, under reduced pressure (b 69°/10mm), 
collecting the middle fraction. Distn from CaH₂ causes some decomposition of solvent. Isonitriles can be 
removed by preliminary treatment with conc HCl until the smell of isonitrile has gone, followed by preliminary 
drying with K₂CO₃. (This treatment also removes amines).

Steam distd (to remove small quantities of carbylamine). The distillate was extracted into ether, washed with dil 
Na₂CO₃, dried overnight with CaCl₂, and the ether removed by evaporation. The residue was distd at 40mm (b 
96°) [Kice, Perham and Simons J Am Chem Soc 82 834 1960].

Conductivity grade benzonitrile (specific conductance 2 x 10⁻⁶ mho) was obtained by treatment with anhydrous 
AlCl₃, followed by rapid distn at 40-50° under vacuum. After washing with alkali and drying with CaCl₂, the 
distillate was vac distd several times at 35° before being fractionally crystd several times by partial freezing. It 
was dried over finely divided activated alumina from which it was withdrawn as required [Van Dyke and Harrison 
J Am Chem Soc 73 402 1951].

Purified as light green crystals by recrystn from *C₆H₆ or xylene and sublimes at 320-340° and 0.05mm 

1,3,5-Trinitrobenzene complex m 310-313° (deep red crystals from *C₆H₆); picrate m 267-270° (dark red 

crystals from *C₆H₆); styphnate (2,4,6-trinitroresorcinol complex) m 234° (wine red crystals from *C₆H₆). It 
recrystallises from propan-1-01 [J Chem Soc 466 1959].

3,4-Benzophenanthrene [195-19-7] M 228.3, m 68°. Crystd from EtOH, pet ether, or EtOH/Me₂CO.

Benzophenone [119-61-9] M 182.2, m 48.5-49°, pK -6.0 (aq H₂SO₄). Crystd from MeOH, 
EtOH, cyclohexane, *benzene or pet ether, then dried in a current of warm air and stored over BaO or P₂O₅. 
Also purified by zone melting and by sublimation [Itoh J Phys Chem 89 3949 1985; Naguib et al. J Am Chem 
Chem Soc 91 3033 1987].

Benzophenone oxime [574-6-3] M 197.2, m 142°, pK 11.18. Crystd from MeOH (4mL/g).

Benzopinacol [464-72-2] M 366.5, m 170-180° (depends on heating rate). Crystd from EtOH.

Benz[a]pyrene (3,4 benzpyrene) [50-32-8] M 252.3, m 177.5-178°, 179.0-179.5°. A soln of 
250mg in 100mL of *benzene was diluted with an equal volume of hexane, then passed through a column of alumina, Ca(OH)₂ and Celite (3:1:1). The adsorbed material was developed with a 2:3 *benzene/hexane mixture. 
(If showed as an intensely fluorescent zone.) The main zone was eluted with 3:1 acetone/EtOH, and was 
transferred into 1:1 *benzene/hexane by adding H₂O. The soln was washed, dried with Na₂SO₄, evaporated and 
crystd from *benzene by the addition of MeOH [Lijinsky and Zechmeister J Am Chem Soc 75 5495 1953]. 
Alternatively it can be chromatographed on activated alumina, eluted with a cyclohexane-*benzene mixture 
containing up to 8% *benzene, and the solvent evapd under reduced pressure [Cahnmann Anal Chem 27 1235 
1955], and recrystd from EtOH [Nithipatikom and McGown Anal Chem 58 3145 1986].

CARCINOGENIC.

passage through an Al₂O₃ column (Woelm, basic, activity I) and eluted with *C₆H₆ and recrystd from 2 
volumes of EtOH-*C₆H₆ (4:1). Forms colourless or light yellow prisms or needles. [J Chem Soc 3659 1954; 
Justus Liebigs Ann Chem 705 190 1967.] 1,3,5-Trinitrobenzene complex m 253-254° (orange needles from
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EtOH); the picrate prepared by mixing 20mg in 1mL of *C₆H₆ with 20mg of picric acid in 2mL *C₆H₆, collecting the deep red crystals, and recrystallising from *C₆H₆ m 228-229° [Synth J Chem Soc 398 1967; NMR: J Chem Phys 47 2020 1967]. CARCINOGEN.

3,4-Benzquinoline (phenanthridine) [229-87-8] M 179.2, m 108-109°, b 350°, pK² 4.61. Chromatographed on activated alumina from *benzene soln, with diethyl ether as eluent. Evapn of ether gave crystalline material which was freed from residual solvent under vacuum, then further purified by fractional crystn under N₂, from its melt. Sublimes in vacuo. See also p. 324.

5,6-Benzquinoline [85-02-9] M 179.0, m 93°, b 350°, pK² 5.11. As 3,4-benzoquinoline above.

7,8-Benzquinoline [230-27-3] M 179.0, m 52.0-52.5°, pK² 4.21. As 3,4-benzoquinoline above.

p-Benzquinone [106-51-4] M 108.1, m 115.7°. Usually purified in one or more of the following ways: steam distn, followed by filtration and drying (e.g. in a desiccator over CaCl₂); crystn from pet ether (b 80-100°), *benzene (with, then without, charcoal), water or 95% EtOH; sublimation under vacuum (e.g. from room temperature to liquid N₂). It slowly decomposes, and should be stored, refrigerated, in an evacuated or sealed glass vessel in the dark. It should be resublimed before use. [Wolfenden et al. J Am Chem Soc 109 463 1987.]

1-Benzosuberone (6,7,8,9-tetrahydrobenzocyclohepten-5-one) [826-73-3] M 160.2, b 80-85°/0.5mm, 90-93°/1mm, 138-139°/12mm, 154°/15mm, 175-176°/40mm, d² 1.086, n² 1.5638. Purified by dissolving in toluene, washing with aqueous 5% NaOH, then brine, dried (MgSO₄), and distd. 2,4-Dinitrophenylhydrazone has m 210°, 207-208° (from CHC₃ + MeOH). Z-0-Picryloxime has m 156-157° (from Me₂CO + MeOH); the E-0-picryloxime has m 107°. The oxime has m 106.5-107.5°. [W J Am Chem Soc 73 1951; 75 3744 1953; Chem Ber 90 1844 1957.]
2-Benzoylbenzoic acid [85-52-9] M 226.2, m 126-129°, 129°, 130°, pK\textsuperscript{25} 3.54. Recrystd from \(^{94}C_6H_6\) or cyclohexane, but is best recrystallised by dissolving in a small volume of hot toluene and then adding just enough pet ether to cause pptn and cool. Dry in a low vacuum at 80°. It can be sublimed at 230-240\(^0\)/0.3mm [J Chem Soc 265 1957]. The S-benzylthiouronium salt has m 177-178° (from EtOH). [J Am Chem Soc 75 4087 1953; Chem Ber 90 1208 1957.]

3-Benzoylbenzoic acid [579-18-0] M 226.2, m 164-166°, pK\textsubscript{Est} -3.5. Cryst from EtOH;vac subl.

4-Benzoylbenzoic acid [611-95-0] M 226.2, m 196.5-198°, 197-200°, pK\textsubscript{Est} -3.7. Dissolve in hot H\(_2\)O by adding enough aqueous KOH soln till distinctly alkaline, filter and then acidify with drops of conc HCl. Filter off, wash solid with cold H\(_2\)O, dry at 100°, and recrystallise from EtOH. [J Am Chem Soc 55 2540 1933.]

(S +) and (R -) 1-Benzoyl-2-tert-butyl-3-methyl-4-imidazolinone [R- 101055-57-6] [S-101055-56-5] M 260.3, m 142-143°, 145.6-146.6°, 145-147°, [\(\alpha\)]\textsubscript{D}\textsuperscript{20} (+) and (-) 155°, [\(\alpha\)]\textsubscript{D}\textsuperscript{20} (+) and (-) 133° (c 1, CHCl\(_3\)). Recrystd from boiling EtOH (sol 1.43g/mL) or better by dissolving in CH\(_2\)Cl\(_2\) and adding pentane, filter and dry for at least 12h at 60\(^0\)/0.1mm and sublimed at 135°/0.01mm. It has also been purified by flash column chromatography with Merck silica gel at 0.04-0.063mm and using Et\(_2\)O/pet ether. Barkov and Weisgerber (racemate) is purified in a similar manner and has m 104-105° [NMR: Helv Chim Acta 68 949 1985].

Benzoyl chloride [98-88-4] M 140.6, b 56°/4mm, 196.8°/745mm, d 1.1210, n\(^D\) 1.5537. A soln of benzoyl chloride (300mL) in \(^{94}C_6H_6\) (200mL) was washed with two 100mL portions of cold 5% NaHCO\(_3\) soln, separated, dried with CaCl\(_2\) and distd [Oakwood and Weisgerber Org Synth III 113 1955]. Repeated fractional distn at 4mm Hg through a glass helices-packed column (avoiding porous porcelain or silicon-carbide boiling chips, and hydrocarbon or silicon greases on the ground joints) gave benzoyl chloride that did not darken on addition of AlCl\(_3\). Further purification was achieved by adding 3 mol% each of AlCl\(_3\) and silicon-carbide boiling chips, and hydrocarbon or silicon greases. Benzoyl chloride (300mL) in \(^{94}C_6H_6\) (200mL) was washed with two 100mL portions of cold 5% NaHCO\(_3\) soln, separated, dried with CaCl\(_2\) and distd [Oakwood and Weisgerber Org Synth III 113 1955]. Repeated fractional distn at 4mm Hg through a glass helices-packed column (avoiding porous porcelain or silicon-carbide boiling chips, and hydrocarbon or silicon greases on the ground joints) gave benzoyl chloride that did not darken on addition of AlCl\(_3\). Further purification was achieved by adding 3 mol% each of AlCl\(_3\) and toluene, standing overnight, and distilling off the benzoyl chloride at 1-2mm [Brown and Jenzen J Am Chem Soc 80 2291 1958]. Refluxing for 2h with an equal weight of thionyl chloride before distn, has also been used. Strong IRRITANT. Use in a fume cupboard.

Benzoylformic acid (phenylglyoxylic acid) [611-73-4] M 150.14, m 62-65°, 64.5-65.5°, 67°, b 84°/0.1mm, 163-167°/15mm, pK\textsuperscript{25} 1.39 (1.79). If the sample is oily then it may contain H\(_2\)O. In this case dry in a vacuum desiccator over P\(_2\)O\(_5\) or KOH until crisp. For further purification dissolve 5.5g in hot CCl\(_4\) (750mL), add charcoal (2g, this is necessary otherwise the acid may separate as an oil), filter, cool in ice-water until crystallisation is complete. Filter the acid, and the solvent on the crystals is removed by keeping the acid (4.5g) in a vacuum desiccator for 2 days. Slightly yellow crystals are obtained. It can be recrystd also from \(^{94}C_6H_6\)/pet ether, and can be distilled in vacuum. The acid is estimated by titration with standard NaOH. The phenylhydrazone is recrystallised from EtOH, m 163-164°; the semicarbazone acid has m 259°(dec) (from EtOH). The methyl ester distils at 137°/14mm, 110-111°/2mm, n\(^D\) 1.5850. [J Am Chem Soc 67 1482 1945; J Org Chem 24 1825 1959.]

Benzoyl glycine (hippuric acid) [495-69-2] M 179.2, m 188°, pK\textsuperscript{40} 3.59. Cryst from boiling H\(_2\)O. Dried over P\(_2\)O\(_5\).

Benzoyl isothiocyanate [532-55-8] M 163.2, m 25.5-26°, b 72.5-73°/6mm, 88-91°/20mm, 94-96°/21mm, 202.5-204°/724mm, 250-255°/atm, d\textsuperscript{25} 1.213, n\textsuperscript{D} 1.637. Distil over a small amount of P\(_2\)O\(_5\), whereby the distillate crystallises in prisms. It is readily hydrolysed by H\(_2\)O to give benzamide and benzoylurea, but with NH\(_3\) it gives benzoylurea m 210° which can be recrystd from EtOH. [J Am Chem Soc 62 1595 1940. 76 580 1954; Org Synth Coll Vol III 735 1955.]

Benzoyl peroxide [94-36-0] M 242.2, m 95°(dec). Dissolved in CHCl\(_3\) at room temperature and pptd by adding an equal volume of MeOH or pet ether. Similarly ppted from acetone by adding two volumes of distilled water. Has also been crystd from 50% MeOH, and from diethyl ether. Dried under vacuum at room
temperature for 24h. Stored in a desiccator in the dark at 0\(^\circ\). When purifying in the absence of water it can be EXPLOSIVE and it should be done on a very small scale with adequate protection. Large amounts should be kept moist with water and stored in a refrigerator. [Kim et al. J Org Chem 52 3691 1987.]

**p-Benzoylphenol (4-hydroxybenzophenone)** \[\{1137-42-4\} M 198.2, m 133.4-134.8\(^\circ\), pK\textsubscript{25} 7.95.** Dissolved in hot EtOH (charcoal), crystd once from EtOH/H\textsubscript{2}O and twice from benzene [Grunwald J Am Chem Soc 73 4934 1951; Dryland and Sheppard J Chem Soc Perkin Trans 1 125 1986].

**N-Benzoyl-N-phenylhydroxylamine** \[\{304-88-1\} M 213.2, m 121-122\(^\circ\). Recrystd from hot water, benzene or acetic acid.

**2-Benzoylpyridine** \[\{191-02-1\} M 191.2, m 118-119\(^\circ\), 147-148\(^\circ\), 152-153\(^\circ\), 155-156\(^\circ\)/18mm, \(n_r\) 1.6032, \(\varepsilon 422\) -2.4. Dissolve in Et\(_2\)O, shake with aqueous NaHCO\(_3\), H\(_2\)O, dry over MgSO\(_4\), it solidifies on cooling. The solid can be recrystd from pet ether. Its hydrochloride crystallises from Me\(_2\)CO, m 126-127\(^\circ\), and the 2,4-dinitrophenylhydrazone has m 193-195\(^\circ\). [J Organomet Chem 24 623 1970.]

**Benzoyl sulfide** \[\{644-32-6\} M 174.4, m 131.2-132.3\(^\circ\). About 300mL of solvent was blown off from a filtered soln of benzoyl disulfide (25g) in acetone (350mL). The remaining acetone was decanted from the solid which was recrystd first from 300mL of 1:1 (v/v) EtO\(_2\)乙酰乙酯, then from 300mL of EtOH, and finally from 240mL of 1:1 (v/v) EtOH/ethyl acetate. Yield about 40% [Pryor and Pickering J Am Chem Soc 84 2705 1962]. Handle in a fume cupboard because of TOXICITY and obnoxious odour.

**2,1-Benzoxathiol-3-one-1,1-dioxide** (sulfobenzoic acid anhydride) \[\{81-08-3\} M 184.2, m 116-124\(^\circ\), 126-127\(^\circ\), 128\(^\circ\), b 184-186\(^\circ\)/18mm. Purified by distn in a vacuum and readily solidifies to a crystalline mass on cooling. [J Am Chem Soc 34 1594 1912.] Alternatively purified by dissolving in the minimum vol of toluene and refluxing for 2h using a Dean-Stark trap. Evaporate under reduced pressure and distil the anhydride at 18mm. It can then be recrystd three times from its own weight of dry C\(_5\)H\(_6\). It is sensitive to moisture and should be stored in the dark in a dry atmosphere. The O-methylxolime has m 110-112\(^\circ\) [Tetrahedron Lett 3289 1972]. [Org Synth Coll Vol I 495 1941.] (See also p. 568 in Chapter 6.)

**Benzoxazolinone** \[\{59-49-4\} M 135.1, m 137-139\(^\circ\), 142-143\(^\circ\)(corrected), b 121-123\(^\circ\)/17mm, 335-337\(^\circ\)/760mm. It can be purified by recrystn from aqueous Me\(_2\)CO then by distn at atm pressure then in a vacuum. The methyl mercury salt recryst from aq EtOH has m 156-158\(^\circ\). [J Am Chem Soc 84 2705 1962].

**N-Benzoyl-o-tolylhydroxylamine** \[\{143-74-4\} M 227.3, m 104\(^\circ\). Recrystd from aqueous EtOH.

**Benzyl-2-acetamido-4,6-O-benzylidene-2-deoxy-\alpha-D-glucopyranoside** \[\{1334-63-0\} M 399.4, m 256-261\(^\circ\), 263-264\(^\circ\), [\(\alpha\)]\textsubscript{D}\textsuperscript{20} +120\(^\circ\) (c 1, pyridine). Wash with cold isoPrOH and crystallise from dioxane/isoPrOH. [J Org Chem 32 2759 1967.]

**Benzyl acetate** \[\{140-11-4\} M 150.2, m -51\(^\circ\), b 92-93\(^\circ\)/10mm, 134\(^\circ\)/102mm, 214.9\(^\circ\)/760mm, \(d\textsuperscript{20}\) 1.0562, \(n\textsuperscript{D}\textsubscript{490} 1.4994.** Purified by fractional distn, preferably in a good vacuum. Values of \(n\textsuperscript{25}\) of 1.5232-1.5242 seem too high and should be 1.4994. [J Org Chem 26 5180 1961.]

**Benzyl acetoacetate** \[\{5396-89-4\} M 192.2, b 130\(^\circ\)/2mm, 156-157\(^\circ\)/10mm, 162-167\(^\circ\)/15mm, 275-277\(^\circ\)/atm, \(d\textsuperscript{20}\) 1.114, \(n\textsuperscript{D}\textsubscript{15} 1.514.** Fractionate and collect fractions of expected physical properties. Otherwise add ca 10% by weight of benzyl alcohol and heat in an oil bath (160-170\(^\circ\), open vessel) for 30min during which time excess of benzyl alcohol will have distd off, then fractionate. [J Org Chem 17 77 1952.]

**4'-Benzylacetophenone** \[\{782-92-3\} M 210.3, m 73\(^\circ\). Crystd from EtOH (ca 1mL/g).

**Benzyl alcohol** \[\{100-51-6\} M 107.2, f -15.3\(^\circ\), b 205.5\(^\circ\), 93\(^\circ\)/10mm, d 0.981, n 1.54033, pK\textsubscript{25} 15.4. Usually purified by careful fractional distn at reduced pressure in the absence of air. Benzaldehyde, if present, can be detected by UV absorption at 283nm. Also purified by shaking with aq KOH and extracting with peroxide-free diethyl ether. After washing with water, the extract was treated with satd NaHS sol, filtered,
washed and dried with CaO and distd under reduced pressure [Mathews J Am Chem Soc 48 562 1926]. Peroxy compounds can be removed by shaking with a soln of Fe(I1) followed by washing the alcohol layer with distd water and fractionally distd.

**Benzylamine** [100-46-9] M 107.2, b 178°/742mm, 185°/768mm, d 0.981, n 1.5392, pK25 9.33. Dried with NaOH or KOH, then distd under N2, through a column packed with glass helices, taking the middle fraction. Has also been distd from zinc dust under reduced pressure.

**Benzylamine hydrochloride** [3287-99-8] M 143.6, m 248° (rapid heating). Crystd from water.

**N-Benzylaniline** [100-46-9] M 183.4, b 306-307°, d 0.981, n 1.5392, pK25 9.33. Crystd from pet ether (b 60-80°) (ca 0.5mL/g).

**1-Benzyl-1-aza-12-crown-4** (10-benzyl-1,4,7-trioxa-10-azacyclododecane) [84227-47-4] M 265.4, 122-125°/0.03mm, 140-143°/0.05mm, d4 1.09, nD 1.52, pK8 7.7. Dissolve in CH2Cl2 or CC4 (lg in 30mL) wash with H2O (30mL), brine (30mL), H2O (30 mL) again, dry over MgSO4 or Na2SO4 and evaporate. The residue in CH2Cl2 is chromatographed through A1203 (eluting with 10% EtOAc in hexane), evaporate, collect the correct fractions and distil (Kugelrohr). Log KN~ in dry MeOH at 25° for Na+ complex is 2.08. [Tetrahedron Lett 26 151 1985; J Org Chem 53 5652 1988.]

**Benzyl bromide** [100-39-0] M 171.0, m -40, b 870/12mm, 192°/760mm, d 1.438, n 1.575. Washed with conc H2SO4 (CARE), water, 10% Na2CO3 or NaHCO3 soln, and again with water. Dried with CaC12, Na2CO3 or MgSO4 and fractionally distd in the dark, under reduced pressure. It has also been thoroughly degassed at mm and redistd in the dark. This gave material with Amax (MeCN): 226nm (E 8200) [Mohammed and Kosower J Am Chem Soc 93 2709 1971]. Handle in a fume cupboard, extremely LACHRYMATORY.

**Benzyl bromoacetate** [5437-45-6] M 229.1, b 96-98°/0.1mm, 146°/12mm, 166-170°/22mm, d4 1.444, nD 1.5412. Dilute with Et2O, wash with 10% aqueous NaHC03, H20, dry (MgS04) and fractionate using a Fenske (glass helices packing) column. [J Chem Soc 1521 1956.]

**N-Benzyl-tert-butylamine** [33 78- 72 -I] M 163.3, b 91°/12mm, 109-110°/25mm, 218-220°/atm, d4 0.899, nD 1.4942., pK25 10.19. Dissolve in Et20, dry over KOH pellets, filter and fractionate in a N2 atmosphere to avoid reaction with CO2 from the air. The hydrochloride has m 245-246° (dec) (from MeOH + Me2CO) and the perchlorate has m 200-201°. [J Am Chem Soc 80 4320 1958.]

**Benzyl carbamate** [621-84-1] M 151.2, m 86°, 86-88°, 90-91°. If it smells of NH3 then dry in a vac desiccator and recryst from 2 vols of toluene and dry in a vac desiccator again. It forms glistening plates from toluene, and can be recrystd from H2O [J Org Chem 6 878 1941; Org Synth Coll Vol III 168 1955].

**Benzyl chloride** [100-44-7] M 126.6, m 139°, b 63°/8mm, d 1.100, n 1.538. Dried with MgSO4 or CaSO4, or refluxed with fresh Ca turnings, then fractionally distd under reduced pressure, collecting the middle fraction and storing with CaH2 or P2O5. Has also been purified by passage through a column of alumina. Alternatively it is dried over MgSO4 and distd in a vacuum. The middle fraction is degassed by several freeze-thaw cycles and then fractionated in an isolated fractionating column (which has been evacuated and sealed off at ~10-6 mm) over a steam bath. The middle fraction is retained. The final samples were vacuum distd from this sample and again retaining the middle fraction. The purity is >99.9% (no other peaks are visible on GLC and the NMR spectrum is consistent with the structure. [Mohammed and Kosower J Am Chem Soc 93 1709 1971.] IRRITANT and strongly LACHRYMATORY.

**N-Benzyl-8-chloropropionamide** [24752-66-7] M 197.7, m 94°. Crystd from MeOH.

**Benzyl cinnamate** [103-41-3] M 238.3, m 34-35°, 39°, b 154-157°/0.5mm, 228-230°/22mm. Recrystd to constant melting point from 95% EtOH and has the odour of balsam. Alternatively dissolve in
Et₂O, wash with 10% aqueous Na₂CO₃, H₂O, dry (Na₂SO₄), evaporate and fractionate under reduced press using a short Vigreux column. It decomposes when boiled at atm press. [J Am Chem Soc 74 547 1952; 84 2550 1962.]

**Benzyl cyanide** [140-29-4] M 117.1, b 100⁰/8mm, 233.5⁰/760mm, d 1.015, n 1.523. Benzyl isocyanide can be removed by shaking vigorously with an equal volume of 50% H₂SO₄ at 60⁰, washing with satd aq NaHCO₃, then half-saturated NaCl soln, drying and fractionally distilling under reduced pressure. Distn from CaH₂ causes some decomposition of this compound: it is better to use P₂O₅. Other purification procedures include passage through a column of highly activated alumina, and distn from Raney nickel. *Precautions should be taken because of possible formation of free TOXIC cyanide; use an efficient fume cupboard.*

**N-Benzyl dimethylamine** [103-83-3] M 135.2, b 66-67⁰/Emm, 83-84⁰/30mm, 92-93⁰/24mm, d 0.898, n 1.516, pK₂₅ 8.91. Dry over KOH pellets and fractionate over Zn dust in a CO₂-free atmosphere. It has a pKa₂₅ of 8.25 in 45% aq EtOH. Store under N₂ or in a vacuum. The picrate has m 94-95⁰, and the picrolonate has m 151⁰ (from EtOH). [Chem Ber 63 34 1930; J Am Chem Soc 55 3001 1933; J Chem Soc 2845 1957.]


**2-Benzyl-1,3-dioxolane** [101-49-5] M 164.2, b 98-99⁰/1mm, 110⁰/5mm, 137-138⁰/34mm, 240-242⁰/atm, d²₀ 1.087, n²₀ 1.532. Dissolve in CH₂Cl₂, wash well with 1M NaOH, dry over K₂CO₃, filter, evaporate and distil through a short path still (Kugelrohr). It has also been purified by preparative gas chromatography. [Synthesis 808 1974; J Org Chem 34 3949 1969.]

**Benzyl ether** [103-50-4] M 198.3, b 298⁰, 158-160⁰/0.1mm, d 1.043, n 1.54057. Refluxed over sodium, then distd under reduced pressure. Also purified by fractional freezing.


**Benzyl ethyl ether** [539-30-0] M 136.2, b 186⁰, 65⁰/10mm, d 0.949, n 1.4955. Dried with CaCl₂ or NaOH, then fractionally distd. [J Am Chem Soc 78 6079 1956.]

**Benzyl ethyl ketone (1-phenylbutan-2-one)** [1007-32-5] M 148.2, b 49-49.5⁰/0.1mm, 66-69⁰/1mm, 83-85⁰/5mm, 101-102⁰/10mm, 229-233⁰/atm, d²₀ 0.989, n²₅ 1.515. Purified by fractionation using an efficient column. It can be converted into the oxime and distd, b 117-118⁰/2mm, 145-146⁰/15mm, d²₀ 1.036, n²₀ 1.5363, decompose oxime and the ketone is redistilled. It can also be purified via the semicarbazone which has m 154 155⁰. [J Am Chem Soc 77 5655 1955; J Org Chem 15 8 1950.]

**S- (+) - and R- (-) Benzyl glycidyl ether (1-benzyloxyoxirane)** [S:14618-80-5] [R:16495-13-9] M 164.2, b 68⁰/10⁴mm, 105⁰/0.4mm, d²₀ 1.072, n²₀ 1.517, [α]₀²⁰ (+) and (-) 5.5⁰, [α]₀²⁰ (+) and (-) 5.1⁰ (c 5, toluene), [α]₀²⁰ (+) and (-) 1.79⁰ (c 5, CHCl₃), [α]₀²⁰ (+) and (-) 15.3⁰ (neat). The ether in EtOAc is dried (Na₂SO₄) then purified by flash chromatography using pet ether/EtOAc (5:1) as eluent. The ether is then distd through a short path dist apparatus (Kugelrohr) as a colourless liquid. Alternatively, distill in CHCl₃, wash with H₂O, dry (Na₂SO₄), evaporate and purify through silica gel chromatography. [J Chem Soc 1021 1967; Heterocycles 16 381 1981; Org Synth 69 82 1990; Synthesis 539 1989; Chem Pharm Bull Jpn 39 1385 1991.]

**3-Benzyl-5-(2-hydroxyethyl)-4-methylthiazolinium chloride** [4568-71-2] M 269.8, m 142-144⁰, 145-147⁰. Purified by recryst from EtOH or H₂O. If placed in a bath at 125⁰ and heated at 28⁰/min the m is 140.5-141.4⁰. [J Biol Chem 167 699 1947, J Am Chem Soc 79 4386 1957.]
O-Benzylhydroxylamine hydrochloride [2687-43-6] M 159.6, m 234-238° (sublimes), pK_{est} ~5.9. Recrystd from H_{2}O or EtOH.

N-Benzylideneaniline [538-51-2] M 181.2, m 48° (54°), b 300°/760mm. Steam volatile and crystd from *benzene or 85% EtOH.

Benzyl isocyanate [3173-56-6] M 181.2, m 48O (54O), b 300°. Steam volatile and

Benzyl isothiocyanate [622-78-6] M 149.2, b 123-124°/1mm, 138-140°/20mm, 255-260°/atm, d_{g}^{1.1234}, n_{D}^{1.6039}. Dissolve in Et_{2}O, filter, if there is any solid, and distil through an efficient column at 1 lmm with bath temperature at ca 150°. Characterise by reacting (0.5mL) in EtOH (1mL) with 50% NH_{2}NH_{2}.H_{2}O (2 mL) to give 4-benzylthiosemicarbazide as colourless needles which are recrystallised from EtOH, m 130°. [J Chem Soc 1582 1950; Justus Liebigs Ann Chem 612 11 1958; IR and UV: Acta Chem Scand 13 442 1959.]

S-Benzyl-isothiouronium chloride [538-28-3] M 202.7, two forms, m 150° and 175°, pK_{est} ~9.8 (free base). Crystd from 0.2M HCl (2mL/g) or EtOH and dried in air.

Benzylmalonic acid [616-75-1] M 194.2, m 121°, pK_{a}^{1} 2.91, pK_{a}^{2} 5.87. Crystd from *C&5.


Benzyl mercaptan [100-53-8] M 124.2, b 70.5-70.7°/9.5mm, d 1.058, m 15761, pK_{25} 9.43. Purified via the mercury salt [see Kern J Am Chem Soc 75 1865 1953], which was crystd from *benzene as needles (m 121°), and then dissolved in CHCl_{3}. Passage of H_{2}S gas regenerated the mercaptan. The HgS ppte was filtered off, and washed thoroughly with CHC_{13}. The filtrate and washings were evaporated to remove CHC_{l3}, then residue was fractionally distilled under reduced pressure [Mackle and McClean, Trans Faraday Soc 58 895 1962].

(-)-N-Benzyl-N-methylephedrinium bromide [benzyl(2-hydroxy-l-methyl-2-phenethyl) dimethylammonium bromide] [58648-09-2] M 350.3, m 209-211°, 212-214°, [α]_{D}^{25} -3.8° (c 1.45, MeOH), [α]_{D}^{25} -8.67° (c 1.45, MeOH). Recrystd from MeOH/Et_{2}O. [Justus Liebigs Ann Chem 710 1978.] The chloride is recrystd from EtOAc/n-hexane, m 198-199° [α]_{D}^{25} -8.67° (c 1.45, MeOH). [J Chem Soc, Perkin Trans 1 574 1981.]

Benzyl 4-nitrophenyl carbonate [13795-24-9] M 273.2, m 78-80°. Dissolve in Et_{2}O, wash with H_{2}O (3x) and satd aq NaCl, dry (MgSO_{4}), evap in vac and recryst residue from a small vol of MeOH, m 78-79°. Alternatively dissolve in Et_{2}O, wash with N HCl (2x), 0.5N NaHCO_{3} (4x) then H_{2}O, dry (Na_{2}SO_{4}), evap Et_{2}O and recryst residue from CHCl_{3}. Passage of H_{2}S gas regenerated the mercaptan. The HgS ppte was filtered off, and washed thoroughly with CHC_{l3}. The filtrate and washings were evaporated to remove CHC_{l3}, then residue was fractionally distilled under reduced pressure [Mackle and McClean, Trans Faraday Soc 58 895 1962].

Benzyl oxyacetyle chloride [19810-31-2] M 184.6, b 81°/0.2mm, 84-87°/0.4mm, 105-107°/5mm, d_{4}^{1.19}, n_{D}^{1.523}. Check IR to see if there are OH bands. If so then it may be contaminated with free acid formed by hydrolysis. Add oxalyl chloride (amount depends on contamination and needs to be judged, ca 3mols) heat at 50° in the absence of moisture for 1h and fractionate twice, b 81°/0.2mm (with bath temp at 81°). Excessive heating results in decomposition to give benzyl chloride. The anilide is formed by adding aniline in CHCl_{3} soln, m 49°. [Hely Chim Acta 16 1130 1933.]

Benzylxybutan-2-one [6278-91-7] M 178.2, b 90°-92°/0.1mm, 88-91°/0.5mm, 121-126°/5mm, d_{4}^{1.0275}, n_{D}^{1.5040}. Dissolve in CHCl_{3}, wash with H_{2}O, aqueous saturated NaHCO_{3}, H_{2}O, dry (MgSO_{4}), evaporate the CHCl_{3}, and fractionate. [J Am Chem Soc 79 2316 1957.]
Benzylloxycarbonyl chloride (Cbz-Cl, benzyl chloroformate) [501-53-1] M 170.6, b 103°/20mm, d 1.195, n 1.5190. Commercial material is better than 95% pure and may contain some toluene, benzyl alcohol, benzyl chloride and HCl. After long storage (e.g. two years at 4°, Greenstein and Winitz [The Chemistry of the Amino Acids Vol 2 p. 890, J Wiley and Sons NY, 1967] recommended that the liquid should be flushed with a stream of dry air, filtered and stored over sodium sulfate to remove CO2 and HCl which are formed by decomposition. It may further be distilled from an oil bath at a temperature below 85° because Thiel and Dent [Annalen 301 257 1898] stated that benzylloxycarbonyl chloride decarboxylates to benzyl chloride slowly at 100° and vigorously at 150°. Redistillation at higher vac below 85° yields material which shows no other peaks than those of benzylloxycarbonyl chloride by NMR spectroscopy.

LACHRYMATORY and TOXIC.


N-Benzylcarbonyl-N'-methyl-L-alaninamide [33628-84-1] M 236.3, m dec >200°. Recrystd from EtOAc.

5-Benzyloxindole [1215-59-4] M 223.3, m 96-97°; 100-103°, 104-106°, pK <0. Recrystd from *C6H6-pet ether or pet ether. The picrate, red crystals from *C6H6, has m 142-143°. [Chem Ind (London) 1035 1953; J Am Chem Soc 76 5579 1954; fluorescence: Biochem J 107 225 1968.]


S-(−)-3-Benzylxopropan-1,2-diol [17325-85-8] M 182.2, m 24-26°, b 117-118°/10-4mm, 115-116°/0.02mm, 121-123°/0.2mm, d16 1.1437, nD22 1.5295, [α]D15 -5.9° (neat). Purified by repeated fractional distn. [J Biol Chem 193 835 1951, 230 447 1958.]

2-Benzylphenol [28994-41-4] M 184.2, m 54.5°, b 312°/760mm, 175°/18mm, pK1m ~10.0 Crystd from EtOH, stable form has m 52° and unstable form has m 21°.

4-Benzylphenol (α-Phenyl-p-cresol) [101-53-1] M 184.2, m 84°, pK1m ~10.2. Crystd from water.

1-Benzyl-4-piperidone [3612-20-2] M 189.3, b 107-108°/0.2mm, 114-116°/0.3mm, 143-146°/5mm, 157-158°/11mm, d 1.059, n 1.538. If physical properties show contamination then dissolve in the minimum volume of H2O, made strongly alkaline with aqueous KOH, extract with toluene several times, dry the extract with K2CO3, filter, evaporate and distil the residue at high vacuum using a bath temp of 160-190°, and redistil. [J Chem Soc 3173 1957, J Am Chem Soc 53 1030 1930.] The hydrochloride has m 159-161° (from Me2CO + Et2O), and the picrate has m 174-182° (from Me2CO + Et2O). [Helv Chim Acta 41 1184 1958.]

2-Benzylpyridine [101-82-6] M 169.2, b 98.5°/4mm, d 1.054, n26 1.5771, pK15 5.13. Dried with NaOH for several days, then distd from CaO under reduced pressure, redistilling the middle fraction.

4-Benzylpyridine [2116-65-6] M 169.2, b 110.0°/6mm, d 1.065, n26 1.5814, pK25 5.59. Dried with NaOH for several days, then distd from CaO under reduced pressure, redistilling the middle fraction.

4-N-Benzylsulfanilamide [1709-54-2] M 262.3, m 175°. Crystd from dioxane/H2O.


Benzylthiocyanate [3012-37-1] M 149.2, m 43°, b 256° (dec). Crystd from EtOH or aqueous EtOH.
Benzyl toluene-\(p\)-sulfonate \([1024-41-5]\) M 162.3, m 58\(^\circ\). Crystd from pet ether (b 40-60\(^\circ\)).

Benzyltributylammonium bromide \([25316-59-0]\) M 356.4, m 169-171\(^\circ\), 174-175\(^\circ\). Recrystd from EtOAc/EtOH and EtOH/Et\(_2\)O. \([J \text{ Am Chem Soc} \ 73 4122 1951, 81 3264 1959.\]

Benzyl 2,2,2-trichloroacetimidate \([81927-55-1]\) M 252.5, b 106\(^\circ\)/0.5mm, m 3\(^\circ\), d 1.349, n 1.545. Purify by distn to remove up to 1% of PhCH\(_2\)OH as stabiliser. A soln in hexane can be stored for up to 2 months without decompn. It is hygroscopic and has to be stored dry. \([\text{Wessel et al. J Am Chem Soc, Perkin Trans 1} 12247 1985.\]

Benzyltrimethylammonium chloride \([156-93-9]\) M 185.7, m 238-239\(^\circ\)(dec). A 60% aq soln was evapd to dryness under vac on a steam bath, and then left in a vac desiccator containing a suitable dehydrating agent. The solid residue was dissolved in a small amount of boiling absolute EtOH and pptd by adding an equal volume of diethyl ether and cooling. After washing, the ppte was dried under vac \([\text{Karusch J Am Chem Soc} 73 1246 1951]\).

Benzyltrimethylammonium hydroxide (Triton B) \([100-85-6]\) M 167.3, d 0.91. A 38% soln (as supplied) was decolorized (charcoal), then evaporated under reduced pressure to a syrup, with final drying at 75\(^\circ\) and 1mm pressure. Prepared anhydrous by prolonged drying over P\(_2\)O\(_5\) in a vacuum desiccator.

Berbamine \([478-61-5]\) M 608.7, m 197-210\(^\circ\), \([\alpha]_D^{20} +115\(^\circ\) \text{(CHCl}_3\), pK\(_2^{20}\) 7.33. Crystd from pet ether.

Berberine \([2086-83-1]\) M 336.4, m 145\(^\circ\), pK\(_1^{20}\) 2.47, pK\(_2^{20}\) 11.73 (pseudobase?). Crystd from pet ether or ether as yellow needles.

Berberine hydrochloride (2H\(_2\)O) \([633-65-8]\) M 407.9, m 204-206\(^\circ\)(dec), pK 2.47. Crystn from water gives the dihydrate. The anhydrous salt may be obtained by recrystn from EtOH/Et\(_2\)O, wash with Et\(_2\)O and dry in a vacuum. The iodide has m 250\(^\circ\)(dec) (from EtOH). \([J \text{ Chem Soc} 113 503 1918; J \text{ Chem Soc} 2036 1969.\]

Betaine \([107-43-7]\) M 117.1, m 301-305\(^\circ\)(dec) (anhydrous), pK\(_2^{25}\) 1.83. Crystd from aq EtOH.

Betamethasone (9\(\alpha\)-fluoro-11\(\beta\),17\(\alpha\),21-trihydroxy-16\(\beta\)-methylpregna-1,4-diene-3,20-dione) \([378-44-9]\) M 392.5, m 231-136\(^\circ\)(dec), 235-237\(^\circ\)(dec), \([\alpha]_D^{20} +108\(^\circ\) \text{(c 1, Me}_2\text{CO)}\). Crystd from ethyl acetate, and has \(A_{\max}\) 238nm (log \(E\) 4.18) in MeOH.

Biacetyl (butan-2,3-dione) \([431-03-8]\) M 86.1, b 88\(^\circ\), d 0.981, n\(^{18.5} 1.3933\). Dried with anhydrous CaSO\(_4\), CaCl\(_2\) or MgSO\(_4\), then vacuum distd under nitrogen, taking the middle fraction and storing it at Dry-ice temperature in the dark (to prevent polymerization).

Bibenzyl \([103-29-7]\) M 182.3, m 52.5-53.5\(^\circ\). Crystd from hexane, MeOH, or 95% EtOH. It has also been sublimed under vacuum, and further purified by percolation through columns of silica gel and activated alumina.

Bicuculline \([485-49-4]\) M 367.4, m 215\(^\circ\) (196\(^\circ\), 177\(^\circ\)), \([\alpha]_D^{20} +159\(^\circ\) \text{(c 1, CHCl}_3\), pK 4.84. See bicuculline entry on p. 515 in Chapter 6.

Bicyclohexyl \([92-51-3]\) M 166.3, b 238\(^\circ\) \text{(cis-cis)}, 217-219\(^\circ\) \text{(trans-trans)}. Shaken repeatedly with aqueous KMnO\(_4\) and with conc H\(_2\)SO\(_4\), washed with water, dried, first from CaCl\(_2\) then from sodium, and distd. \([\text{Mackenzie J Am Chem Soc} 77 2214 1955.]\)

Bicyclo[3.2.1]octane \([6221-55-2]\) M 110.2, m 141\(^\circ\). Purified by zone melting.
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**Biguanide** [56-03-1] M 101.1, m 130° pK$_1$ 3.1, pK$_2$ 12.8. Crystd from EtOH.

**Bilirubin** [635-65-4] M 584.7, ε$_{450\text{nm}}$ 55,600 in CHCl$_3$, pK$_{\text{est}}$ 3.1. An acyclic tetapyrrole bile pigment with impurities which can be eliminated by successive Soxhlet extraction with diethyl ether and MeOH. It crystallises from CHCl$_3$ as deep red brown rhombs, plates or prisms, and is dried to constant weight at 80° under vacuum. [Gray et al. J Chem Soc 2264, 2276 1961.]


(±)-1,1'-Bi-(2-naphthol) [1,1'-di-(2-naphthol)] [602-09-5; 41024-90-2] M 286.3, m 215-217°, 218°, pK$_{\text{est}}$ 7.1, pK$_{\text{est}}$(±) -11.2. Crystd from toluene or benzene (10mL/g). When crystd from chlorobenzene it had m 238°. Sol in dioxane is 5%. [Tetrahedron 27 5999 1971.]

1,1'-Bi-(2-naphthol) [1,1'-di-(2-naphthol)] [R-(+)- 18531-94-7; S-(-) 18531-99-2] M 286.3, m 207.5-208.5°, 209-211°, [α]$_D$ 37.4° (c 0.5, THF), [α]$_D$ 51° (c 0.1, THF), pK as above. Dissolve in cold 2.5N NaOH, extract with CH$_2$Cl$_2$, and acidify with 5% HCl. Collect the white ppt and recryst from aq EtOH and dry in a vacuum. [Tetrahedron 27 5999 1971.]

**1,1'-Binaphthyl** [8-7-8-2] M 254.3, m 188°. Crystd from *benzene.

**Biphenyl** [92-52-4] M 154.2, m 70-71°, b 255°, d 0.992. Crystd from EtOH, MeOH, aq MeOH, pet ether (b 40-60°) or glacial acetic acid. Freed from polar impurities by passage through a alumina column in *benzene, followed by evapn. A in CCl$_4$ has been purified by vac distn and by zone refining. Treatment with maleic anhydride removed anthracene-like impurities. Recrystd from EtOH followed by repeated vacuum sublimation and passage through a zone refiner. [Taliani and Bree J Phys Chem 88 2351 1984.]


4-Biphenylcarbonyl chloride [14002-51-8] M 216.7, m 114-115°. Dissolve in a large volume of pet ether (10 x, b 50-70°), filter through a short column of neutral alumina, evaporate to dryness in vacuo and recryst from pet ether (b 60-80°). LACHRYMATORY.
α-(4-Biphenyl)butyric acid [959-10-4] M 240.3, m 175-177°, pK<sub>est</sub> ~4.5. Crystd from MeOH.

γ-(4-Biphenyl)butyric acid [6057-60-9] M 240.3, m 118°, pK<sub>est</sub> -4.8. Crystd from MeOH.

2,2'-Bipyridyl [366-18-7] M 156.2, m 70.5°, b 273°, pK<sub>i</sub> 5 -0.52, pK<sub>i'</sub> 4.44. Crystd from hexane, or EtOH, or (after charcoal treatment of a CHCl<sub>3</sub> soln) from pet ether. Also ppted from a conc soln in EtOH by addition of H<sub>2</sub>O. Dried in a vacuum over P<sub>2</sub>O<sub>5</sub>. Further purification by chromatography on Al<sub>2</sub>O<sub>3</sub> or by sublimation. [Airoldi et al. J Chem Soc, Dalton Trans 1913 1986.]


2,2'-Bipyridylamine [1202-34-2] M 171.2, m 95.1°, pK<sub>est</sub> ~5.0. Crystd from Me<sub>2</sub>CO.

2,2'-Biquinolin-4,4'-dicarboxylic (2,2'-bicheninonic) acid [1245-13-2] M 344.3, m 367°, pK<sub>est</sub> ~4.0. Dissolve in dilute NaOH and ppte with acetic acid, filter, wash well with H<sub>2</sub>O and dry at 100° in a vacuum oven. Attempts to form a picrate failed. The methyl ester (SOCl<sub>2</sub>-MeOH) has m ~165.6-166°. [J Am Chem Soc 64 1897 1942; 68 2705 1946.] For di-K salt see entry in Chapter 5.  

Bis-acrylamide (N,N'-methylene bisacrylamide) [110-26-9] M 154.2, m >300°. Recrystd from MeOH (100g dissolved in 500mL boiling MeOH) and filtered without suction in a warmed funnel. Allowed to stand at room temperature and then at -15°C overnight. Crystals collected with suction in a cooled funnel and washed with cold MeOH). Crystals air-dried in a warm oven. TOXIC.

Bis-(4-aminophenyl)methane [101-77-9] M 198.3, m 92-93°, b 232°/9mm, pK<sub>est</sub> ~4.9. See 4,4'-diaminodiophenylmethane on p. 189.

2,5-Bis-(4-aminophenyl)-1,3,4-oxadiazole (BAO) [2425-95-8] M 252.3, m 252-255°, 254-255°. Recrystd from EtOH using charcoal and under N<sub>2</sub> to avoid oxidation.


Bis-(p-bromophenyl)ether [53563-56-7] M 328.0, m 60.1-61.7°. Crystd twice from EtOH, once from *benzene and dried under vac [Purcell and Smith J Am Chem Soc 83 1063 1961].

Bis-N-tert-butylxoycarbonyl-L-cystine, [10389-65-8] M 440.5, m 144.5-145°, [α]<sub>D</sub> ~133.2° (c 1, MeOH), pK<sub>est</sub> ~2.9. Crystd from in EtOAc by adding hexane [Ferraro Biochem Prep 13 39 1971].

2R,3R-(+)-1,4-Bis-(4-chlorobenzoyl)-2,3-butanediol [85362-86-3] and 2S,3S-(–)1,4-Bis-(4-chlorobenzoyl)-2,3-butanediol [85362-85-2] M 371.3, m 76-77°, [α]<sub>D</sub> (+) and (-) 6.4° (c 3.11 CHCl<sub>3</sub>). Recrystd from toluene-hexane. [Tetrahedron 40 4617 1984.]

Bis-(β-chloroethyl) ether [111-44-4] M 143.0, b 94°/33mm, 178.8°, d 1.220, n 1.45750. Wash with conc H₂SO₄, then Na₂CO₃ soln, dry with anhydrous Na₂CO₃, and finally pass through a 50cm column of activated alumina before distn. Alternatively, wash with 10% ferrous sulfate soln to remove peroxides, then H₂O, dry with CaSO₄, and dist in vac. Add 0.2% of catechol to stabilise it. VERY TOXIC.

N,N-Bis-(2-chloroethyl)2-naphthylamine (chlnornaphthazine) [494-03-1] M 268.3, m 54-56°, b 210°/5mm, pK₁ 8.84, pK₂ 9.47. Crystd from pet ether. CARCINOGENIC.

Bis-(chloromethyl)durene [3022-16-0] M 231.2, m 197-198°. Crystd three times from *benzene, then dried under vacuum in an Abderhalden pistol.

3,3'-Bis-(chloromethyl)oxacyclobutane [78-71-7] M 155.0, m 18.9°. Shaken with aqueous NaHCO₃ or FeSO₄ to remove peroxides. Separated, dried with anhydrous Na₂SO₄, then distd under reduced pressure from a little CaH₂ [Dainton, Ivin and Walmsley Trans Faraday Soc 65 17884 1960].

2,2-Bis-(p-chlorophenyl)-1,1-dichloroethane (p,p'-DDD) [72-54-8] M 320.1, m 109-111°, 111-112°. Crystd from EtOH and dried in a vac. Purity checked by TLC. TOXIC INSECTICIDE.

2,2-Bis-(p-chlorophenyl)-1,1-dichloroethylene (p,p'-DDE) [72-55-9] M 318.0, m 89-91°. Crystd from EtOH and dried in a vac. Purity checked by TLC. POSSIBLE CARCINOGEN.

2,2-Bis-(4-chlorophenyl)-1,1,1-trichloroethane (p,p'-DDT) [50-29-3] M 354.5, m 108.5-109°, 108°. Crystd from n-propyl alcohol (5mL/g), then dried in air or an air oven at 50-60°. Alternatively crystd from 95% EtOH, and checked by TLC.

2,2'-Bis-[di-(carboxymethyl)-amino]diethyl ether, (HOCH₂COOH)₂N CH₂CH₂OCH₂CH₂N-(CH₂COOH)₂ [923-73-9] M 336.3, pK₁ 1.8, pK₂ 2.76, pK₃ 8.84, K₄ 9.47. Crystd from EtOH.

4,4'-Bis-(diethylamino)benzophenone [90-93-7] M 324.5, m 95-96°, pKₑₐ(1)-1.8, pKₑₐ(2) 3.3. Crystd from EtOH (25mL/G) and dried under vacuum.

Bis-(4-dimethylaminobenzylidene)benzidine [6001-51-0] M 454.5, m 318°, pKₑₐ -0. Crystd from nitrobenzene.

1,8-Bis-(dimethylamino)naphthalene (Proton sponge) [20734-58-1] M 214.3, m 47-48°, pK 12.34 (pK₂ -10.5 from half protonation in 86% H₂SO₄). Crystd from EtOH and dried in a vacuum oven. Stored in the dark. Also see N,N,N',N'-Tetramethyl-1,8-naphthalenediamine on p. 364.

Bis-(dimethylthiocarbamyl)disulfide (tetramethylthiuram disulfide, Thiram) [137-26-8] M 240.4, m 155-156°. See tetramethylthiuram disulfide on p. 365.

Bis-(4-fluoro-3-nitrophenyl) sulfone [312-30-1] M 344.3, m 193-194°. Recrystd from Me₂CO and H₂O (5:1). It should give a yellow colour in aqueous base. [Chem Ber 86 172 1953.]

N,N-Bis-(2-hydroxyethyl)-2-aminoethanesulfonic acid (BES) [10191-18-1] M 213.3, m 150-155°, pK 2.7. Crystd from aqueous EtOH.


3,4-Bis-(4-hydroxyphenyl)hexane [5635-50-7] M 270.4, m 187°. Freed from diethylstilboestrol by zone refining.

1,4-Bismethylaminoanthraquinone (Disperse Blue 14) [2475-44-7] M 266.3, \( \lambda_{\text{max}} \) 640 (594)nm. Purified by thin-layer chromatography on silica gel plates, using toluene/acetone (3:1) as eluent. The main band was scraped off and extracted with MeOH. The solvent was evaporated and the dye was dried in a drying pistol [Land, McAlpine, Sinclair and Truscott J Chem Soc, Faraday Trans I 72 2091 1976].

Bis-(1-naphthylmethyl)amine [5798-49-2] M 329.4, m 62°, \( pK_{\text{est}} \) -8.4. Crystd from pet ether.

\( N,N' \)-Bis-(nicotinic acid) hydrazide [840-78-8] M 227-228°, m dec 200°, \( pK_{\text{est}} \) 3.3. Crystd from water.

Bis-(4-nitrophenyl) carbonate [5070-13-3] M 304.3, m 142-143°. Dissolve in CHC13, wash with 2N NaOH (3 x) and once with conc HCl, dry (Na2SO4), evaporate and crystallise from toluene (authors say 15 vols of benzene, prisms). [Helv Chim Acta 46 795 1963.]

Bis-(2-nitrophenyl) disulfide [55500-6] M 308.3, m 192-195°, 195°, 194-197°, 198-199°. Purified by recrystn from glacial AcOH or from \( \text{C}_6\text{H}_5\text{O}_2\text{N}_2 \) and the yellow needles are dried in an oven at 100° until the odour of the solvent is absent. It is sparingly soluble in EtOH and Me2CO. [Bogert and Stull Org Synth Coll Vol I 220 1941; Bauer and Cymeman J Chem Soc 3434 1949.]

Bis-(4-nitrophenyl) ether [101-63-3] M 260.2, m 142-143°. Crystd from *C6H6, and dried under vacuum.

Bis-(4-nitrophenyl) methane [1817-74-9] M 258.2, m 183°. Crystd twice from *C6H6, and dried under vacuum.

Bisnorcholanic acid (pregnane-20-carboxylic acid) [28393-20-6] M 332.5, m 214° (\( \alpha \)-form), 242° (\( \beta \)-form), 210-211° (\( \gamma \)-form), 184° (\( \delta \)-form), 181° (\( \epsilon \)-form), \( pK_{\text{est}} \) 5.0. Crystd from EtOH (\( \alpha \)-form), or acetic acid (all forms).

3,3'-Bis-(phenoxy methyl)oxacyclobutane [1224-69-7] M 270.3, m 67.5-68°. Crystd from MeOH.

1,4-Bis-(2-pyridyl-2-vinyl)benzene [20218-87-5] M 284.3, \( pK_{\text{est}} \) 5.4. Recrystd from xylene, then chromatography (in the dark) on basic silica gel (60-80-mesh), using CH2Cl2 as eluent. Vacuum sublimed in the dark to a cold surface at 10-3 torr.

Bis-(trichloromethyl) carbonate (triphosgene) [32315-10-9] M 296.8, m 79-83°, 81-83°, b 203-206° (slight decomp). A good solid substitute for phosgene (using a third mol per mol). Cryst from pet ether and wash with anhydrous cold Et2O, degas at 200mm then dry at 0.1mm (over H2SO4). It is a lachrymator, is TOXIC and should be handled with gloves and in an efficient fume hood. [Eckert and Forster Angew Chem, Int Ed Engl 26 894 1987; Aldrichimica Acta 21 47 1988.]

Bistrifluoroacetamide [407-24-9] M 209.1, m 85°, b 135-136°/744mm, 141°/760mm. Major impurity is trifluoroacetamide. Add trifluoroacetic anhydride, reflux for 2h and fractionate using a Vigreux column at atmospheric pressure. [J Chromatogr 78 273 1973.]

Bis-(trifluoroacetoxyl)iodobenzene [2712-78-9] M 430.0, m 112-114° (dec), 120-121°, 124-126°. Cryst from warm trifluoroacetic acid and dry over NaOH pellets. Recrystd from Me2CO/pet ether. Melting point depends on heating rate. [Synthesis 445 1973.]

Biuret (allophanic acid amide, carbamoylurea) [108-19-0] M 103.1, sinters at 218° and chars at 270°, \( pK_{1} \) 0.88, \( pK_{2} \) >4. Crystd from BoOH.
Bixin (6,6'-diapoy, 6,6'-carotenedioic acid monomethyl ester) [6983-79-5] M 394.5, m 198°, 217°(dec), $\lambda_{max}$ (CHCl$_3$) 209, 475 and 443nm, $pK_{est}$ ~4.3. Crystd from Me$_2$CO (violet prisms) [Pattenden et al. J Chem Soc (C) 235 1970].


(±)-Borneol [6627-72-1] M 154.3, m 130°(dec). Crystd from pet ether (b 60-80°).

Brazilin [474-07-7] M 269.3, m 130°(dec), $pK_{est(1)}$ -9.3, $pK_{est(2)}$ -10.0, $pK_{est(3)}$ -12.5 (all phenolic). Crystd from EtOH. 


Brilliant Green (4-dimethylaminotriphenyl carbinol) [633-03-4] M 482.7, m 209-211°(dec), $pK$ 4.75. Purified by pptn as the perchlorate from aqueous soln (0.3%) after filtering, heating to 75° and adjustment to pH 1-2. Recrystd from EtOH/water (1:4) [Kerr and Gregory Analyst (London) 94 1036 1969].


4-Bromoacetanilide [103-88-8] M 214.1, m 167°. Crystd from aq MeOH or EtOH. Purified by zone refining.

Bromoacetic acid [79-08-3] M 138.9, m 50°, b 118°/15mm, 208°/760mm, $pK$ 2.92. Crystd from pet ether (b 40-60°). Diethyl ether soln passed through an alumina column, and the ether evaporated at room temperature under vacuum. LACHRYMATORY.

Bromoaceton [598-31-2] M 137.0, b 31.5°/8mm. Stood with anhydrous CaCO$_3$, distd under low vacuum, and stored with CaCO$_3$ in the dark at 0°. LACHRYMATORY.


$\omega$-Bromoacetophenone (phenacyl bromide) [70-11-1] M 199.1, m 57-58°. Crystd from EtOH, MeOH or from pet ether (b 80-100°). [Tanner J Org Chem 52 2142 1987].

4-Bromoaniline [106-40-1] M 172.0, m 66°, $pK$ 3.86. Crystd (with appreciable loss) from aqueous EtOH.

2-Bromoanisole [578-57-4] M 187.0, f 2.5°, b 124°/40mm, d 1.513, n$^2$ 1.5717. Crystd by partial freezing (repeatedly), then distd under reduced pressure.

4-Bromoanisole [104-92-7] M 187.0, f 13.4°, b 124°/40mm, d 1.495, n$^2$ 1.5617. Crystd by partial freezing (repeatedly), then distd under reduced pressure.


4-Bromobenzal diacetate [55605-27-1] M 287.1, m 95°. Crystd from hot EtOH (3mL/g).
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Bromobenzene [108-86-1] M 157.0, b 155.9°, d 1.495, n 1.5588, n\(^{15} \) 1.56252. Washed vigorously with conc H\(_2\)SO\(_4\), then 10% NaOH or NaHCO\(_3\) solns, and H\(_2\)O. Dried with CaCl\(_2\) or Na\(_2\)SO\(_4\), or passed through activated alumina, before refluxing with, and distilling from, CaH\(_2\), using a glass helix-packed column.

4-Bromobenzene diazonium tetrafluoroborate [673-40-5] M 270.8, m 133° (dec), 135-140° (dec). Wash with Et\(_2\)O until the wash is colourless and allow to dry by blowing N\(_2\) over it. Store at 0-4° in the dark. [Chem Ber 64 1340 1931.]

4-Bromobenzenesulfonyl chloride [98-58-8] M 255.5, m 73-75°, 74.3-75.1, 75-76°, 77°, b 153°/15mm, 150.6°/13mm. Wash with cold water, dry and recryst from pet ether, or from ethyl ether cooled in powdered Dry-ice after the ether soln had been washed with 10% NaOH until colourless, then dried with anhydrous Na\(_2\)SO\(_4\). Alternatively dissolve in CHCl\(_3\), wash with H\(_2\)O, dry (Na\(_2\)SO\(_4\)), evaporate and crystallise. [J Am Chem Soc 62 51 1940.]

Test for the SO\(_2\)Cl group by dissolving in EtOH and boiling with NH\(_4\)CNS whereby a yellow amorphous ppt forms on cooling [J Am Chem Soc 25 198 1901.]

o-Bromobenzoic acid [88-65-3] M 201.0, m 148.9°, pK\(^{20} \) 2.88. Crystd from C\(_6\)H\(_6\) or MeOH.

m-Bromobenzoic acid [585-76-2] M 201.0, m 155°, pK\(^{25} \) 3.81. Crystd from acetone/water, MeOH or acetic acid.

p-Bromobenzoic acid [586-76-5] M 219.5, m 36-39°, 39.8°, 41°, b 62°/0.1mm, 104.5°/6mm, 126.4-127.2°/14mm. Check IR of a film to see if OH bands are present. If absent then recryst from pet ether and dry in a vacuum. If OH bands are weak then distil in vacuo and recryst if necessary. If OH bands are very strong then treat with an equal volume of redistilled SOCl\(_2\) reflux for 2h then evaporate excess of SOCl\(_2\) and distill residual oil or low melting solid. Store in the dark away from moisture. LACHRYMATORY. [Martin and Partington J Chem Soc 1175 1936.]

p-Bromobenzophenone [90-90-4] M 261.1, m 81°. Crystd from EtOH.

p-Bromobenzoyl chloride [586-75-4] M 219.5, m 36-39°, 39.8°, 41°, b 62°/0.1mm, 104.5°/6mm, 126.4-127.2°/14mm. Check IR of a film to see if OH bands are present. If absent then recryst from pet ether and dry in a vacuum. If OH bands are weak then distill in vacuo and recryst if necessary. If OH bands are very strong then treat with an equal volume of redistilled SOCl\(_2\) reflux for 2h then evaporate excess of SOCl\(_2\) and distill residual oil or low melting solid. Store in the dark away from moisture. LACHRYMATORY. [Martin and Partington J Chem Soc 1175 1936.]

p-Bromobenzyl bromide [589-15-1] M 249.9, m 60-61°. Crystd from EtOH. LACHRYMATORY.

p-Bromobenzyl chloride [589-17-3] M 205.5, m 40-41°, b 105-115°/12mm. Crystd from EtOH. LACHRYMATORY.

p-Bromobiphenyl [92-66-0] M 233.1, m 88.8-89.2°. Crystd from abs EtOH and dried under vacuum.

2-Bromobutane [78-76-2] M 137.0, b 91.2°, d 1.255, n 1.4367, n\(^{25} \) 1.4341. Washed with conc HCl, water, 10% aqueous NaHSO\(_3\), and then water. Dried with CaCl\(_2\), Na\(_2\)SO\(_4\) or anhydrous K\(_2\)CO\(_3\), and fractionally distd through a 1m column packed with glass helices.

(+)3-Bromocamphor-8-sulfonic acid [5344-58-1] M 311.2, m 195-196°(anhydrous), [\(\alpha\)]\(_D^{20} \) +88.3° (in H\(_2\)O), pK ~0. Crystd from water.

IR(endo,anti)-3-Bromocamphor-8-sulfonic acid ammonium salt see entry in Chapter 5.

(+)3-Bromocamphor-10-sulfonic acid hydrate [67999-30-8] M 329.2, m 119-121°, [\(\alpha\)]\(_D^{20} \) +98.3° (in H\(_2\)O), pK ~0. Crystd from water.
4-Bromo-4'-chlorobenzophenone \([27428-57-5]\) M 295.6, m 150°. Crystd from EtOH or \(\text{C}_6\text{H}_6\) and further purified by zone refining (100 passes) [Grove and Turner \textit{J Chem Soc} 509 1929; Lin and Hanson \textit{J Phys Chem} 91 2279 1987].

Bromocresol Green (3',3'',5',5''-tetrabromo-m-cresolsulfonphthalein) \([76-60-8]\) M 698.0, m 218-219°(dec), 225°(dec), pK 4.51. Crystd from glacial acetic acid or dissolved in aqueous 5% NaHCO\(_3\) soln and ppted from hot soln by dropwise addition of aqueous HCl. Repeated until the extinction did not increase \(\lambda_{\text{max}} 423\text{nm}\). Indicator at pH 5.2 (yellow) and pH 6.8 (purple).

Bromocresol Purple (5',5''-dibromo-o-cresolsulfonphthalein) \([15-40-2]\) M 540.2, m 241-242°(dec), pK\(_1\) -2.15, pK\(_2\) 6.3. Dissolved in aqueous 5% NaHCO\(_3\) soln and ppted from hot soln by dropwise addition of aqueous HCl. Repeated until the extinction did not increase \(\lambda_{\text{max}} 419\text{nm}\). Can also be crystd from benzene. Indicator at pH 5.2 (yellow) and pH 6.8 (purple).

5-Bromocytosine \([2240-25-7]\) M 190.0, m 245-255°(dec), 250°(dec), pKi5 3.04, pKi5 10.33. Recryst from H\(_2\)O or 50% aq EtOH. Alternatively, dissolve ca 3g in conc HCl (10mL) and evaporate to dryness. Dissolve the residual hydrochloride in the minimum volume of warm H\(_2\)O and make faintly alkaline with aq NH\(_3\). Collect the crystals and dry in a vacuum at 100°. [\textit{J Am Chem Soc} 56 134 1934.1

p-Bromo-N,N-dimethylaniline \([586-77-6]\) M 200.1, m 55°, b 264°, pK\(_2\) 4.23. Refluxed for 3h with two equivalents of acetic anhydride, then fractionally distd under reduced pressure.

1-Bromo-2,4-dinitrobenzene \([584-48-5]\) M 247.0, m 75°. Crystd from ethyl ether, isopropyl ether, 80% EtOH or absolute EtOH.

2-(2-Bromoethyl)-1,3-dioxane \([33884-43-4]\) M 195.1, b 67-70°/2.8mm, 71-72°/4mm, 95°/15mm, d \(20 1.44, n \gamma 1.4219\). Purify by vacuum fractionation. Also dissolve in Et\(_2\)O, wash with aqueous NaHCO\(_3\), dry extract with Na\(_2\)SO\(_4\), filter and fractionate. NMR in CCl\(_4\) has \(6 1.3 (m, 1H), 2.1 (m, 3H), 3.36 (t, 2H), 3.90 (m, 4H) and 4.57 (t, H). [\textit{J Org Chem} 34 1122 1969; \textit{J Pharm Sci} 60 1250 1971.1

2-(2-Bromoethyl)-1,3-dioxolane \([18742-02-4]\) M 181.1, b 68-80°/8mm, 68-73°/10mm, 78-80°/20mm, d \(20 1.510, n \gamma 1.479\). Dissolve in pentane, wash with 5% aqueous NaHCO\(_3\), dry (Na\(_2\)SO\(_4\)), and evaporate. Distil the residue. [NMR: \textit{J Org Chem} 34 1122 1969; \textit{J Pharm Sci} 60 1250 1971.1

N-(2-Bromoethyl)phthalimide \([574-98-1]\) M 254.1, m 81-83°, 82.5-83.5°. The following is to be carried out in an efficient FUME HOOD. Dissolve the compound (180g) in CS\(_2\) (500 mL) by refluxing for 15 min (to cause the separation of the most likely impurity, 1,2-diphthalimidoethane), filter and evaporate under reduced pressure. The product forms light tan crystals. (m 78-80°). Recryst from EtOH (charcoal) [the compound (50g) is dissolved in hot 75% EtOH (200mL), boiled for ca 10 min, carbon added (5g, Norite), filtered and cooled to 0°, as white crystals (40g) which can be recrystd (m 80-81°) and further recrystn gave m 82-83°. [\textit{Org Synth} Coll Vol I 119 1932, \textit{Synthesis} 389 1976; NMR: \textit{Bull Soc Chim Fr} II-165 1979.]

Bromoform \([75-25-2]\) M 252.8, f 8.1°, 55-56°/35mm, 149.6°/760mm, d \(15 2.9038, d \gamma 2.86460, n \gamma 1.60053, n \lambda 1.5988\). Storage and stability of bromoform and chloroform are similar. Ethanol, added as a stabilizer, is removed by washing with H\(_2\)O or with saturated CaCl\(_2\) soln, and the CHBr\(_3\), after drying with CaCl\(_2\) or K\(_2\)CO\(_3\), is fractionally distd. Prior to distn, CHBr\(_3\) has also been washed with conc H\(_2\)SO\(_4\) until the acid layer no longer became coloured, then dilute NaOH or NaHCO\(_3\), and H\(_2\)O. A further purification step is fractional crystn by partial freezing.

3-Bromofuran \([22037-28-1]\) M 147.0, b 38.5°/40mm, 50°/110mm, 102.5-103°/atm, d 1.661, n 1.4970. Purified by two steam distillations and dried over fresh CaO. It can be dried over Na metal (no obvious reaction) and fractionated. It is not very soluble in H\(_2\)O but soluble in organic solvents. Freshly distilled, it is a clear oil, but darkens on standing and eventually resinifies. It can be stored for long periods by covering the oil with an alkaline soln of hydroquinone and redistilled when required. It forms a characteristic
(±)-2-Bromohexadecanoic acid (2-bromopalmitic acid) \[18263-25-7\] M 335.3, m 51-53°, 52.3-52.5°, 53°, pK\(_{\text{Em}}\) ~3.2. Recryst from pet ether (b 60-80°, charcoal) and finally from EtOH. The ethyl ester has b 177-178°/2mm, d\(_2^28\) 1.0484, n\(_D^23\) 1.4560. [IR: J Org Chem 21 1426 1956.]

5-Bromoindole \[10075-50-0\] M 196.1, m 90.5-91°, 90-92°, pK 16.13 (NH). Purified by steam distn from a faintly alkaline soln. Cool the aqueous distillate, collect the solid, dry in a vacuum desiccator over P\(_2\)O\(_5\) and recryst from aqueous EtOH (35% EtOH) or pet ether-Et\(_2\)O.

5-Bromoisatin \[87-48-9\] M 226.0, m 245°(dec), 251-153°, 255-256°. Forms red prisms or needles from EtOH. The N-acetate crystallises as yellow prisms from C\(_6\)H\(_6\), m 170-172°, and the N-methyl derivative form orange-red needles from MeOH, m 172-173°. [Chem Ber 47 360 1914, 53 1545 1920; Red Trav Chim Pays-Bas 73 197 1954; Tetrahedron Lett 215 1978.]

6-Bromoisatin \[6326-79-0\] M 226.0, m 270°, pK 10.35. Recryst from AcOH (yellow needles). It is a plant growth substance. [Sadler J Org Chem 21 169 1956.]

2-Bromomethylanthraquinone \[7598-10-9\] M 301.1, m 200-202°. Recryst from AcOH, the crystals are washed with a little Et\(_2\)O, dried in air and then in vac at 100°. It is prepared by bromination of 2-methylanthraquinone with Br\(_2\)/PhN\(_2\O2\) at 145-150°, or N-bromosuccinimide in CCl\(_4\) containing a trace of (PhC\(_O\)O)\(_2\).

1-Bromonaphthalene [90-11-9] M 207.1, b 118°/6mm, d 1.489. Purified by passage through activated alumina, and three vacuum distns.

2-Bromonaphthalene [580-13-2] M 207.1, m 59°. Purified by fractional elution from a chromatographic column. Crystd from EtOH.

1-Bromo-2-naphthol [573-97-7] M 223.1, m 76-78°, pKₑᵦ ~8.0. Crystd from EtOH.


5-Bromonicotinic acid [20826-04-4] M 202.0, m 178-182°, 189-190°, pKₑᵦ ~4.4, pKₑᵦ ~4.02 (50% aq EtOH). Recryst from H₂O and then from EtOH using charcoal. The amide has m 219-219.5° (from aq EtOH) and the methyl ester prepared by addition of ethereal diazomethane can be purified by sublimation in a vacuum and has m 98-99°, the acid chloride also can be sublimed in vacuo and has m 74-75° and gives the methyl ester in MeOH. [J Prakt Chem 138 244 1933; J Am Chem Soc 70 2381 1948; 82 4430 1960; J Chem Soc 35 1978.]

o-Bromo-4-nitroacetophenone [199-81-0] M 244.1, m 98°. Crystd from *C₆H₆-pet ether.


1-Bromo-octadecane [112-89-0] M 333.4, m 26°, 27.3°, 28-30°, b 178-179°/2mm, 214-218°/15mm, d²⁰ 0.976, nᵣ 1.461. Twice recryst from the melt then distilled under vacuum three times and using the middle cut. Alternatively, wash the oil with aqueous Na₂SO₄, then conc H₂SO₄ (cool) and again with aqueous Na₂SO₄ and then fractionate. [J Am Chem Soc 55 1574 1933; 72 171 1950; IR: Aust J Chem 12 743 1959; IR: Bull Soc Chim Fr 516 1957.]


p-Bromophenacyl bromide [99-73-0] M 277.9, m 110-111°. Crystd from EtOH (ca 8mL/g).

o-Bromophenol [95-56-7] M 173.0, b 194°, d 1.490, pKₑᵦ ~8.45. Purified by at least two passes through a chromatographic column.

p-Bromophenol [106-41-2] M 173.0, m 64°, pKₑᵦ ~9.36. Crystd from CHCl₃, CCl₄, pet ether (b 40-60°), or water and dried at 70° under vacuum for 2h.

Bromophenol Blue (3,3',5,5'-tetrabromophenolsulfonephthalein) [115-39-9] M 670.0, m 270-271°(dec), 273°(dec), λmax 422nm, pK 3.62. Crystd from benzene or acetone/glacial acetic acid, and air dried. Indicator at pH 3.0 (yellow) and pH 4.6 (purple).

(4-Bromophenoxy)acetic acid [1878-91-7] M 231.1, m 158°, pKₑᵦ ~3.13. Crystd from EtOH.
3-(4-Bromophenoxy)propionic acid [93670-18-9] M 247.1, m 146°, pK_{EtOH} ~4.2. Crystd from EtOH.


4-Bromophenylhydrazine [589-21-9] M 187.1, m 108-109°, pK 20-5.6 (aq H₂SO₄), pK 3 5.05. Crystd from H₂O.

4-Bromophenyl isocyanate [2492-02-9] M 189.0, m 41-42°. Crystd from pet ether (b 30-40°).


Any insoluble material is most probably the corresponding urea. It can be purified by steam distn, cool the receiver, add NaCl and extract in Et₂O, wash extract with N H₂SO₄; dry (MgSO₄), evaporate and recrystallise the residual solid. [Org Synth Coll Vol IV 700 1963; Coll Vol I 447 1941.]

Bromopicrin (tribromonitromethane) [464-10-8] M 297.8, m 8-10°, b 85-87°/16mm, d 2.788, n 1.579. Steam distd, dried with anhydrous Na₂SO₄ and vacuum distd. TOXIC.

R-(+)-2-Bromopropionic acid [10009-70-8] M 153.0, b 78°/4mm, [α] 25 +27.2° (neat), pK 2 4.07. Dissolve in Et₂O, dry (CaCl₂), evap and distil through a short column. Distillation through a Podbielniak column led to decomposition. [Podbielniak column. A plain tube containing "Heli-Grid" Nichrome or Inconel wire packing. This packing provides a number of passage-ways for the reflux liquid, while at the same time, channelling and flooding are minimised. A column 1m high has been stated to have an efficiency of 200-400 theoretical plates (for further details, see Podbielniak Ind Eng Chem (Anal Ed) 13 639 1941; Mitchell and O'Gorman Anal Chem 20 315 1948). Store in the dark under N₂, preferably in sealed ampoules. Even at -10° it slowly decomposes. [J Am Chem Soc 76 6054 1954.]

3-Bromopropionic acid [590-92-1] M 153.0, m 62.5°, 62.5-63.5°, 63-64°. Crystallises as plates from CCl₄. It is soluble in organic solvents and H₂O. It has a pK₂ 5 in H₂O of 4.01, and its methyl ester has m 25°/18mm and 80°/27mm. The S-benzyliothioсuromium salt has m 136°. [Org Synth Coll Vol I 134 1948; Justus Liebigs Ann Chem 599 140 1956.]

N-(3-Bromopropyl)phthalimide [5460-29-7] M 268.1, m 72-74°, 74°. Place in a Soxhlet and extract with Et₂O, whereby the bis-phthalimido impurity is not extracted. Evaporate the Et₂O and recryst from EtOH or aqueous EtOH or pet ether. [Chem Ber 21 2669 1888; Justus Liebigs Ann Chem 614 83 1958; Can J Chem 31 1060 1953.]

2-Bromopyridine [109-04-6] M 158.0, b 49.0°/2.7mm, d 1.660, n 1.5713, pK 25 0.90. Dried over KOH for several days, then distd from CaO under reduced pressure, taking the middle fraction.


Bromopyruvic acid [1113-59-3] M 167.0, m 79-82°, pK_{EtOH} ~1.6. Dried by azeotropic distn (toluene), and then recryst from dry CHCl₃. Dried for 48h at 20° (0.5 Torr) over P₂O₅. Stored at 0°. [Labandiniere et al. J Org Chem 52 157 1987.]

5-Bromosalicyl hydroxamic acid [5798-94-7] M 210.1, m 232°(dec), pK_{EtOH(1)} ~1.5, pK_{EtOH(2)} ~7.0, pK_{EtOH(3)} ~8.7. Crystd from EtOH.
Purification of Organic Chemicals

4-Bromostyrene \[[2039-82-9]\] M 183.1, b 49.5-50°/2.5mm, 87-88°/12mm, 102-104°/20mm, d 1.3984, n 1.5925. It polymerises above 75° in the presence of benzoyl peroxide. To purify, if it has not gone to a solid resin, dissolve in Et2O, dry (MgSO4), add ca.0.1g of 4-tertbutylcatechol (polymerisation inhibitor) per 100g of bromostyrene. Filter, evap under reduced press (use as high a vac as possible) and distil.

N-Bromosuccinimide \[[128-08-5]\] M 178.0, m 183-184°(dec). N-Bromosuccinimide (30g) was dissolved rapidly in 300mL of boiling water and filtered through a fluted filter paper into a flask immersed in an ice bath, and left for 2h. The crystals were filtered, washed thoroughly with cu 100mL of ice-cold water and drained on a Buchner funnel before drying under vac over P2O5 or CaCl2 [Dauben and McCoy J Am Chem Soc 81 4863 1959]. Has also been crystd from acetic acid or water (10 parts, washed in water and dried in vacuo, [Wilcox et al. J Am Chem Soc 108 7693 1986; Shell et al. J Am Chem Soc 108 121 1986; Phillips and Cohen J Am Chem Soc 108 2013 1986].

Bromotetronic acid \[[21151-51-9]\] M 179.0, m 183°(dec), pK2 2.23. Decolorised, and free bromine was removed by charcoal treatment of an ethyl acetate soln, then recrystd from ethyl acetate [Schuler, Bhatia and Schuler J Phys Chem 78 1063 1974].

Bromothymol Blue \[[76-59-5]\] M 624.4, m 201-203°, pK1 -0.66, pK2 6.99. Dissolved in aq 5% NaHCO3 soln and ppted from the hot soln by dropwise addn of aq HCl. Repeated until the extinction did not increase (λmax 420nm). Indicator at pH 6.0 (yellow) and 7.6 (blue).


α-Bromo-4-toluic acid \[[6232-88-8]\] M 215.1, m 229-230°, pK1 -3.2. Crystd from Me2CO.

Bromotrichloromethane \[[75-62-7]\] M 198.5, f -5.6°, m 21°, b 104.1°, d 2.01, n 1.5061. Washed with aq NaOH soln or dilute Na2CO3, then with H2O, and dried with CaCl2, BaO, MgSO4 or P2O5 before distilling in diffuse light and storing in the dark. Has also been purified by treatment with charcoal and by fractional crystn by partial freezing. Purified also by vigorous stirring with portions of conc H2SO4 until the acid did not discolour during several hours stirring. Washed with Na2CO3 and water, dried with CaCl2 and then illuminated with a 1000W projection lamp at 15cm for 10h, after making it 0.01M in bromine. Passed through a 30 x 1.5cm column of activated alumina and fractionally redistilling through a 12-in Vigreux column. [Firestone and Willard J Am Chem Soc 83 3511 1961; see also Cadogan and Duell J Chem Soc 4154 1962.]

5-Bromovaleric (γ-bromopentanoic) acid [2067-33-6] M 181.0, m 40°,_pk_{Est} ~ 4.6. Crystd from pet ether.

α-Bromo-p-xylene [104-81-4] M 185.1, m 35°, b 218-220°/740mm. Crystd from EtOH or pentane.


Bufotenine hydrogen oxalate [2963-79-3] M 294.3, m 96.5°. Crystd from Et2O.

1,3-Butadiene [106-99-0] M 54.1, b -2.6°. Dried by condensing with a soln of triethylaluminium in decahydronaphthalene; then flash distd. Also dried by passage over anhydrous CaCl2 or distd from NaBH4. Also purified by passage through a column packed with molecular sieves (4A), followed by cooling in Dry-ice/MeOH bath overnight, filtering off the ice and drying over CaH2 at -78° and distd in a vacuum line.

n-Butane [106-97-8] M 58.1, m -135°, b -0.5°. Dried by passage over anhydrous Mg(C104)2 and molecular sieves type 4A. Air was removed by prolonged and frequent degassing at -107°.

1,4-Butanediol (tetramethylene glycol) [110-63-4] M 90.1, f 20.4°, b 107-108°/4mm, 127°/20mm, d 1.02, n 1.4467. Distd and stored over Linde type 4A molecular sieves, or crystd twice from anhydrous diethyl ethedacetone, and redistd. Also purified by recrystn from the melt and doubly distd in vacuo in the presence of Na2SO4.


1-Butanesulfonyl chloride [2386-60-9] M 156.6, b 75-76°/7mm, 98°/13mm, d_{D}^{19} 1.2078, n_{D}^{19} 1.4559. It has a pungent odour and is LACHRMYMATORY. If IR shows OH bands then dissolve in Et2O, wash with cold saturated aq NaHCO3 (care since CO2 will be generated) then H2O, dry over solid Na2SO4, filter evaporate and distil the residue twice. Characterised by shaking a soln in Et2O or *C6H6 with aq NH3, collect the solid and recryst from CHCl3, CC14 or Et2O-pet ether, m 48°. [J Am Chem Soc 60 1488 1938; J Org Chem 5 83 1940.]

1-Butanethiol [109-79-5] M 90.2, b 98.4°, d_{25} 0.837, n 1.443, n_{25} 1.440, pK_{Est} ~ 11.3. Dried with CaSO4 or Na2SO4, then refluxed from magnesium; or dried with, and distd from CaO, under nitrogen [Roberts and Friend J Am Chem Soc 108 7204 1986.] Has been separated from hydrocarbons by extractive distillation with aniline.

Dissolved in 20% NaOH, with a small amount of *C8H6, then steam distd, until clear. The soln was then cooled and acidified slightly with 15% H2SO4. The thiol was distd out, dried with CaSO4 or CaCl2, and fractionally distd under N2 [Mathias and Filho J Phys Chem 62 1427 1958]. Also purified by pptn as lead mercaptide from alcoholic soln, with regeneration by adding dilute HCl to the residue after steam distn. All operations should be carried out in a fume cupboard due to the TOXICITY and obnoxious odour of the thiol.

2-Butanethiol [513-53-1] M 90.2, b 37.4°/134mm, d_{25} 0.846, n_{25} 1.4338, pK_{Est} ~ 11.4. Purified as for 1-butanethiol.

n-Butanol [71-36-3] M 74.1, b 117.7°, d_{25} 0.80572, n 1.39922, n_{15} 1.40118. Dried with MgSO4, CaO, K2CO3, Ca or solid NaOH, followed by refluxing with, and distn from, calcium, magnesium activated with iodine, aluminium amalgam or sodium. Can also dry with molecular sieves, or by refluxing with n-butyl phthalate or succinate. (For method, see Ethanol.) n-Butanol can also be dried by efficient fractional distn, water passing over in the first fractn as a binary azeotrope (contains about 37% water). An ultraviolet-
transparent distillate has been obtained by drying with magnesium and distilling from sulfanilic acid. To remove bases, aldehydes and ketones, the alcohol has been washed with dil H$_2$SO$_4$, then NaHSO$_4$ soln; esters were removed by boiling for 1.5h with 10% NaOH. Also purified by adding 2g NaBH$_4$ to 1.5L butanol, gently bubbling with argon and refluxing for 1 day at 50°. Then added 2g of freshly cut sodium (washed with butanol) and refluxed for 1 day. Distd and the middle fraction collected [Jou and Freeman J Phys Chem 81 909 1977].

2-Butanone (methyl ethyl ketone, MEK) [78-93-0] M 72.1, b 79.6°, d 0.853, n 1.37850, n$^2$ 1.37612, pK$_{25}$ -7.2 (aq H$_2$SO$_4$). In general, purification methods are the same as for acetone. Aldehydes can be removed by refluxing with KMnO$_4$ + CaO, until the Schiff aldehyde test is negative, prior to distn. Shaking with satd K$_2$CO$_3$, or passage through a small column of activated alumina, removes cyclic impurities. The ketone can be dried by careful distillation (an azeotrope containing 11% water boils at 73.4°), or by CaSO$_4$, P$_2$O$_5$, Na$_2$SO$_4$, or K$_2$CO$_3$, followed by fractional distillation. Purification as the bisulfite addition compound is achieved by shaking with excess satd Na$_2$SO$_3$, cooled to 0°, filtering off the ppt, washing with a little ethyl ether and drying in air; this is followed by decomposition with a slight excess of Na$_2$CO$_3$ soln and steam distillation, the distillate being satd with K$_2$CO$_3$ so that the ketone can be separated, dried with K$_2$CO$_3$, filtered, and distill.

Purification as the Na$_1$ addition compound (m 73-74°) is more convenient. (For details, see Acetone.) Small quantities of 2-butanone can be purified by conversion to the semicarbazone, recrystallization to constant melting point, drying under vac over CaCl$_2$ and paraffin wax, refluxing for 30min with excess oxalic acid, followed by steam distillation, salting out, drying, and distilling [Cowan, Jeffery and Vogel J Chem Soc 171 1940].

cis-2-Butene [590-18-1] M 56.1, b 2.95-3.05°/746mm. The gas is dried with CaH$_2$. Purified by gas chromatography. HIGHLY FLAMMABLE.

trans-2-Butene [624-64-6] M 56.1, b 0.3-0.4°/744mm. The gas is dried with CaH$_2$. Purified by gas chromatography. HIGHLY FLAMMABLE.

2-Butene-1,4-dicarboxylic acid (trans-3-hexenedioic acid, trans-hydromuconic acid) [4456-74-2] M 144.1, m 194-197°, 195-196°, pK$_{est(1)}$ -4.2, pK$_{est(2)}$ ~5.00. Crystallized from boiling water, then dried at 50-60° in a vacuum oven.

But-3-en-2-one (methyl vinyl ketone) [78-94-4] M 70.1, b 79-80°/760mm, d 0.842. See entry on p.302.

2-tert-Butoxyacetylimino-2-phenylacetonitrile (BOC-ON) [58632-95-4] M 246.3, m 87-89°. Triturate solid with 90% aq MeOH, filter, wash with 90% aq MeOH and dry in a vac. Recryst from MeOH (needles or plates), but use warm MeOH and cool to crystal, do not boil as it decomposes slowly. IR has v 1785 (C=O) cm$^{-1}$ and NMR (CDCl$_3$) usually shows two tert-butyl singlets for syn and anti isomers. Store in a brown bottle (fridge). It evolves CO$_2$ at room temp (stoppered bottle can explode!), but can be stored over silica gel which can extend its useful life to more than a year. [Itoh et al. Org Synth 59 95 1980.]

2-Butoxyethanol (butyl cellosolve) [111-76-2] M 118.2, b 171°/745mm, d 0.903, n 1.4191. Peroxides can be removed by refluxing with anhydrous SnCl$_2$ or by passage under slight pressure through a column of activated alumina. Dried with anhydrous K$_2$CO$_3$ and CaSO$_4$, filtered and distill, or refluxed with, and distill from NaOH.


n-Butyl acetate [123-86-4] M 116.2, b 126.1°, d 0.882, n 1.394. Distilled, refluxed with successive small portions of KMnO$_4$ until the colour persisted, dried with anhydrous CaSO$_4$, filtered and redistilled.

tert-Butyl acetate [540-88-5] M 116.2, b 97-98°, d 0.72. Washed with 5% Na$_2$CO$_3$ soln, then saturated aqueous CaCl$_2$, dried with CaSO$_4$ and distill.
Purification of Organic Chemicals

**tert-Butyl acetoacetate** [1694-31-1] M 158.2, b 71°/10mm, 85°/20mm, d\(^1\)\(^0\) 0.954, n\(^2\)\(^0\) 1.42. Dist under reduced press through a short column. [Org Synth 42 28 1962.] HARMFUL VAPOUR.

**tert-Butylacetylchloride** [7065-46-5] M 134.6, b 68-71°/100mm, 81°/180mm, 128-132°/atm, d\(^2\)\(^0\) 0.964, n\(^1\)\(^0\) 1.423. Distil under vacuum. If IR shows OH group then treat with thionyl chloride or oxalyl chloride at ca 50° for 30min, evap and fractionate using a short column. Strongly LACHRYMATORY, use a good fume hood. [J Am Chem Soc 72 222 1950; J Org Chem 22 1551 1957.]

**Butyl acrylate** [141-32-2] M 128.2, b 59°/25mm, d 0.894, n\(^1\)\(^2\) 1.425. Washed repeatedly with aqueous NaOH to remove inhibitors such as hydroquinone, then with distilled water. Dried with CaCl\(_2\). Fractionally dist under reduced pressure in an all-glass apparatus. The middle fraction was sealed under nitrogen and stored at 0° in the dark until used [Mallik and Das J Am Chem Soc 82 4269 1960].

**tert-Butyl alcohol** [75-65-0] M 74.1, m 23-28°, 25.7°, b 28.3°/60mm, 43.0°/123.8mm, 61.8°/315mm, 72.5°/507mm, 82.4°/760mm, d\(^1\)\(^0\) 0.7858, n\(^2\)\(^2\) 1.3878. Synthesised commercially by the hydration of 2-methylpropene in dilute H\(_2\)SO\(_4\). Dried with CaO, K\(_2\)CO\(_3\), CaSO\(_4\) or MgSO\(_4\), filtered and fractionally distd. Dried further by refluxing with, and distilling from, either magnesium activated with iodine, or small amounts of calcium, sodium or potassium, under nitrogen. Passage through a column of type 4A molecular sieve is another effective method of drying. So, also, refluxing with tert-butyl phthalate or succinate. (For method see Ethanol.) Other methods include refluxing with excess aluminium tert-butylate, or standing with CaH\(_2\), and distilling as needed. Further purification is achieved by fractional crystn by partial freezing, taking care to exclude moisture. tert-Butyl alcohol samples containing much water can be dried by adding *benzene, so that the water distils off as a tertiary azeotrope, b 67.3°. Traces of isobutylene have been removed from dry tert-butyl alcohol by bubbling dry pre-purified nitrogen through for several hours at 40-50° before using. It form azeotropic mixtures with a large number of compounds. It has also been purified by distn from CaH\(_2\) into Linde 4A molecular sieves which had been activated at 350° for 24h [Jaeger et al. J Am Chem Soc 101 717 1979].

**Rapid purification:** Dry tert-butanol with CaH\(_2\) (5% w/w), distil and store over 3A molecular sieves.

**n-Butylamine** [109-73-9] M 73.1, b 77.8°, d 0.740, n\(^1\)\(^0\) 1.4009, n\(^2\)\(^5\) 1.399, pK\(^2\) 10.66. Dried with solid KOH, K\(_2\)CO\(_3\), LiAlH\(_4\), CaH\(_2\) or MgSO\(_4\), then refluxed with, and fractionally distd from P₂O₅, CaH\(_2\), CaO or BaO. Further purified by pptn as the hydrochloride, m 213-213°, from ether soln by bubbling HCl gas into it. Re-ppted three times from EtOH by adding ether, followed by liberation of the free amine using excess strong base. The amine was extracted into ether, which was separated, dried with solid KOH, the ether removed by evapn and then the amine was distd. It was stored in a desiccator over solid NaOH [Bunnett and Davis J Am Chem Soc 82 665 1960; Lycan et al. Org Synth Coll Vol II 319 1943]. SKIN IRRITANT.

**R-(-)-sec-Butylamine** [13250-12-9] M 73.1, b 61-63°/atm, 62.5°/atm, d\(^1\)\(^0\) 0.731, n\(^2\)\(^0\) 1.393, [α]\(^D\)\(^2\) 9+7.5° (neat), pK 10.56. Dry over solid NaOH overnight and fractionate through a short helices packed column. The L-hydrogen tartrate salt has m 139-140° (from H₂O), the 1H₂O has m 96° [α]\(^D\)\(^2\) +18.1° (c 11, H₂O); the hydrochloride has m 152° [α]\(^D\)\(^2\) -1.1° (c 13, H₂O) and the benzoyl derivative crystallises from EtOH as needles m 97°, [α]\(^D\)\(^2\) -34.9° (c 11, H₂O). [J Chem Soc 921 1956; Acta Chem Scand 11 898 1957.]

**tert-Butylamine** [75-64-9] M 73.1, b 42°, d 0.696, pK 10.68. Dried with KOH or LiAlH\(_4\). Distd from CaH\(_2\) or BaO.
n-Butyl p-aminobenzoate \([94-25-7]\) \(M\) 193.2, \(m\) 57-59°, \(pK_{\text{B}}\) ~2.5. Crystd from EtOH.

tert-Butylammonium bromide \([60469-70-7]\) \(M\) 154.1, \(m\) >250°(dec). Recrystd several times from absolute EtOH and thoroughly dried at 105°.

4-tert-Butylaniline \([769-92-6]\) \(M\) 193.2, \(m\) 14.5-15°, 15-16°, \(b\) 98.5-99°/3mm, 122°/20mm, \(d_2^0\) 0.945, \(n_\text{D}^o\) 1.538, \(pK_{15}^2\) 4.95. Isolate as sulfate salt then liberate the free base with 10% aqueous NaOH, separate layers, dry over solid KOH and dist twice from Zn dust in a vacuum and store in brown containers. It has \((\text{H}_2\text{O})\) 4.95 and \((50\%\text{aq EtOH})\) 4.62. [Am Chem Soc 76 2349 1954.]

The anilide has \(m\) 171.5-172.3°, and the hydrochloride has \(m\) 270-274°. [J Am Chem Soc 68 1952; J Am Chem Soc 76 6179 1954.]

2-tert-Butylaniline \([13719-97-6]\) \(M\) 234.3, \(m\) 148-149°. Recrystd from EtOH and finally purified by TLC.

\(n\)-Butylbenzene \([104-51-8]\) \(M\) 134.2, \(b\) 183.3°, \(d\) 0.860, \(n\) 1.4897, \(n_{25}^2\) 1.487. Distd from sodium. Washed with small portions of conc H\(_2\)SO\(_4\) until the acid was no longer coloured, then with water and aqueous Na\(_2\)CO\(_3\), and dist twice from Na, collecting the middle fraction [Vogel J Chem Soc 607 1948].

tert-Butylbenzene \([98-06-6]\) \(M\) 134.2, \(b\) 169.1°, \(d\) 0.867, \(n\) 1.493, \(n_{25}^2\) 1.490. Washed with cold conc H\(_2\)SO\(_4\) until a fresh portion of acid was no longer coloured, then with 10% aqueous NaOH, followed by distd water until neutral. Dried with CaSO\(_4\) and distd in a glass helices-packed column, taking the middle fraction.

4-tert-Butyl benzoyl chloride \([1710-98-1]\) \(M\) 196.7, \(b\) 135°/10mm, 149.9-150.3°/14mm, 266-268°(dec), \(d_4^0\) 1.082, \(n_{15}^D\) 1.536. Distil under vac. If IR shows OH group then treat with thionyl chloride or oxalyl chloride at \(ca\) 50° for 30min, evap and fractionate in a vac using a short column. Strongly LACHRYMATORY, use a good fume hood. [Bull Chem Soc Jpn 32 960 1959; J Am Chem Soc 64 5433 1942, 65 986 1943.]

\(n\)-Butyl bromide \([109-65-9]\) \(M\) 137.0, \(b\) 101-102°, \(d_{25}^0\) 1.2678, \(n\) 1.4399, \(n_{25}^2\) 1.4374. Washed with conc H\(_2\)SO\(_4\), water, 10% Na\(_2\)CO\(_3\) and again with H\(_2\)O. Dried with CaCl\(_2\), CaSO\(_4\) or K\(_2\)CO\(_3\), and distd. Redistd after drying with P\(_2\)O\(_5\), or passed through two columns containing 5:l silica gel/Celite mixture and stored with freshly activated alumina.

tert-Butyl bromoacetate \([5292-43-3]\) \(M\) 195.1, \(b\) 52°/10mm, 74-76°/25mm, \(d_4^0\) 1.324, \(n_{15}^D\) 1.4162. Dissolve in Et\(_2\)O, wash well with ice cold 10% aqueous K\(_2\)CO\(_3\), dry over CaCl\(_2\), filter and evaporate the Et\(_2\)O then fractionate through a Vigreux column in a vacuum. LACHRYMATORY [Org Synth 34 28 1954, Coll Vol III 144 1955; J Am Chem Soc 72 5433 1950.]

4-tert-Butylcalix[4]arene \([60705-62-6]\) \(M\) 648.9, \(m\) >300° (dec), 380° (dec), 344-346°. Recrystd from CHCl\(_3\) in large solvated prisms (m 380° dec) effloresces on drying in air; tetra-acetate crystals from Ac\(_2\)O in colourless prisms \(m\) 332-333° dec. Crysts from CCl\(_4\) or chlorobenzene + EtOH (m >300°) and tetra-acetate crys from CHCl\(_3\) + EtOH \(m\) >290° dec. Crysts from toluene in white plates with toluene of crystallisation \(m\) 344-346° (330-332°); the tetra-acetate crystallises with 1AcOH of crystallisation \(m\) 383-386° (softening at 330-340°, also \(m\) 283-286°), but acetylation with Ac\(_2\)O-NaOAc gives triacetate which recrysts from AcOH with 1AcOH of crys \(m\) 278-281°. 4-tert-Butylcalix[4]arene (100mg) is unchanged after boiling for 4h with 10N KOH (0.04mL) in xylene (4mL). [Br J Pharmacol 10 73 1955; Monatsh Chem 109 767 1978; J Am Chem Soc 103 3782 1981; see also J.Vicens and V.Bohner eds,Calixarenes, Kluawer Academic Publ., Boston, 1991.]

4-tert-Butylcalix[6]arene \([78092-53-2]\) \(M\) 972.3, \(m\) >300°, 380-381°. Recryst from CHCl\(_3\) or CHCl\(_3\) - MeOH as a white solid from the mother liquids of the calix[8]arene preparation. The hexa-acetate (Ac\(_2\)O-H\(_2\)SO\(_4\)) crystallises from CHCl\(_3\)-MeOH \(m\) 360-362° dec, and the (SiMe\(_2\))\(_2\) derivative crystallises from
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4-tert-Butylcalix[8]arene [68971-82-4] M 1297.8, m 411-412°. Recryst from CHCl₃ in fine colourless glistening needles. It melts sharply between 400-401° and 411-412° depending on the sample and is sensitive to traces of metal ions. TLC on silica gel (250μm thick) and elution with CHCl₃-hexane (3:4); it has Rf 0.75. The octa-acetate is prepared from 8g in Ac₂O (50mL) and 2 drops of conc H₂SO₄ refluxed for 2h. On cooling a colourless ppte separates and is recryst from Ac₂O (1.2g 48%) m 353-354°. The (SiMe₃)₈ is prepared from 4-tert-butylcalix[8]arene (0.65g) in pyridine (4mL) with excess of hexamethyldisilazane (1mL) and trimethylchlorosilane (0.5mL) and refluxed under N₂ for 2h. Cool, evaporate the pyridine, triturate gummy residue with MeOH. Chromatography on silica gel using hexane-CH₂Cl₂ gave 0.5g (61%) with one spot on TLC. Crystallises from hexane-Me₂CO as colourless needles m 358-360°.

4-tert-Butylcarbazate [870-46-2] M 132.2, m 41-42°, b 64°/0.01mm, 55-57°/0.4mm. Dist in a Claisen flask with a water or oil bath at ca 80°. After a couple of drops have distd the carbazate is collected as an oil which solidifies to a snow white solid. It can be crystd with 90% recovery from a 1:1 mixt of pet ether (b 30-60°) and pet ether (b 60-70°). [Org Synth 44 20 1964.]

4-tert-Butylcatchol [98-29-3] M 166.22, m 47-48°, 55-56°, 75°, b 265°/atm, pKₑₐ₅(1) ~9.5, pKₑₐ₅(2) ~13.0. Vacuum dist and recryst from pentane or pet ether (or *C₆H₆).

n-Butyl chloride [109-69-3] M 92.6, b 78°, d 0.886, μ 1.4021. Shaken repeatedly with conc H₂SO₄ (until no further colour developed in the acid), then washed with water, aq NaHCO₃ or Na₂CO₃, and more water. Dried with CaCl₂ or MgSO₄ (then with P₂O₅ if desired), decanted and fractionally distd. Alternatively, a stream of oxygen continuing ca three times as long as was necessary to obtain the first coloration of starch iodide paper by the exit gas. After washing with NaHCO₃ soln to hydrolyze ozonides and to remove the resulting organic acid, the liquid was dried and distd [Chien and Willard J Am Chem Soc 75 6160 1953].

 tert-Butyl chloride [507-20-0] M 92.6, f -24.6°, b 50.4°, d 0.851, n 1.38564. Purification methods commonly used for other alkyl halides lead to decomposition. Some impurities can be removed by photochlorination with a small amount of chlorine prior to use. The liquid can be washed with ice water, dried with CaCl₂ or CaCl₂ + CaO and fractionally distd. It has been further purified by repeated fractional crystn by partial freezing.

ertert-Butyl chloroacetate [107-59-5] M 150.6, b 48-49°/11mm, 60.2°/15mm, 155°/atm (dec), d₄ 1.4204, n_D 1.4259. Check the NMR spectrum, if satisfactory then dist in a vac, if not then dissolve in Et₂O, wash with H₂O, 10% H₂SO₄ until the acid extract does not become cloudy when made alkaline with NaOH. Wash the organic layer again with H₂O, then saidaq NaHCO₃, dry over Na₂SO₄, evap and fractionate through a carborundum-packed column or a 6-inch Widmer column (see tert-butyl ethyl malonate for precautions to avoid decomposition during distn). [J Chem Soc 940 1940; J Am Chem Soc 75 4995 1953; Org Synth Coll Vol 14 1944.]


tert-Butyl cyanide (trimethylacetonitrile) [630-18-2] M 83.1, m 16-18°, d 0.765, b 104-106°. Purified by a two stage vac distn and degassed by freeze-pump-thaw technique. Stored under vac at 0°. TOXIC, use efficient fume hood.

tert-Butyl cyanoacetate [1116-98-9] M 141.2, b 40-42°/0.1mm, 54-56°/0.3mm, 90°/10mm, 107-108°/23mm, d₄ 0.989, n_D 1.4198. The IR spectrum of a film should have bands at 1742 (ester
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CO) and 2273 (C=N) but not OH band (ca 3500 broad) cm⁻¹. If it does not have the last named band then fractionally dist, otherwise dissolve in Et₂O, wash with satd aq NaHCO₃, dry over K₂CO₃, evaporate Et₂O, and distill residue under a vacuum (see tert-butyl ethyl malonate for precautions to avoid decomposition during distillation). [J Chem Soc 423 1955; Helv Chim Acta 42 1214 1959].


n-Butyl disulfide [629-45-8] M 178.4, b 110-113°/15mm, d 0.938, n² 1.494. Shaken with lead peroxide, filtered and distilled in vacuum under N₂.

n-Butyl wave (di-n-butyl ether) [142-96-1] M 130.2, b 52-53°/26mm, 142.0°/760mm, d 0.764, n 1.39925, n² 1.39685, pK 15.5-5.40 (aq H₂SO₄). Peroxides (detected by the liberation of iodine from weakly acid (HCl) solutions of 2% KI) can be removed by shaking 1L of ether with 5-10mL of a solution comprising 6.0g of ferrous sulfate and 6mL conc H₂SO₄ and 1 lOmL of water, with aq Na₂S₂O₃, or with acidified NaI, water, then Na₂S₂O₃. After washing with dil NaOH, KOH, or Na₂CO₃, then water, the ether is dried with CaCl₂ and distill. It can be further dried by distillation from CaH₂ or Na (after drying with P₂O₅), and stored in the dark with Na or NaH. The ether can also be purified by treating with CS₂ and NaOH, expelling the excess sulfide by heating. The ether is then washed with water, dried with NaOH and distilled [Kusama and Koike J Chem Soc Japan, Pure Chem Sect 72 229 1951]. Other purification procedures include passage through an activated alumina column to remove peroxides, or through a column of silica gel, and distillation after adding about 3% (v/v) of a 1M solution of MeMgI in n-butyl ether.

n-Butyl ethyl ether [628-81-9] M 102.2, b 92.7°, d 0.751, n 1.38175, n² 1.3800. Purified by drying with CaS₂O₄, by passage through a column of activated alumina (to remove peroxides), followed by prolonged refluxing with Na and then fractional distillation.

tert-Butyl ethyl ether [637-92-3] M 102.2, b 71-72°, d 0.741. Dried with CaS₂O₄, passed through an alumina column, and fractionally distilled.

ter-Butyl ethyl malonate [32864-38-3] M 188.2, b 83-85°/8mm, 93-95°/17mm, 107-109°/24mm, d 0.994, n² 1.4150. Likely impurity is monoethyl malonate, check IR for OH bands at 3330 br. To ca 50g of ester add ice cold NaOH (50g in 200mL of H₂O and 200g of ice). Swirl a few times (filter off ice if necessary), place in a separating funnel and extract with 2 x 75mL of Et₂O. Dry extract (MgSO₄) (since traces of acid decompose the t-Bu group of the ester, the distillation flask has to be washed with aq NaOH, rinsed with H₂O and allowed to dry). Addition of some K₂CO₃ or MgO before distillation is recommended to inhibit decomposition. Distill under reduced pressure through a 10 cm Vigreux column. Decomposition is evidenced by severe foaming due to autocatalytic decomposition and cannot be prevented from accelerating except by stopping the distillation and rewashing the distillation flask with alkali again. [J Am Chem Soc 66 1287 1944, 64 2714 1942; Org Synth Coll Vol IV 417 1963; Org Synth 37 35 1957.]

n-Butyl formate [592-84-7] M 102.1, b 106.6°, d 0.891, n 1.3890. Washed with satd NaHCO₃ solution in the presence of satd NaCl, until no further reaction occurred, then with saturated NaCl solution, dried (MgSO₄) and fractionally distilled.


tert-Butyl hydroperoxide (TBHP) [75-91-2] M 90.1, f 5.4°, m 0.5-2.0°, b 38°/18mm, d 0.900, n 1.4013, pK 12.8. Care should be taken when handling this peroxide because of the possibility of EXPLOSION. It explodes when heating over an open flame. Alcoholic and volatile impurities can be removed by prolonged refluxing at 40° under reduced pressure, or by steam distillation. For example, Bartlett, Benzing and Pincock [J Am Chem Soc 82 1762 1960] refluxed at 30mm pressure in an azeotropic separation apparatus until two phases no longer separated, and then distilled at 41°/23mm. Pure
material is stored under N₂, in the dark at 0°. Crude commercial material has been added to 25% NaOH below 30°, and the crystals of the sodium salt have been collected, washed twice with benzene and dissolved in distilled water. After adjusting the pH of the solution to 7.5 by adding solid CO₂, the peroxide was extracted into pet ether, from which, after drying with K₂CO₃, it was recovered by distilling off the solvent under reduced pressure at room temperature [O’Brien, Beringer and Mesrobian J Am Chem Soc 79 6238 1957]. The temperatures should be kept below 75°. It has also been distilled through a helices packed column (ca 15 plates) and material collected had b 34-35°/20 mm. Similarly, a solution in pet ether has been extracted with cold aq NaOH, and the hydroperoxide has been regenerated by adding at 0°, MSO₄ at a pH not higher than 4.5, then extracted into diethyl ether, dried with MgSO₄, filtered and the ether evaporated in a rotary evaporator under reduced pressure [Milac and Djokic J Am Chem Soc 84 3098 1962].

A 3M solution of TBHP in CH₂Cl₂ is prepared by swirling 85mL (0.61mol) of commercial TBHP (70% TBHP-30% H₂O, d 0.935 ca 7.2mmol/mL) with 140mL of CH₂Cl₂ in a separating funnel. The milky mixture is allowed to stand until the phases separate (ca 30min). The organic (lower) layer (ca 200mL) containing 0.60mole of TBHP was separated from the aqueous layer (ca 21mL) and used without further drying. TBHP is assayed by iodometric titration. With 90% grade TBHP (w/w, d 0.90, cu 9.0mmole/mL) no separation of layers occurs; i.e. when TBHP (66.67mL, 0.60mole) is added to CH₂Cl₂ (140mL) the resulting solution (ca 200mL) is clear. [J Am Chem Soc 77 60032 1955; 74 4742 1952; Akashi, Palenno and Sharpless J Org Chem 43 2063 1978] states quality of available grades, handling and compatibility for reactions.

2-tert-Butyl hydroquinone [1948-33-0] M 166.2, m 125-127°, 127-128°, 129°, pKₐ(1) -10.5, pKₐ(2) -11.6. Recrystallized from H₂O or MeOH and dried in a vacuum at 70°. Store in a dark container. [Angew Chem 69 699 1957.]

n-Butyl iodide (1-iodobutane) [542-69-8] M 184.0, b 130.4°, d 1.616, n₂5 1.44967. Dried with MgSO₄ or P₂O₅, fractionally distilled through a column packed with glass helices, taking the middle fraction and storing with calcium or mercury in the dark. Also purified by prior passage through activated alumina or by shaking with conc H₂SO₄ then washing with Na₂SO₃ solution. It has also been treated carefully with sodium to remove free HI and H₂O, before distilling in a column containing copper turnings at the top. Another purification consisted of treatment with bromine, followed by extraction of free halogen with Na₂S₂O₃, washing with H₂O, drying and fractional distillation.

tert-Butyl iodide [558-17-8] M 184.0, b 100°(dec), d 1.544. Vacuum distillation has been used to obtain a distillate which remained colourless for several weeks at -5°. More extensive treatment has been used by Boggs, Thompson and Crain [J Phys Chem 61 625 1957] who washed with aq NaH₂SO₃ solution to remove free iodine, dried for 1h with Na₂SO₃ at 0°, and purified by four or five successive partial freezeings of the liquid to obtain colourless material which was stored at -78°.

tert-Butyl isocyanate [1609-86-5] M 99.1, m 10.5-11.5°, b 30.5-32°/10mm, 64°/52mm, d₂5 0.9079, n₂5 1.470. It is LACHRYMATORY and TOXIC, and should have IR with 2251 (C=N) cm⁻¹ and no OH bands. The NMR should have one band at 1.37 ppm from TMS. Purified by fractional distillation under reduced pressure. [J Org Chem 36 3056 1971; J Prakt Chem. 125 152 1930.]

tert-Butyl isocyanide [7188-38-7] M 83.1, b 91-92°/730mm, 90°/758mm, d₂0 0.735. Dissolve in pet ether (b 40-60°) wash with H₂O, dry (Na₂SO₄), remove pet ether under slight vacuum, dist using a vacuum-jacketed Vigreux column at atmospheric pressure, IR: ν 2134 cm⁻¹. [Chem Ber 93 239 1960.]

tert-butyl isocyanoacetate [2769-72-4] M 141.2, b 50°/0.1mm, 49-50°/10mm, 63-65°/15mm, d₂0 0.970, n₂0 1.420. If it contains some free acid (OH bands in IR) then dissolve in Et₂O, shake with 20% Na₂CO₃, dry over anhydrous K₂CO₃, evaporate and distil. [Chem Ber 94 2814 1961.]

n-Butyl methacrylate [97-88-1] M 142.2, b 49-52°/0.1mm, d 0.896, n 1.424. Purified as for butyl acrylate.
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tert-Butyl methacrylate \([585-07-9]\) M 142.2, f -48°, b 135-136°/760mm, d 0.878, n 1.415. Purified as for butyl acrylate.

2-tert-Butyl-4-methoxyphenol \((2\text{-}\text{tert-}\text{butyl}\text{-}4\text{-}\text{hydroxyanisole})\) \([121-00-6]\) M 180.3, m 64.1°, pK\(\text{Em}\) -10.8. Fractionally distd in vacuo, then passed as a soln in CHCl₃ through alumina, and the solvent evaporated from the eluate. Recryst from pet ether.

n-Butyl methyl ether \([628-28-4]\) M 88.2, b 70°, d 0.744, pK -3.50 (aq H₂SO₄). Dried with CaSO₄, passed through an alumina column to remove peroxides, and fractionally distd.

tert-Butyl methyl ether \([11634-04-4]\) M 88.2, b 56°, n 1.369. Same as for n-butyl methyl ether.

tert-Butyl methyl ketone \([75-97-8]\) M 100.2, b 105°/746mm, 106°/760mm, d 0.814, n 1.401. Refluxed with a little KMnO₄. Dried with CaSO₄ and distd.

8-sec-Butylmetrazole \([3282-56-2]\) M 179.2, m 28.4°. Fractionally crystd three times by partially freezing a mixture of the mono-nitro isomers, then recryst from MeOH twice and dried under vacuum \([Brown J Am Chem Soc 81 3232 1959]\).

N-(n-Butyl)-5-nitro-2-furamide \([14121-89-2]\) M 212.2, m 89-90°. Recrystd twice from EtOH/water mixture.

Butyloxirane \((1\text{-}\text{hexene oxide})\) \([1436-34-6]\) M 100.2, b 116-117°/atm, 116-119°/atm, d\(^2\) 0.833, n\(^D\) 1.44051. Purified by fractional distn through a 2ft helices packed column at atmospheric pressure in a N₂ atm. \([J Org Chem 30 1271 1965; J Chem Soc 2433 1927; 13C NMR J Chem Soc Perkin Trans 2 861 1975]\).

tert-Butyl peracetate \([107-71-1]\) M 132.2, b 23-24°/0.5mm, n\(^D\) 1.4030. Washed with NaHCO₃ from a *benzene soln, then redistd to remove *benzene \([Kochi J Am Chem Soc 84 774 1962]\). Handle with adequate protection due to possible EXPLOSIVE nature.

tert-Butylperoxy isobutyrate \([109-13-7]\) M 160.2, f -45.6°. After diluting 90mL of the material with 120mL of pet ether, the mixture was cooled to 5° and shaken twice with 90mL portions of 5% NaOH soln (also at 5°). The non-aqueous layer, after washing once with cold water, was dried at 0° with a mixture of anhydrous MgSO₄ and MgCO₃ containing ca 40% MgO. After filtering, this material was passed, twice, through a column of silica gel at 0° (to remove tert-butyl hydroperoxide). The soln was evapd at 0°/0.1mm to remove the solvent, and the residue was recrystd several times from pet ether at -80°, then subjected to high vac to remove traces of solvent \([Milos and Golubovic J Am Chem Soc 80 5994 1958]\). Handle with adequate protection due to possible EXPLOSIVE nature.

tert-Butyl perphthalic acid \([15042-77-0]\) M 238.2, pK\(\text{Em}\) ~6.2. Crystd from Et₂O and dried over H₂SO₄. Possibly EXPLOSIVE.

p-tert-Butylphenol \([98-54-4]\) M 150.2, m 99°, pK\(^{15}\) 10.39. Crystd to constant melting point from pet ether (b 60-80°). It sublimes. Also purified via its benzoate, as for phenol.
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**tert-Butyl phenyl carbonate** [6627-89-0] M 194.2, b 74-78°/0.5mm, 83°/0.6mm, d\textsubscript{4}° 1.05, n\textsubscript{D}° 1.480. If IR is free from OH then purify by redistillation, otherwise, dissolve in Et\textsubscript{2}O, wash with 5% HCl, then H\textsubscript{2}O, dry over MgSO\textsubscript{4}, evap and distil through a Claisen head under vacuum. Care should be taken in the distillation as distn of large quantities can lead to decomposition with liberation of CO\textsubscript{2} and isobutylene, use the necessary precautions. [\textit{J Am Chem Soc} 79 98 1957.]

**n-Butyl phenyl ether** [1126-79-0] M 150.2, b 210.5°, d 0.935. Dissolved in diethyl ether, washed first with 10% aq NaOH to remove traces of phenol, then repeatedly with distilled water, followed by evaporation of the solvent and distn under reduced pressure [Arnett and Wu \textit{J Am Chem Soc} 82 5660 1960].

**N-tert-Butyl \(\alpha\)-phenyl nitrone** [3376-24-7] M 177.2, m 73-74°. Crystd from hexane.

**Butyl phthalate** [84-74-2] M 278.4, f -35°, b 340°/760mm, d 1.043. Freed from alcohol by washing with H\textsubscript{2}O, or from acids and butyl hydrogen phthalate by washing with dilute NaOH. Distd at 10torr or less. (See also p. 195.)

**4-tert-Butyl pyridine** [3978-81-2] M 135.2, f -44.4°, b 194-197° atm, 197°/765mm, d\textsubscript{4}° 0.923, n\textsubscript{D}° 1.495, \(\text{pK}^{25} 5.82\). It is dried over solid KOH and is purified by fractional distn through an efficient column under dry N\textsubscript{2}. Its picrate has m 153.9-154°, and the hydrochloride has m 151.7-154.8° (from Me\textsubscript{2}CO). [\textit{J Am Chem Soc} 73 3308, 3310 1951, IR: \textit{J Am Chem Soc} 100 214 1978; \textit{J Chem Soc} 4454 1960.]

**Butyl stearate** [123-95-5] M 340.6, m 26.3°, d 0.861. Acidic impurities removed by shaking with 0.05M NaOH or a 2% NaH\textsubscript{2}CO\textsubscript{3} soln, followed by several water washes, then purified by fractional freezing of the melt and fractional crystn from solvents with boiling points below 100°.

**S-tert-Butyl thioacetate** [999-90-6] M 132.2, b 31-32°/11mm, 38°/14mm, 44-45°/28mm, 67°/54mm, 135.6-135.9°/773mm, d\textsubscript{4}° 0.9207, n\textsubscript{D}° 1.4532. Dissolve in CHCl\textsubscript{3} (EtOH-free), wash with H\textsubscript{2}O, 10% H\textsubscript{2}SO\textsubscript{4}, saturated aqueous NaH\textsubscript{2}CO\textsubscript{3} (care CO\textsubscript{2} liberated), H\textsubscript{2}O again, dried over Drierite and anhydrous K\textsubscript{2}CO\textsubscript{3}, and fractionate under reduced pressure. [\textit{J Am Chem Soc} 72 3021 1950.]

**p-tert-Butyltoluene** [98-51-1] M 148.3, f -53.2°, b 91°/28mm, d 0.854, n 1.4920. A sample containing 5% of the meta-isomer was purified by selective mercuration. Fractional distn of the solid arylmercuric acetate, after removal from the residual hydrocarbon, gave pure \(p\)-tert-butyltoluene [Stock and Brown \textit{J Am Chem Soc} 81 5615 1959].

**tert-Butyl 2,4,6-trichlorophenyl carbonate** [16965-08-5] M 297.6, m 64-66°. Crystd from a mixture of Me\textsubscript{2}O (90mL) and water (6mL) using charcoal [Broadbent et al. \textit{J Chem Soc (C)} 2632 1967].

**N-tert-Butyl urea** [1118-12-3] M 116.2, m 182°, 185° (dec). Possible impurity is \(N,N'\)-di-\(p\)-tert-butyl urea which is quite insol in H\textsubscript{2}O. Recrystd from hot H\textsubscript{2}O, filter off insol material, and cool to 0° to -5° with stirring. Dry in vac at room temp over KOH or H\textsubscript{2}SO\textsubscript{4}. If dried at higher temperatures it sublimes slowly. It can be recrystd from EtOH as long white needles or from 95% aq EtOH as plates. During melting point determination the bath temp has to be raised rapidly as the urea sublimes slowly above 100° at 760mm. [\textit{Org Synth Coll Vol III} 151 1955.]

**n-Butyl vinyl ether** [111-34-2] M 100.2, b 93.3°, d 0.775. After five washings with equal volumes of water to remove alcohols (made slightly alkaline with KOH), the ether was dried with sodium and disted under vacuum, taking the middle fraction [Coombes and Eley \textit{J Chem Soc} 3700 1957]. Stored over KOH.

**2-Butyne** [503-17-3] M 54.1, b 0°/253mm, d 0.693. Stood with sodium for 24h, then fractionally distd under reduced pressure.
2-Butyne-1,4-diol [110-65-6] M 86.1, m 54-57°, 56-58°, b 238°. Crystd from EtOAc.

n-Butyraldehyde [123-72-8] M 72.1, b 74.8°, d 0.810, n 1.37911, n\(^{15}\) 1.38164. Dried with CaCl\(_2\) or CaSO\(_4\), then fractionally distd under N\(_2\). Lin and Day [J Am Chem Soc 74 5133 1952] shook with batches of CaSO\(_4\) for 10min intervals until a 5mL sample, on mixing with 2.5mL of CCl\(_4\) containing 0.5g of aluminium isopropoxide, gave no ppte and caused the soln to boil within 2min. Water can be removed from n-butyraldehyde by careful distn as an azeotrope distilling at 68°. The aldehyde has also been purified through its bisulfite compound which, after decomposing with excess NaHCO\(_3\) soln, was steam distd, extracted under N\(_2\) into ether and, after drying, the extract was fractionally distd [Kyte, Jeffery and Vogel J Chem Soc 4454 1960].

Butyramide [514-35-5] M 87.1, m 115°, b 230°. Crystd from acetone, *benzene, CCl\(_4\)-pet ether, 20% EtOH or water. Dried under vacuum over P\(_2\)O\(_5\), CaCl\(_2\) or 99% H\(_2\)SO\(_4\).

n-Butyric acid [107-92-6] M 88.1, f -5.3°, b 163.3°, d 0.961, n\(^{25}\) 1.396, pK\(^Z5\) 2.82. Distd, mixed with KMnO\(_4\) (20g/L), and fractionally redistd, discarding the first third [Vogel J Chem Soc 1814 1948].

n-Butyric anhydride [106-31-0] M 158.2, b 198°, d 0.968. Dried by shaking with P\(_2\)O\(_5\), then distd.

\(\gamma\)-Butyrolactone [96-48-0] M 86.1, b 83.9°/12mm, d 1.124. Dried with anhydrous CaSO\(_4\), then fractionally distd. Handle in a fume cupboard due to TOXICITY.

Butyronitrile [110-74-0] M 69.1, b 117.9°, d 0.793, n 1.3846, n\(^{30}\) 1.37954. Treated with conc HCl until the smell of the isonitrile had gone, then dried with K\(_2\)CO\(_3\) and fractionally distd [Turner J Chem Soc 1681 1956]. Alternatively it was twice heated at 75° and stirred for several hours with a mixture of 7.7g Na\(_2\)CO\(_3\) and 1.5g KMnO\(_4\) per L of butyronitrile. The mixture was cooled, then distd. The middle fraction was dried over activated alumina. [Schoeller and Wiemann J Am Chem Soc 108 22 1986.]

Butyryl chloride (butanoyl chloride) [1141-75-3] M 106.6, f -89°, b 101-102°/atm, d\(^4\) 1.026, n\(^4\) 1.412. Check IR to see if there is a significant peak at 3000-3500 cm\(^{-1}\) (br) for OH. If OH is present then reflux with less than one mol equiv of SOCl\(_2\) for 1h and distil directly. The fraction boiling between 85-100° is then refractionated at atm pressure. Keep all apparatus free from moisture and store the product in sealed glass ampoules under N\(_2\). LACHRYMATORY - handle in a good fume hood. [Org Synth Coll Vol I 147 1941.]

Cacotheline (2,3-dihydro-4-nitro-2,3-dioxo-9,10-secoastrynidin-10-oic acid) [561-20-6] M 508.4, pK\(_{\text{eff}(1)}\) -4.4 (CO\(_2\)H), pK\(_{\text{eff}(2)}\) ~10.2 (N). Yellow crystals from H\(_2\)O. It is then dried over H\(_2\)SO\(_4\) which gives the dihydrate, and in a vacuum over H\(_2\)SO\(_4\) at 105° to give the anhydrous compound. The hydrochloride separates as the hydrate (on heating in vacuum at 80°) in orange-yellow prisms or plates, m 250°(dec), and forms a resorcinol complex which gives brown crystals from EtOH, m 325°, and a hydroquinone complex as dark red crystals from EtOH, m 319°. [Chem Ber 43 1042 1910, 86 232, UV: 242 1953; complexes: Gatto Gazz Chim Ital 85 1441 1955.] Used in the titrimetric estimation of Sn\(^{2+}\) ions [Szrvas and Lantos Talanta 10 477 1963].


Caffeine [58-08-2] M 194.2, m 237°, pK\(^{40}\) 0.10, pK\(^{55}\) 1.22. Crystd from water or absolute EtOH.

\((+)-\)Calarene (+ \(\beta\)-gurjunen, 1,3,3,11-tetramethyltricyclo[5.4.0.0\(^2\)4]undecan-7-ane, (1aR)-1,1,7c,7ac-tetramethyl-1a,2,3,5,6,7a,7b-octahydro-IH-cyclopenta[c]napththalene, new name 1(10)aristolene) [17334-55-3] M 204.35, b 45-47°/0.008-0.01mm, 255-258°/atm, d\(^2\) 0.9340, n\(^D\) 1.55051, [\(\alpha\)]\(^D\) +58° (EtOH), +81.8° (neat). Purified by gas chromatography (7%
propylene glycol adipate on unglazed tile particles of size 0.2-0.3 mm, 400 cm column length and 0.6 cm diameter, at 184°C with N₂ carrier gas at a flow rate of 0.54 mL/sec using a thermal detector). Also purified by chromatography on alumina (200 times the weight of calarene) and eluted with pet ether. UV: λ_max 200 and 210 nm (ε 9560, 5480) in EtOH. [IR: Sorm Collect Czech Chem Commun 18 512 1953, 29 795 1964; Tetrahedron Lett 827 1962, 225 1963.]


Calmagite [3147-14-6] M 358.4, m 300°, pK₁ 8.1, pK₂ 12.4. Crude sample was extracted with anhydrous diethyl ether [Lindstrom and Diehl Anal Chem 32 1123 19601. Complexes with Ca, Mg and Th.


Camphor (1R-bornan-2-one) [R-(+)- 464-49-3; S-(-)- 464-48-2] M 136.2, m 178.8°, 179.97°(open capillary), b 204°/atm, [α]₂⁴ (++) and (-) 59.6° (in EtOH), [α]₁⁰ (++) and (-) 44.3° (c 10, EtOH), [α]₁⁷⁹ (++) and (-) 70.85° (melt). Crystd from EtOH, 50% EtOH/water, MeOH, or pet ether or from glacial acetic acid by addition of water. It can be sublimed (50°/14mm) and also fractionally crystd from its own melt. It is steam volatile. It should be stored in tight containers as it is appreciably volatile at room temperature. The solubility is 0.1% (H₂O), 100% (EtOH), 173% (Et₂O) and 300% (CHCl₃). The R-oxime (from Et₂O, CHCl₃, or dil EtOH) m 119°[α]₂⁰ (-42.4° (c 3, EtOH); the s oxime has m 118-119°. [Chem Ber 67 1432 1934; Allan and Rodgers J Chem Soc (B) 632 1971; UV, NMR: Fairley et al. J Chem Soc, Perkin Trans 1 2109 1973; J Am Chem Soc 84 1808 1962.]

Camphoric acid (1,2,2-trimethyl-cyclopentan-1r,3c-dicarboxylic acid) [1R,2S)-(++) 124-83-4; 1S,2R)-(--) 560-09-8] M 200.2, m 186-188°, 187°, 186.5-189°, [α]₂⁴ (++) and (-) 57° (c 1,
EtOH), \([\alpha]_D^{10}\) (+) and (-) 47.7° (c 4, EtOH), \(pK_a^{15}\) 4.71, \(pK_a^{12}\) 5.83 (for + isomer). Purified by repptn from an alkaline soln by HCl, filtered, and recrystd from water several times, rejecting the first crop. It forms leaflets from EtOH and Me₂CO and H₂O and is insol in CHCl₃. Sol in H₂O is 0.8% at 25° and 10% at 50°; 50% (EtOH) and 5% in ethylene glycol. The (+)-acid has \(m\) 202-203°. The (+)-1-methyl ester had \(m\) 86° (from pet ether) \([\alpha]_D^{10}+45.0°\) (c 4, EtOH), and the (+)-3-methyl ester has \(m\) 77° (from pet ether) \([\alpha]_D^{10}+53.9°\) (c 3, EtOH). \([\text{J Am Chem Soc} 53 1661 1931; \text{Helv Chim Acta} 30 933 1947; \text{Acta Chem Scand} 2 597 1948; \text{J Am Chem Soc} 80 63 16\)]

**Camphorquinone** (borna-2,3-dione) \([IR-(+)-10334-26-6; IS-(+)-2767-84-2]\) M 166.2, \(m\) 198-199°, 197-201°, \([\alpha]_D^{10}\) (+) and (-) 101.1° (c 2, EtOH). It can be purified by steam distillation, recrystn (yellow prisms) from EtOH, *C₂H₅ or Et₂O-pet ether and can be sublimed in a vacuum. The (+)-quinone forms needles from EtOH, \(m\) 197-198°. \([\text{Helv Chim Acta} 13 1026; \text{Chem Ber} 67 1432 1934.1]\)

**RS-Camphorquinone** \([10373-78-1]\) M 166.2, \(m\) 199-202°. Purification is same as for above isomers.

**2,10-Camp horsultam** \([IR-(+)-108448-77-7; IS-(+)-94594-90-8]\) M 215.3, m 181-183°, 185-187°, \([\alpha]_D^{10}\) (+) and (-) 32.2° (c 3, CHCl₃). If free from OH bands in the IR then recryst from Et₂O or pet ether, otherwise treat with SOCl₂ at 50° for 30min, evaporate, dry residue over KOH in a vacuum and recrystallise. The (+)-acid chloride has \(m\) 85°. Characterised as the amide (prisms from EtOH) \(m\) 132°, \([\alpha]_D^{10}\) (+) and (-) 1.5° (EtOH). \([\text{Shriner et al. J Am Chem Soc} 60 2794 1938.1]\)

**S-Canavanine** \([543-38-4]\) M 176.2, \(m\) 184°, \([\alpha]_D^{10}\) +19.4° (c 2, H₂O), \(pK_a^{15}\) 2.43, \(pK_a^{15}\) 9.41. Crystd from aqueous EtOH.

**S(L)-Canavanine sulfate** \([2219-31-0]\) M 274.3, \(m\) 172°(dec). See L-canavanine sulfate on p. 518 in Chapter 6.

**Cannabinol** \([521-35-7]\) M 310.4, \(m\) 76-77°, b 185°/0.05mm. Crystd from pet ether. Sublimed.

**Canthaxanthin (trans)** \([514-78-3]\) M 564.9, m 211-212°, \(A_{1\text{cm}}^{1\text{%}}\) 2200 (470nm) in cyclohexane. Purified by chromatography on a column of deactivated alumina or magnesium oxide, or on a thin layer of silica gel G (Merck), using dichloromethane/diethyl ether (9:1) to develop the chromatogram. Stored in the dark and in an inert atmosphere at -20°.

**Capric acid (decanoic acid)** \([334-48-5]\) M 172.3, m 31.5°, b 148°/11mm, d 0.886, \(n_2\) 1.424, \(pK_a\) -4.9. Purified by conversion to its methyl ester, b 114.0°/15mm (using excess MeOH, in the presence of H₂SO₄). After removal of the H₂SO₄ and excess MeOH, the ester was distd under vacuum through a 3ft
column packed with glass helices. The acid was then obtained from the ester by saponification. [Trachtman and Miller J Am Chem Soc 84 (1962)].

**n-Caproamide (n-hexanamide)** [628-02-4] M 115.2, m 100°. Crystd from hot water.

**Caproic acid (hexanoic acid)** [142-62-1] M 116.2, b 205.4°, d 0.925, n 1.417, \( pK_{25}^{25} 4.85 \). Dried with MgSO₄ and fractionally distilled from CaSO₄.

**Caprolactam (azepan-2-one, aza-2-cycloheptanone, 2-oxohexamethyleneimine)** [105-60-2] M 113.2, m 70°, 70.5-71.5°, 70-71°, 262.5°/760mm. Distd at reduced pressure, crystd from acetone or pet ether and redistd. Purified by zone melting. Very hygroscopic. Discolours in contact with air unless small amounts (0.2g/L) of NaOH, Na₂CO₃ or NaBO₂ are present. Crystd from a mixture of pet ether (185mL of b 70°) and 2-methyl-2-propanol (30mL), from acetone, or pet ether. Distd under reduced pressure and stored under nitrogen. [Synthesis 614 (1978)].

**Capronitrile (hexanenitrile)** [124-12-9] M 125.2, b 163.7°, n 1.4069, \( n_{25}^{25} 1.4048 \). Washed twice with half-volumes of conc HCl, then with saturated aqueous NaHCO₃, dried with MgSO₄, and distilled.

**Caprylolactam (azanon-2-one, azacyclononan-2-one, 8-aminooctanoic acid lactam)** [935-30-81] M 141.2, m 72°, 73°, 74-76°, 75°, 76-77°, b 119-122°/7.7mm, 150-151°/7-8mm, 164°/14mm, \( d_{73}^{23} 1.009 \), \( n_{D}^{25} 1.489 \), \( pK_{25}^{25} 0.55 \) (AcOH). Dissolve in CHCl₃, decolorise with charcoal, evaporate to dryness and recrystallise from CHCl₃-hexane. The oxime has m 117° (from *C₆H₆ or pet ether). [J Med Chem 14 (1971); Justus Liebigs Ann Chem 607 (1957)].

**Capsaicin (E-N-[(4-hydroxy-3-methoxyphenyl)-methyl]-8-methy-6-nonenamide)** [404-86-4] M 305.4, m 64-66°, 65°, 66.1°, b 210-220°/0.01mm. Recrystd from pet ether (b 40-60°), or pet ether-EtOAC (9:1). Also purified by chromatography on neutral Al₂O₃ (grade V) and eluted successively with *C₆H₆ or pet ether, needles. [J Chem Soc 11025 (1955); J Chem Soc(C) 442 (1968)].

**Capsorubin (3,3'-dihydroxy-α,α-carotene-6,6'dione)** [470-38-2] M 604.9, m 218°, \( \lambda_{max} 443, 468, 503 \) nm, in hexane. Possible impurities: zeaxanthin and capsanthin. Purified by chromatography on a column of CaCO₃ or MgO. Crystd from *benzene/pet ether or CS₂.

**Captan (N-trichloromethylmercapto-cyclohex-4-ene-1,2-dicarboxamide)** [133-06-2] M 300.5, m 172-173°. Crystd from CCl₄. Large quantities internally cause diarrhoea and vomiting.

**Captopril (S-l-[3-mercapto-2-methyl-1-oxopropyl]-L-proline)** [62571-86-2] M 217.3, m 103-104° (polymorphic unstable form m 86°, melts at 87-88° solids and then melts again at 104-105°), \( [\alpha]_{D}^{20} -131° \) (c 1.7, EtOH), \( pK_{1} 3.7 \), \( pK_{2} 9.8 \). Purified by recrystn from EtOAc-hexane. Also purified by dissolving in EtOAc and chromatographed on a column of Wakogel C200 using a linear gradient of MeOH in EtOAc (0-100%) and fractions which give a positive nitroprusside test (for SH) are combined, evap and recrystd from EtOAc-hexane (1:1), white crystals \( [\alpha]_{D}^{20} -128.2° \) (c 2.0, EtOH). [Nam J Pharm Sci 73 (1984)]. Alternatively, dissolve in H₂O, apply to a column of AG-50Wx2 (BioRad) and eluted with H₂O. The free acid is converted to the dicyclohexylamine salt in MeCN by addition until the pH is 8-9 (moist filter paper). The salt is converted to the free acid by shaking with EtOAc and 10% aq KH₂SO₄ or passage through an AG50Wx2 column. The EtOAc soln is dried (MgSO₄) and recrystd as above from EtOAc-hexane. [Biochem J 16 (1977); NMR and IR: Horii and Watanabe; Yakugaku Zasshi (J Pharm Soc Japan) 81 (1961)].

**4-(Carbamoylmethoxy)acetanilide** [14260-41-4] M 208.2, m 208°. Crystd from water.

**3-Carbamoyl-1-methylpyridinium chloride (1-methylnicotinamide chloride, Trigonellamide)** [1005-24-9] M 172.6, m 240°(dec). Crystd from MeOH.
Carbanilide (sym-diphenylurea) [102-07-8] M 212.3, m 242°. Crystd from EtOH or a large volume (40mL/g) of hot water.


Carbazole [86-74-8] M 167.2, m 240-243°, pK<0. Dissolved (60g) in conc H2SO4 (300mL), extracted with three 200mL portions of *benzene, then stirred into 1600mL of an ice-water mixture. The ppt was filtered off, washed with a little water, dried, crystd from *benzene and then from pyridine/*benzene. [Feldman, Pantages and Orchin J Am Chem Soc 73 4341 1951]. Has also been crystd from EtOH or toluene, sublimed in vacuum, zone-refined, and purified by TLC.

Carbazole-9-carbonyl chloride [73500-82-0] M 300.0, m 100-103°, 103.5-104°. Recrystd from *C6H6. If it is not very pure (presence of OH or NH bands in the IR) dissolve in pyridine, shake with phosgene in toluene, evaporate and recrystallise the residue. Carry out this experiment in a good fume cupboard as COC12 is very TOXIC, and store the product in the dark. It is moisture sensitive. The amide has m 246.5-247°, and the dimethylaminoethylylamide hydrochloride has m 197-198°. [Weston et al. J Am Chem Soc 75 4006 1953].

4-Carboethoxy-3-methyl-2-cyclohexen-1-one (Hagemann's ester) [487-51-4] M 182 , b 79-80°/0.2mm, 121-123°/4mm, 142-144°/15mm, d4 1.038. Dissolve in ether, shake with solid K2CO3, aqueous saturated NaHCO3, dry (MgSO4) and distil. Semicarbazone has m 165-167° (169°). [J Am Chem Soc 65,631,1943].

1-Carbethoxy-4-methylpiperazine hydrochloride [532-78-5] M 204.7, m 168.5-169°, pK 7.31. Crystd from absolute EtOH.


Carbon Black Leached for 24h with 1:1 HCl to remove oil contamination, then washed repeatedly with distilled water. Dried in air, and eluted for one day each with *benzene and acetone. Again dried in air at room temp, then heated in a vacuum for 24h at 600° to remove adsorbed gases. [Tamamushi and Tamaki Trans Faraday Soc 55 1007 1959].

Carbon disulfide [75-15-0] M 76.1, b 46.3°, d 1.264, n 1.627. Shaken for 3h with three portions of KMnO4 soln (5g/L), twice for 6h with mercury (to remove sulfide impurities) until no further darkening of the interface occurred, and finally with a soln of HgSO4 (2.5g/L) or cold, satd HgCl2. Dried with CaCl2, MgSO4, or CaH2 (with further drying by refluxing with P2O5), followed by fractional distillation in diffuse light. Alkali metals cannot be used as drying agents. Has also been purified by standing with bromine (0.5mL/L) for 3-4h, shaking with KOH soln, then copper turnings (to remove unreacted bromine), and drying with CaCl2. CS2 is highly TOXIC, and highly FLAMMABLE. Work in a good fume hood. Small quantities of CS2 have been purified (including removal of hydrocarbons) by mechanical agitation of a 45-50g sample with a soln of 130g of sodium sulfide in 150mL of H2O for 24h at 35-40°. The aqueous sodium thio carbonate soln was separated from unreacted CS2, then ppted with 140g of copper sulfate in 350g of water, with cooling. After filtering off the copper thiocarbonate, it was decomposed by passing steam into it. The distillate was separated from H2O and distd from P2O5. [Ruff and Golla Z Anorg Chem 138 17 1924].

Carbon tetrabromide [558-13-4] M 331.7, m 92.5°. Reactive bromide was removed by refluxing with dilute aqueous Na2CO3, then steam distd, crystd from EtOH, and dried in the dark under vacuum. [Sharpe and Walker J Chem Soc 157 1962]. Can be sublimed at 70° at low pressure.
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Carbon tetrachloride [56-23-5] M 153.8, b 76.8°, d_{25} 1.5842. For many purposes, careful fractional distillation gives adequate purification. Carbon disulfide can be removed by shaking vigorously for several hours with saturated KOH, separating, and washing with water; this treatment is repeated. The CCl₄ is shaken with conc H₂SO₄ until there is no further coloration, then washed with water, dried with CaCl₂ or MgSO₄ and distilled (from P₂O₅ if desired). **It must not be dried with sodium.** An initial refluxing with mercury for 2h removes sulfides. Other purification steps include passage of dry CCl₄ through activated alumina, and distillation from KMnO₄. Carbonyl containing impurities can be removed by percolation through a Celite column impregnated with 2,4-dinitrophenylhydrazine (DNPH), H₃PO₄ and water. (Prepared by dissolving 0.5g DNPH in 6mL of 85% H₃PO₄ by grinding together, then mixing with 4mL of distilled water and Celite.) [Schwartz and Parks *Anal Chem 33* 1396 1961]. Photochlorination of CCl₄ has also been used: CCl₄ to which a small amount of chlorine has been added is illuminated in a glass bottle (e.g. for 24h with a 200W tungsten lamp near it), and, after washing out the excess chlorine with 0.02M Na₂S₂O₃, the CCl₄ is washed with distilled water and distilled from P₂O₅. It can be dried by passing through 4Å molecular sieves and distilled. Another purification procedure is to wash CCl₄ with aq NaOH, then repeatedly with water and N₂ gas bubbled through the liquid for several hours. After drying over CaCl₂ it is percolated through silica gel and distilled under dry N₂ before use [Klassen and Ross *J Phys Chem 91* 3664 1987].

**Rapid purification:** Distill, discarding the first 10% of distillate or until the distillate is clear. The distilled CCl₄ is then stored over 5Å molecular sieves.

Carbon tetrafluoride [75-73-0] M 88.0, b -15°. Purified by repeated passage over activated charcoal at solid-CO₂ temperatures. Traces of air were removed by evacuating while alternately freezing and melting. Alternatively, liquefied by cooling in liquid air and then fractionally distilled under vacuum. (The chief impurity originally present was probably CF₃Cl).


1,1'-Carbonyldi(1,2,4-triazole) [41864-22-6] M 164.1, m 134-136°, 145-150°. Dissolve in tetrahydrofuran and evaporate at 10mm until it crystallises. Wash crystals with cold tetrahydrofuran and dry in a vacuum desiccator.


(-)-Caryophyllene oxide (1S,5S-6-epoxy-6c,10,10-trimethyl-2-methylene-1r,9t-bicyclo-[7.2.0]undecan$J$) [1139-30-6] M 220.4, m 62-63°, 63.5-64°, 64°, b 114-117°/1.8mm, 141-142°/11mm, d₄ 0.9666, nD²⁰ 1.49564, [α]D⁰ -79° (c 2,CHCl₃), [α]D²⁰ -68° (supercooled melt). Purified by TLC on silica gel with EtOAc-pet ether (b 60-80°) (15:85), and recrystallised from MeOH or *C₆H₆. [NMR: Warnhoff *Can J Chem 42* 1664 1964, Ramage and Whitehead *J Chem Soc* 4336 1954.]


Cation exchange resin. Conditioned before use by successive washing with water, EtOH and water, and taken through two H⁺-Na⁺-H⁺ cycles by successive treatment with M NaOH, water and M HCl then washed with water until neutral.
(+)-Cedrol (octahydro-3,6,8,8-tetramethyl-1-3a,7-methanoazulen-6-ol, 8aS-6c-hydroxy-3c,6c,8,8-tetramethyl[8a-H]-octahydro-3H,3at,7t-methanoazulene), [77-53-2] m 82-86°, 86-87°, [α]D +10.5° (c 5, CHCl₃), [α]D +13.1° (c 5.5, EtOH), [α]D +14.3° (c 10, dioxane). Purified by recrystn from aqueous MeOH. It is estimated colorimetrically with H₃PO₄ in EtOH followed by vanillin and HCl [Hayward and Seymour Anal Chem 20 572 1948]. The 3,5-dinitrobenzoyl derivative has m 92-93°. [J Am Chem Soc 83 3114 1961.]

β-Cellobiose [528-50-7] M 342.3, m 228-229°(dec), [α]D +33.3° (c 2, water). 75% aqueous EtOH. Crystd from Cellulose triacetate [9012-09-3] M 72,000-74,000. Extracted with cold EtOH, dried in air, washed with hot distilled water, again dried in air, then dried at 50° for 30 min. [Madorsky, Hart and Straus J Res Nat Bur Stand 60 343 1958.]

Cerulenin (heliccocerin, 2R,3S-2,3-epoxy-4-0-7E,10E-dodecadienamide) [17397-89-6] M 223.3, m 93-94°, 93-95°, b 120°/10-8 mm, [α]D +31° (c 2, MeOH). White needles from *C₆H₆. Also purified by repeated chromatography from Florisil and silica gel. It is soluble in EtOH, MeOH, *C₆H₆, slightly soluble in H₂O and pet ether. The dl-form has m 40-42° (from *C₇H₆-hexane), and the 2R,3S-tetrahydrocerulenin has m 86-87°, [α]D +44.4° (c 0.25, MeOH after 24 h). [Tetrahedron Lett 2095 1978, 2039 1979; J Am Chem SOC 99 2805 1977; J Org Chem 47 1221 1982.]

Cetyl acetate [629-70-9] M 284.5, m 18.3°. Vacuum distd twice, then crystallized several times from diethyl ether/MEOH.


Cetylamide [629-54-9] M 255.4, m 106-107°, b 235-236°/12 mm. Crystd from thiophene-free *benzene and dried under vacuum over P₂O₅.

Cetylamine (1-hexadecylamine) [143-27-1] M 241.5, m 48°, b 162-165°/5.2 mm, pK₂ 10.60. Crystd from thiophene-free *benzene and dried under vacuum over P₂O₅.

Cetylammonium chloride [1602-97-7] M 278.0, m 178°. Crystd from MeOH.

Cetyl bromide (1-bromohexadecane) [112-82-3] M 305.4, m 15°, b 193-196°/14 mm. Shaken with H₂SO₄, washed with water, dried with K₂CO₃ and fractionally distd.

Cetyl ether [4113-12-6] M 466.9, m 54°. Vacuum distd then crystallized several times from MeOH/*benzene.


Cetyltrimethylammonium bromide (cetrimonium bromide, CTAB) [57-09-0] M 364.5, m 227-235°(dec). Crystd from EtOH, EtOH/*benzene or from wet acetone after extracting twice with pet ether. Shaken with anhydrous diethyl ether, filtered and dissolved in a little hot MeOH. After cooling in the refrigerator, the ppte was filtered at room temperature and redissolved in MeOH. Anhydrous ether was added and, after warming to obtain a clear soln, it was cooled and crystalline material was filtered. [Dearden and Wooley J Phys Chem 91 2404 1987; Hakemi et al. J Am Chem Soc 91 120 1987.]

Charcoal. Charcoal (50g) was added to 1L of 6M HCl and boiled for 45min. The supernatant was discarded, and the charcoal was boiled with two more lots of HCl, then with distilled water until the supernatant no longer gave a test for chloride ion. The charcoal (which was now phosphate-free) was filtered on a sintered-glass funnel and air dried at 120° for 24h. [Lippin, Talbert and Cohn J Am Chem Soc 76 2871 1954.]

The purification can be carried out using a Soxhlet extractor (without cartridge), allowing longer extraction times. Treatment with conc H2SO4 instead of HCl has been used to remove reducing substances.

Chaulmoogric acid [(13-cyclopent-2-enyl)tridecanoic acid] [29106-32-9] M 280.4, m 68.5°, b 247-248°/20mm, [α]D 20 +60° (c 4, CHCl3), pK1 5.0. Crystd from pet ether or EtOH.

The Me ester [24828-59-9] has m 220, b 227°/20mm and [α]D 15 +50° (c 5, CHCl3).

Chaulmoogric acid [34346-15-9] M 389.4, m 207°. Crystd from CHCl3 by addition of MeOH.

Chelerythrine [34316-15-9] M 389.4, m 207°. Crystd from CHCl3 by addition of MeOH.

Chelex 100 [II 139-85-81. Washed successively with 2M ammonia, water, 2M nitric acid and water. Chelex 100 may develop an odour on long standing. This can be removed by heating to 800° for 2h in 3M ammonia, then washing with water. [Ashbrook J Chromatogr 105 151 1975.]

Chelidonic acid (4-oxopyran-2,6-dicarboxylic acid) [99-32-1] M 184.1, m 207°. Crystd from aqueous EtOH.

Chenodesoxycholic acid [474-25-9] M 392.6, m 143°. See 3α,7α-dihydroxycholic acid on p. 207.

Chenodesoxycholic acid [474-25-9] M 392.6, m 143°. See 3α,7α-dihydroxycholic acid on p. 207.

Chimyl alcohol (1-0-n-hexadecylglycerol) [( k) 506-03-6; 10550-58-0 (chimyl alcohol)] M 316.5, m 64°. Crystd from hexane.

Chloral 17.5-87-6; 302-17-0 (hydrate) M 141.4, b 98°, pK2 10.04. Distd, then dried by distilling through a heated column of CaSO4.

Chloralacetone chloroform [512-47-0] M 324.9, m 65°. Crystd from *benzene.

Chloralacetone chloroform [512-47-0] M 324.9, m 65°. Crystd from *benzene.

α-Chloralose (R-1,2-O-[2,2,2-trichloroethylidene]-α-D-glucofuranose) [15879-93-3] M 309.5, m 180-182°, 187°, 186-188°, [α]D 19.5° (c 11, pyridine). Recrystd from EtOH, 38% aqueous EtOH, Et2O, H2O or CHCl3. The solubility is 0.44% in H2O at 15°, 0.83% in H2O at 37°, 6.7% in EtOH at 25°. [Whitson and Hixon J Am Chem Soc 55 2438 1933; Helv Chim Acta 6 621 1923.] The β-isomer is less soluble in H2O, EtOH or Et2O and has m 237.5-238° [J Am Chem Soc 59 1955 1937; Acta Chem Scand 19 359 1965].

Chloranilic acid (2,5-dichloro-3,6-dihydroxy-1,4-benzoquinone) [87-88-7] M 209.0, m 283-284°, pK1 1.22, pK2 3.01. A soln of 8g in 1L of boiling water was filtered while hot, then extracted twice at about 50° with 200mL portions of *benzene. The aq phase was cooled in ice-water. The crystals were filtered off, washed with three 10mL portions of water, and dried at 115°. It can be sublimed in vacuum. [J Phys Chem 61 765 1957.] The diacetate has m 182-185° [J Am Chem Soc 46 1866 1924; Thamer and Voight J Phys Chem 56 225 1952].
Chlorendic anhydride (1,4,5,6,7,7-hexachloro-5-norbornene-2,3-dicarboxylic anhydride) [115-27-5] M 370.9, m 234-236°, 235-237°, 238°. Steam distn or recrystn from H₂O yields the diacid. The purified diacid yields the anhydride with AqO. [Prill J Am Chem Soc 69 62 1947.]


α-Chloroacetic acid [79-11-8] M 94.5, m 62.8°, b 189°, pK₂ 2.87. Crystd from CHCl₃, CCl₄, *benzene or water. Dried over P₂O₅ or conc H₂SO₄ in a vacuum desiccator. Further purification by distn from MgSO₄, and by fractional crystn from the melt. Stored under vac or under dry N₂. [Bernasconi et al. J Am Chem Soc 107 3621 1985.]


Chloroacetonitrile [107-14-2] M 75.5, b 125°. Refluxed with P₂O₅ for one day, then distd through a helices-packed column. Also purified by gas chromatography. LACHRYMATOR, HIGHLY TOXIC.

o-Chloroaniline [95-51-2] M 127.6, m -1.9°, b 208.8°, d 1.213, n 1.588, pK₂ 2.66. Freed from small amounts of the p-isomer by dissolving in one equivalent of H₂SO₄ and steam distilling. The p-isomer remains behind as the sulfate. [Sidgwick and Rubie J Chem Soc 1013 1921.] An alternative method is to dissolve in warm 10% HCl (11mL/g of amine) and on cooling, the hydrochloride of o-chloroaniline separates out. The latter can be recrystl until the acetyl derivative has a constant melting point. (In this way, yields are better than for the recrystn of the picrate from EtOH or of the acetyl derivative from pet ether.) [King and Orton J Chem Soc 1377 1911.]

Chloroaniline [106-47-8] M 127.6, m 70-71°, pK₂ 3.98. Crystd from MeOH, pet ether (b 30-60°), or 50% aq EtOH, then *benzene/pet ether (b 60-70°), then dried in a vacuum desiccator. Can be distd under vacuum (b 75-77°/33mm).

Chloroanisole [623-12-1] M 142.6, b 79°/11.5mm, 196.6°/760mm, d 1.164, n₂⁰ 1.5326. Washed with 10% (vol) aqueous H₂SO₄ (three times), 10% aqueous KOH (three times), and then with water until neutral. Dried with MgSO₄ and fractionally distd from CaH₂ through a glass helices-packed column under reduced pressure.


o-Chlorobenzaldehyde [89-98-5] M 140.6, m 11°, b 213-214°, d 1.248, n 1.566. Washed with 10% Na₂CO₃ soln, then fractionally distd in the presence of a small amount of catechol.
3-Chlorobenzaldehyde \([587-04-2]\) M 140.6, \(m 18^\circ\), \(b 213-214^\circ\), \(d 1.241\), \(n 1.564\). Purified by low temperature crystn from pet ether (b 40-60\(^\circ\)).

4-Chlorobenzaldehyde \([104-88-1]\) M 140.6, \(m 47^\circ\). Crystd from EtOH/water (3:1), then sublimed twice at 2mm pressure at a temperature slightly above the melting point.

Chlorobenzene \([108-90-7]\) M 112.6, \(b 131.7^\circ\), \(d 1.107\), \(n 1.5248\). The main impurities are likely to be chlorinated impurities originally present in the *benzene used in the synthesis of chlorobenzene, and also unchlorinated hydrocarbons. A common purification procedure is to wash several times with conc H\(\text{H}_2\text{SO}_4\) then with aq Na\(\text{HCO}_3\) or Na\(\text{CO}_3\), and water, followed by drying with CaCl\(_2\), K\(_2\text{CO}_3\) or CaSO\(_4\), then with P\(_2\text{O}_5\), and distn. It can also be dried with Linde 4A molecular sieve. Passage through, and storage over, activated alumina has been used to obtain low conductance material. [Flaherty and Stern J Am Chem Soc 80 1034 1958.]

4-Chlorobenzensulfonyl chloride \([98-60-2]\) M 211.1, \(m 53^\circ\), \(b 141^\circ/15\text{mm}\). Crystd from ether in powdered Dry-ice, after soln had been washed with 10% NaOH until colourless and dried with Na\(\text{SO}_4\).

4-Chlorobenzhydrazide \([536-40-3]\) M 170.6, \(m 164^\circ\). Crystd from water.

2-Chlorobenzoic acid \([118-91-2]\) M 156.6, \(m 139-140^\circ\), \(pK_{z5} 2.91\). Crystd successively from glacial acetic acid, aq Et\(\text{OH}\), and pet ether (b 60-80\(^\circ\)). Other solvents include hot water or toluene (ca 4mL/g). Crude material can be given an initial purification by dissolving 30g in 100mL of hot water containing 5g of charcoal for 15min, then filtering and adding 31mL of 1:1 aq HCl: the ppt is washed with a little water and dried at 100\(^\circ\).

3-Chlorobenzoic acid \([535-80-8]\) M 156.6, \(m 154-156^\circ\), \(15\%\) \(d_{25} 1.496\), \(pK_{25} 3.82\) (5.25 in 50\% dimethylacetamide). Crystd successively from glacial acetic acid, aqueous Et\(\text{OH}\) and pet ether (b 60-80\(^\circ\)). It also recrysts from \(\text{C}_6\text{H}_5\text{O}_2\) or Et\(\text{O}\)-hexane, and sublimes at 55\(^\circ\) in a vacuum. [Anal Chem 26 726 1954] The methyl ester has \(m 21^\circ\), \(b 231^\circ/\text{atm}\). The S-benzyl thiouronium salt has \(m 164-165^\circ\) (from Et\(\text{OH}\)) [Acta Chem Scand 9 1425 1955; J Chem Soc 1318 1960.]

4-Chlorobenzoic acid \([74-11-3]\) M 156.6, \(m 238-239^\circ\), \(pK_{25} 3.99\). Same as for \(m\)-chlorobenzoic acid. Has also been crystd from hot water, and from Et\(\text{OH}\).

2-Chlorobenzonitrile \([873-32-5]\) M 137.6, \(m 45-46^\circ\). Crystd to constant melting point from \(\ast\)benzene/pet ether (b 40-60\(^\circ\)).

4-Chlorobenzophenone \([134-85-0]\) M 216.7, \(m 75-76^\circ\). Recrystd for Et\(\text{OH}\). [Wagner et al. J Am Chem Soc 108 7727 1986.]

2-Chlorobenzothiazole \([615-20-3]\) M 169.6, \(m 21^\circ\), \(90-91.4^\circ/4\text{mm}\), \(135-136^\circ/28\text{mm}\), \(d_{25}^0 1.303\), \(n_{D}^{20} 1.6398\). It is purified by fractional distn in vacuo. The 2-chloro-3-methylbenzothiazolinium 2,4-dinitrobenzenesulfonate crystallises from Ac\(\text{O}\), \(m 162-163^\circ\) (dec). [J Am Chem Soc 73 4773 1951; J Org Chem 19 1830 1954; J Chem Soc 2190 1930.]

\(o\)-Chlorobenzotrifluoride \([88-16-4]\) M 180.6, \(b 152.3^\circ\). Dried with CaSO\(_4\), and distd at high reflux ratio through a silvered vacuum-jacketed glass column packed with one-eight inch glass helices [Potter and Saylor J Am Chem Soc 73 90 1951].

\(m\)-Chlorobenzotrifluoride \([98-15-7]\) M 180.6, \(b 137.6^\circ\). Same as for \(o\)-chlorobenzotrifluoride above.

\(p\)-Chlorobenzotrifluoride \([98-56-6]\) M 180.6, \(b 138.6^\circ\). Same as for \(o\)-chlorobenzotrifluoride above.

p-Chlorobenzyl chloride [104-83-6] M 161.0, m 28-29°, b 96°/15mm. Dried with CaSO4, then fractionally distilled under reduced pressure. Crystallized from heptane or dry diethyl ether. LACHRYMATORY.


2-Chlorobutane [78-86-4] M 92.6, b 68.5°, d 0.873, n25 1.3945. Purified in the same way as n-butyl chloride.

2-(4-Chlorobutyl)-1,3-dioxolane [118336-86-0] M 164.6, b 56-58°/0.1mm, d4 1.106, n2 1.457. If the IR has a CHO band then just distil in vacuum. If it is present then dissolve in Et2O, wash with H2O, then saturated NaHCO3, evaporate and distill. [J Am Chem Soc 73 1365 1951.]

N-Chlorocarbonyl isocyanate [27738-96-1] M 105.5, m -68°, b 63.6°/atm, d4 1.310. Fractionally distilled at atmospheric pressure using a 40 cm column. TOXIC vapour use a good fume hood. Store dry, v 2260 (NCO), 1818 (CO) and 1420 (NCO sym) cm⁻¹. [Chem Ber 106 1752 1975.]


Chlorocyclohexane [542-18-7] M 118.6, b 142.5°, d 1.00, n25 1.46256. Washed several times with dilute NaHCO3, then repeatedly with distilled water. Dried with CaCl2 and fractionally distilled.

4-Chloro-2,6-diaminopyrimidine (2,4-diamino-6-chloropyrimidine) [156-83-2] M 144.6, m 198°, 199-202°, pK25 3.57. Purified by recrystallization from boiling H2O (charcoal) as needles; also crystallizes from Me2CO. [Böttner Chem Ber 36 2232 1903; Roth J Am Chem Soc 72 1914 1950; UV: J Chem Soc 3172 1962.]

4-Chloro-3,5-dimethylphenol [88-04-0] M 156.6, m 115.5°, pK25 9.70. Crystallizes from benzene or toluene.

1-Chloro-2,4-dinitrobenzene [97-01-7] M 202.6, m 48-50°, 51°, 52-54°, 54°, b 315°/atm, d2 1.697. Usually crystallized from EtOH or MeOH. Has also been crystallized from Et2O. *C6H6, *C6H5-pet ether or isopropyl alcohol. A preliminary purification step has been to pass its solution through an alumina column. Also purified by zone refining. It exists in three forms: one stable and two unstable. The stable form crystallizes as yellow needles from Et2O, m 51°, b 315°/atm with some dec, and is soluble in EtOH. The labile forms also crystallize from Et2O, m 43°, and is more soluble in organic solvents. The second labile form has m 27°. [Hoffman and Dame, J Am Chem Soc 41 1015 1919, Welsh J Am Chem Soc 63 3276 1941; J Chem Soc 2476 1957.]

4-Chloro-3,5-dinitrobenzoic acid [118-97-8] M 246.6, m 159-161°, pK25 -2.5. Crystallizes from EtOH/water, EtOH or *benzene.

2-Chloro-3,5-dinitropyridine [2578-45-2] M 203.5, m 62-65°, 63-65°, 64°, pK25 ~-5. Dissolved in CHCl3, shake with saturated NaHCO3, dry (MgSO4), evaporate and apply to an Al2O3 column, elute with pet ether (b 60-80°), evaporate and recrystallized from *C6H6 or pet ether. [Chem Pharm Bull Jpn 8 28 1960; Rec Trav Chim Pays-Bas 72 573 1953.]
2-Chloroethanol (ethylene chlorohydrin) [107-07-3] M 80.5, b 51.0°/31 mm, 128.6°/760 mm, d 1.201, n\(_{15}\) 1.444. Dried with, then distd from, CaSO\(_4\) in the presence of a little Na\(_2\)CO\(_3\) to remove traces of acid.

2-Chloroethyl bromide (1-bromo-2-chloroethane) [107-04-0] M 143.4, b 106-108°. Washed with conc H\(_2\)SO\(_4\), water, 10% Na\(_2\)CO\(_3\) soln, and again with water, then dried with CaCl\(_2\) and fractionally distd before use.

2-Chloroethyl chloroformate [627-11-2] M 143.0, b 52-54°/12 mm, 153°/760 mm, d\(_{15}\) 1.376, n\(_{15}\) 1.446. Purified by fractional distn, preferably in a vacuum and stored in dry atmosphere. [J Chem Soc 2735 1957.]

1-(2-Chloroethyl)pyrrolidine hydrochloride [7250-67-1] M 170.1, m 167-170°, 173.5-174°, pK\(_{\text{m}}\) -8.5 (free base). Purified by recrystn from isopropanol-di-isopropyl ether (charcoal) and recrystallised twice more. The free base, b 55-56°/11 mm, 60-63°/23 mm and 90°/56 mm, is relatively unstable and should be converted to the hydrochloride immediately, by dissolving in isopropanol and bubbling dry HCl through the soln at 0°, and filtering off the hydrochloride and recrystallising it. The picrate has m 107.3-107.8° (from EtOH) [Cason J Org Chem 24 247 1959; J Am Chem Soc 70 3098 1948].

2-Chloroethyl vinyl ether [110-75-8] M 106.6, b 109°/760 mm, d 1.048, n 1.437. Washed repeatedly with equal volumes of water made slightly alkaline with KOH, dried with sodium, and distd under vacuum. TOXIC.

Chloroform [67-46-3] M 119.4, b 61.2°, d\(_{15}\) 1.49845, d\(_{10}\) 1.47060, n\(_{15}\) 1.44858. Reacts slowly with oxygen or oxidising agents, when exposed to air and light, giving, mainly, phosgene, Cl\(_2\) and HCl. Commercial CHCl\(_3\) is usually stabilized by addn of up to 1% EtOH or of dimethylaminoazobenzene. Simplest purifications involve washing with water to remove the EtOH, drying with K\(_2\)CO\(_3\) or CaCl\(_2\), refluxing with P\(_2\)O\(_5\), CaCl\(_2\), CaSO\(_4\) or Na\(_2\)SO\(_4\), and distilling. It must not be dried with sodium. The dist CHCl\(_3\) should be stored in the dark to avoid photochemical formation of phosgene. As an alternative purification, CHCl\(_3\) can be shaken with several small portions of conc H\(_2\)SO\(_4\), washed thoroughly with water, and dried with CaCl\(_2\) or K\(_2\)CO\(_3\) before filtering and distilling. EtOH can be removed from CHCl\(_3\) by passage through a column of activated alumina, or through a column of silica gel 4-ft long by 1.75-in diameter at a flow rate of 3 mL/min. (The column, which can be held about 8% of its weight of EtOH, is regenerated by air drying and then heating at 600° for 6h. It is pre-purified by washing with CHCl\(_3\), then EtOH, leaving in conc H\(_2\)SO\(_4\) for about 8hr, washing the washings are neutral, then air drying, followed by activation at 600° for 6h. Just before use it is reheated for 2h to 154°.) [McLaughlin, Kaniecki and Gray Anal Chem 30 1517 1958.]

Carbonyl-containing impurities can be removed from CHCl\(_3\) by percolation through a Celite column impregnated with 2,4-dinitrophenylhydrazine, phosphoric acid and water. (Prepared by dissolving 0.5g DNPH in 6mL of 85% H\(_3\)PO\(_4\) by grinding together, then mixing with 4mL of distilled water and 10g of Celite.) [Schwartz and Parks Anal Chem 33 1396 1961]. Chloroform can be dried by distn from powdered type 4A Linde molecular sieves. For use as a solvent in IR spectroscopy, chloroform is washed with water (to remove EtOH), then dried with CaCl\(_2\) or K\(_2\)CO\(_3\) before filtering and distilling. EtOH can be removed from CHCl\(_3\) by passing through a column of activated alumina or through a column of silica gel 4-ft long by 1.75-in diameter at a flow rate of 3 mL/min. (The column, which can hold about 8% of its weight of EtOH, is regenerated by air drying and then heating at 600° for 6h. It is pre-purified by washing with CHCl\(_3\), then EtOH, leaving in conc H\(_2\)SO\(_4\) for about 8hr, washing the washings are neutral, then air drying, followed by activation at 600° for 6h. Just before use it is reheated for 2h to 154°.) [McLaughlin, Kaniecki and Gray Anal Chem 30 1517 1958.]

Rapid purification: Pass through a column of basic alumina (Grade I, 10g/mL of CHCl\(_3\)), and either dry by standing over 4A molecular sieves, or alternatively, distil from P\(_2\)O\(_5\) (3% w/v). Use immediately.


Chlorohydroquinone (2-chloro-1,4-dihydroxybenzene) [615-67-8] M 144.6, m 106°, b 263°, pK\(_{\text{H}1}\) 8.81, pK\(_{\text{H}2}\) 10.78. Crystd from CHCl\(_3\) or toluene.

5-Chloro-8-hydroxy-7-idoquinoline (violform) [130-26-7] M 305.5, m 178-179°, pK\(_{\text{H}1}(1)\) -2.6, pK\(_{\text{H}1}(2)\) -7.0. Crystd from abs EtOH.
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5-Chloroindole [17422-32-1] M 151.6, m 69-71°, 72-73°, b 120-130°/0.4mm, pK_Bet < 0. It is distd at high vacuum and recrystallises from pet ether (b 40-60°) or (b 80-100°) as glistening plates. The picrate has m 147° (146.5-147.5°) [J Chem Soc 3493 1955; J Org Chem 44 578 1979].

4-Chloriodobenzene [637-87-6] M 238.5, m 53-54°. Crystd from EtOH.

2,3-Chloromaleic anhydride [1122-17-4] M 167.0, m 121-121.5°. See 2,3-dichloromaleic anhydride on p. 198.

5-Chloro-2-methoxyaniline (2-amino-4-chloroanisole) [95-03-4] M 157.6, m 81-83°, 82-84°, pK_2' 3.56. Purified by steam distn and recryst from H2O or 40% aqueous EtOH. The N-acetate forms needles from hot H2O m 104°; the N-benzoyl derivative forms needles from aq EtOH m 77-78°; the picrate has m 194° dec [J Am Chem Soc 48 2657 1926].

9-Chloromethyl anthracene [24463-19-2] M 226.7, m 141-142° dec, 141-142.5°. If it is free from OH in the IR then recryst from hexane-CH2Cl2, or CH2Cl2 as needles. If OH is present then some solvolysis has occurred. In this case treat 8.5g with SOCl2 (4.8g) in dioxane (60mL) and reflux for 5h, then evaporate to dryness and wash the residue with cold CH2Cl2 and recrystallise. With KI/Me2CO it forms the iodomethyl derivative [Martin et al. Helv Chim Acta 38 2009 1955; J Org Chem 21 1512 1956].


Chloromethyl methyl ether (MOMCI) [107-30-2] M 80.5, b 55-57°, d 1.060, n 1.396. If suspect (check IR), shake with satd aq CaCl2 soln, dry over CaCl2 and fractionally distil taking middle fraction. [Marvel and Porter Org Synth Coll Vol I 377 1941] VERY TOXIC and CARCINOGENIC.


4-Chloro-2-methylphenoxycetic acid (MCPA) [94-74-6] M 200.6, m 113-117°, 120°, 122-123°, pK_2 3.62 (3.05). It is insoluble in H2O (sol 0.55g/L at 20°), and recrystallises from *C6H6 or chlorobenzene as plates [Acta Chem Scand 6 993 1952]. The S-benzylthiouronium salt has m 164-165°. and the Cu^2+ salt has m 247-249° dec [Armarego et al. Nature 183 1176 1959; UV: Duvaux and Grabe Acta Chem Scund 4 806 1950; IR: Joberg Acta Chem Scund 4 798 1950].

Chloromethyl phenyl sulfide [7205-91-6] M 158.7, b 63°/0.1mm, 98°/12mm, 113-115°/20mm. Dissolve in CH2Cl2 or CCl4 and dry over CaCl2, or pass through a tube of CaCl2 and fractionally distil using a fractionating column. Harmful vapours. It gives the sulfone (b 130°/1mm and m 53° from EtOH) on oxidation with permnophthalic acid. [Justus Liebig's Ann Chem 563 54 64 1949].


4-(Chloromethyl)pyridine hydrochloride [1822-51-1] M 164.0, m 170-175°, 172-173°, pK_Bet ~ 5.6. Purified by recrystn from EtOH or EtOH-dry Et2O. It melts between 171° and 175° and the clear melt resolidifies on further heating at 190° and turns red to black at 280° but does not melt again. The picrate-hydrochloride (prepared in EtOH) has m 146-147°. The free base is an oil, [Mosher and Tessieri J Am Chem Soc 73 4925 1951].

2-Chloro-1-methylpyridinium iodide [14338-32-0] M 255.5, m 203-205°, 205-206°(dec), 207°. Purified by dissolving in EtOH and adding dry Et2O. The solid is washed with Me2CO and dried at
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20°/0.35mm. Store in the dark. Attempted recrystn from Me₂CO-EtOH-pet ether (b 40-60°) caused some exchange of the Cl substituent by I. The picrate has m 106-107°, and the perchlorate has m 212-213°. [UV and solvolysis: Barlin and Benbow J Chem Soc, Perkin Trans 2 790 1974.]

1-Chloronaphthalene [90-13-1] M 162.6, f -2.3°, b 136-136.5°/20mm, 259.3°/760mm, d 1.194, n 1.6326. Washed with dilute NaHCO₃, then dried with Na₂SO₄ and fractionally distd under reduced pressure. Alternatively, before distn, it was passed through a column of activated alumina, or dried with CaCl₂, then distd from sodium. It can be further purified by fractional crystn by partial freezing or by crystn of its picrate to constant melting point (132-133°) from EtOH, and recovering from the picrate.

2-Chloronaphthalene [91-58-7] M 162.6, m 61°, b 264-266°. dried under vacuum. Crystd from 25% EtOH/water and dried from sodium. It can be further purified by fractional crystn by partial freezing or by crystn of its picrate to constant melting point (132-133°) from EtOH, and recovering from the picrate.


4-Chloro-1-naphthol [604-44-4] M 178.6, m 116-117°, 120-121°, pK₂° 8.86. Crystd from EtOH or chloroform.


4-Chloro-2-nitroaniline [89-63-4] M 172.6, m 116-116.5°, pK₂° -0.99. Crystd from hot water or EtOH/water and dried for 10h at 60° under vacuum.

2-Chloro-4-nitrobenzamide [3011-89-0] M 200.6, m 172°. Cryst from EtOH.

2-Chloro-1-nitrobenzene [88-73-3] M 157.6, m 32.8-33.2°. Crystd from EtOH, MeOH or pentane (charcoal).

3-Chloro-1-nitrobenzene [121-73-3] M 157.6, m 45.3-45.8°. Crystd from MeOH or 95% EtOH (charcoal), then pentane.

4-Chloro-1-nitrobenzene [100-00-5] M 157.6, m 80-83°, 83.5-84°, b 113°/8mm, 242°/atm, d 1.2914. Crystd from 95% EtOH (charcoal) and sublimes in a vacuum. [Emmons J Am Chem Soc 76 3470 1954; Newman and Forres J Am Chem Soc 69 1221 1947.]

4-Chloro-7-nitrobenzofurazane (7-chloro-4-nitrobenzoxadiazole) [10199-89-0] M 199.6, m 96.5-97°, 97°, 99-100°. Wash the solid with H₂O and recrystallise from aqueous EtOH (1:1) as pale yellow needles. It sublimes in a vacuum [UV, NMR: Bolton, Gosh and Katritzky J Chem Soc 1004 1966].


3-Chloroperbenzoic acid [937-14-4] M 172.6, m 92-94° (dec), pK_{25} 7.57. Recrystd from CH₂Cl₂ [Traylor and Mikszta J Am Chem Soc 109 2770 1987]. Peracid of 99+% purity can be obtained by washing commercial 85% material with phosphate buffer pH 7.5 and drying the residue under reduced pressure. Alternatively the peracid can be freed from m-chlorobenzoic acid by dissolving 50% of benzene and washing with an aq soln buffered at pH 7.4 (NaH₂PO₄/NaOH) (5 x 100mL). The organic layer was dried over MgSO₄ and carefully evaporated under vacuum. Necessary care should be taken in case of EXPLOSION. The solid was recrystd twice from CH₂Cl₂/Et₂O and stored at 0° in a plastic container as glass catalyses the decomposition of the peracid. The acid is assayed iodometrically. [J Org Chem 29 1976 1964; Bortolini et al. J Org Chem 52 5093 1987.]

2-Chlorophenol [95-57-8] M 128.6, m 8.8°, b 61-62°/10mm, 176°/atm, pK_{25} 8.34. Passed at least twice through a gas chromatograph column. Also purified by fractional distn.

3-Chlorophenol [108-43-0] M 128.6, m 33°, b 44.2°/1mm, 214°/atm, pK_{25} 9.13. Could not be obtained solid by crystn from pet ether. Purified by distn under reduced pressure.

4-Chlorophenol [106-48-9] M 128.6, m 43°, 100-101°/10mm, pK_{25} 9.38. Distd, then cryst from pet ether (b 40-60°) or hexane, and dried under vacuum over P₂O₅ at room temp. It has pKₐ 9.38 at 20° in water. [Bernasconi and Paschalis J Am Chem Soc 108 2969 1986.]

4-Chlorophenoxyacetic acid [122-88-3] M 186.6, m 157°, pK₂ 3.00. Crystd from EtOH.

α-4-Chlorophenoxypropionic acid [3307-39-9] M 200.6, m 116°, pK_{EtOH} ~3.2. Crystd from EtOH.

β-4-Chlorophenoxypropionic acid [3284-79-5] M 200.6, m 138°, pK_{EtOH} ~4.2. Crystd from EtOH.

3-Chlorophenylacetic acid [1878-65-5] M 170.6, m 74°, pK₂ 4.11. Crystd from EtOH/water, or as needles from C₆H₆ or H₂O (charcoal). The acid chloride (prepared by boiling with SOCl₂) has b 127-129°/15mm. [Dippy and Williams J Chem Soc 61 1934; Misra and Shukla J Indian Chem Soc 28 480 1951.]


4-Chloro-1-phenylbutan-1-one [939-52-6] M 182.7, m 19-20°, b 134-137°/5mm, d₂ 1.149, nD 1.55413. Fractionate several times using a short column. It can be recrystd from anhydrous pet ether at -20° as glistening white rosettes and filtered at 0° and dried in a vacuum desiccator over H₂SO₄. The semicarbazone has m 136-137°. [J Am Chem Soc 46 1882 1924, 51 1174 1929, Hart and Curtis J Am Chem Soc 79 931 1957.]

1-(2-Chlorophenyl)-1-(4-chlorophenyl)-2,2-dichloroethane (Mitotane, o,p' -DDD) [53-19-0] M 320.1, m 75.8-76.8°, 76-78°. Purified by recrystallisation from pentane and from MeOH or EtOH. It is sol in isooctane and CCl₄. [Haller et al. J Am Chem Soc 67 1600 1945.]

3-(4-Chlorophenyl)-1,1-dimethylurea (monuron) [150-68-5] M 198.7, m 171°. Crystd from MeOH.
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4-Chloro-1,2-phenylenediamine [95-83-0] M 142.6, m 69-70°, pKa1^25-0.27 (aq H2SO4), pKa2 3.35 (3.67). Recrystd from pet. ether.

4-Chlorophenyl isocyanate [104-12-1] M 153.6, m 28-31°, 31-32°, 32°, 32°, b 80.6-80.9°/9.5mm, 115-117°/45mm. Purified by recrystn from pet ether (b 30-40°) or better by fractional distn. TOXIC irritant.

4-Chlorophenyl isothiocyanate [2131-55-7] M 169.6, m 44", 43-45", 45°, 46°, 47°, b 110-115°/4rnm, 135-136°/24mm. Check the IR first. Triturate with pet ether (b 30-60°) and decant the solvent. Repeat 5 times. The combined extracts are evap under reduced press to give almost pure compound as a readily crystallisable oil with a pleasant anise dour. It can be recrystd from the minimum vol of EtOH at 50° (do not boil too long in case it reacts). It can be purified by vac distn. IRRITANT.

4-Chlorophenyl 2-nitrobenzyl ether [109669-56-9] M 263.7, m 69°. Crystd from EtOH.

4-Chlorophenyl 4-nitrobenzyl ether [5442-44-4] M 263.7, m 102°. Crystd from EtOH.

9-Chloro-9-phenylxanthene (Pixyl chloride) [42506-03-6] M 292.8, m 105-106°. Possible impurity is 9-hydroxy-9-phenylxanthene. If material contains a lot of the hydroxy product then boil log in CHCl3 (50mL) with redistd acetyl chloride (1mL) until liberation of HCl is complete. Evapn leaves the chlorophenylxanthene as the hydrochloride which on heating with *benzene loses HCl; and on adding pet ether prisms of chlorophenylxanthene separate and contain 0.5mol of *benzene. The *benzene-free compound is obtained on drying and melts to a colourless liquid. [Justus Liebigs Ann Chem 370 142 1909.] The 9-phenylxanthyl group is called pixyl. [J Chem Soc, Chem Commun 639 1978.]

Chlorophyll a [479-61-8] M 983.5, m 117-120°, 150-153°, 178-180° (sinters at -150°), [α]D^25 -262° (Me2CO). Forms green crystals from Me2CO, Et2O + H2O, Et2O + hexane + H2O or Et2O + pentane + H2O. It is sparingly soluble in MeOH and insol in pet ether. In alkaline soln it gives a blue-green colour with deep red fluorescence. A very crude chlorophyll mixture has been purified by chromatography on low melting polyethylene (MI 0.044; 'Dow' melting index MI <2) and developed with 70% aq Me2CO. The order of effluent from the bottom of the column is: xanthophylls, chlorophyll b, chlorophyll a, phaeophytins and carotenes. A mixture of chlorophylls a and b is best separated by chromatography on sugar and the order is chlorophyll b elutes first followed by chlorophyll a. To an Me2CO-H2O soln of chlorophylls 200mL of iso-octane is added and the mixt shaken in a separating funnel and the H2O is carefully removed. The iso-octane layer is dried (Na2SO4) and applied to a glass column (5cm diameter) dry packed with 100mL of powdered sucrose which has been washed with 250mL of iso-octane is added and the mixt shaken in a separating funnel and the H2O is carefully removed. The iso-octane layer is dried (Na2SO4) and applied to a glass column (5cm diameter) dry packed with 100mL of powdered sucrose which has been washed with 250mL of iso-octane. Elution with 0.5% of isopropanol in iso-octane gives chlorophyll a. Keeping the eluate overnight at 0° yields micro crystals which are collected by filtration or centrifugation (Yield 40mg). UVEt0" has & 660, 613, 577, 531, 498, 429 and 409 nm. [Anderson and Calvin Nature 194 285 1962; Stoll and Weidemann Helv Chim Acta 16 739 757 1933; NMR Katz et al. J Am Chem Soc 90 6841 1968, 85 3809 1963 for a and b; ORD: Inhoffen et al. Justus Liebig's Ann Chem 704 208 1967; Willstätter and Isler Justus Liebig's Ann Chem 390 269, 233 1912.]

Chlorophyll b [519-62-0] M 907.52, sinters at 86-92°, sinters at 170°, dec at 160-170°, m 183-185°, 190-195°, [α]D^25 -267° (Me2CO + MeOH), [α]D^25 -133° (MeOH + Pyridine 95:5). See purification of chlorophyll a, and is separated from "a" by chromatography on sucrose [UV, IR: Stoll and Weidemann Helv Chim Acta 42 679, 681 1959]. It forms red-black hexagonal bipyramids or four sided plates from dilute EtOH and has been recrystd from CHCl3-MeOH. It is soluble in MeOH, EtOH, EtOAc and insoluble in pet ether. [J Am Chem Soc 88 5037 1966.]

Chloropicrin (trichloronitromethane) [76-06-2] M 164.5, b 112°. Dried with MgSO4 and fractionally distd. EXTREMELY NEUROTOXIC, use appropriate precautions.

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S-(-)-2-Chloropropionic acid \([29617-65-1]\) M 108.5, b \(77^\circ/10\text{mm}\), \(80.7^\circ/10\text{mm}\), \(185-188^\circ/\text{atm}\), \(d^2_{25} 1.2485\), \(n^2_{D} 1.4366\), \([\alpha]^2_{D} -14.6^\circ\) (neat). Purified by twice fractionating through a 115 cm Podbielniak column (calcd 50 theoretical plates at atm pressure, see p. 141) using a take-off ratio of 1:5. The acid chloride is prepared by dissolving the acid in SOCl\(_2\) adding a few drops of PCl\(_3\), refluxing and then distilling through a 30 cm column, b \(53^\circ/100\text{mm}\), \([\alpha]_{i} -4.6^\circ\) (neat), \(d^3_{1.2689}, n^2_{i} 1.4368\). [Fu et al., J Am Chem Soc 76 6954 1954].

3-Chloropropionic acid [107-94-8] M 108.5, m \(41^\circ\), pK\(_2\) 4.08. Crystd from pet ether or *benzene.

3-Chloropropyl bromide (1-bromo-3-chloropropane) [109-70-6] M 157.5, b \(142-145^\circ\), \(n^2_{25} 1.2689, n^2_{i} 1.4368\). Washed with conc H\(_2\)SO\(_4\), water, 10% Na\(_2\)CO\(_3\) soln, water again and then dried with CaCl\(_2\) and fractionally distd just before use [Akagi, Oae and Murakami J Am Chem Soc 78 4034 1956].

6-Chloropurine [87-42-3] M 154.6, m \(179^\circ\) (dec), pK\(_2\) 0.45, pK\(_3\) 7.88. Crystd from water.

2-Chloropyrazine [14508-49-7] M 114.5, b \(62-63^\circ/31\text{mm}\), \(153-154^\circ/\text{atm}\), \(d^3_{4} 1.302\), \(n^2_{D} 1.535\), pK\(_{E_{st}}\) <0. Fractionally distil through a short column packed with glass helices. It has a penetrating mildly pungent odour with a high vapour pressure at room temperature [Erickson and Spoerri J Am Chem Soc 68 400 1946; J Org Chem 28 1682 1963].

2-Chloropyridine [109-09-1] M 113.6, b \(49.0^\circ/7\text{mm}\), d \(1.20\), n \(1.532\), pK\(_2\) 0.49 (0.72). Dried with NaOH for several days, then distd from CaO under reduced pressure.

3-Chloropyridine [626-60-8] M 113.6, b \(148^\circ\), d \(1.194\), n \(1.5304\), pK\(_{2}\) 2.84. Distd from KOH pellets.

4-Chloropyridine [626-61-9] M 113.6, b \(85-86^\circ/100\text{mm}\), \(147-148^\circ/760\text{mm}\), pK\(_2\) 3.84. Dissolved in distilled water and excess of 6M NaOH was added to give pH 12. The organic phase was separated and extracted with four volumes of diethyl ether. The combined extracts were filtered through paper to remove water and the solvent evaporated. The dark brown residual liquid was kept under high vacuum [Vaidya and Mathias J Am Chem Soc 108 5514 1986]. It can be distd but readily darkens and is best kept as the hydrochloride [7379-35-3] M 150.1, m \(163-165^\circ\) (dec).

2-Chloroquinoline [1722-12-9] M 114.5, m 63-65\(^\circ\), \(66^\circ\), b \(91^\circ/26\text{mm}\), pK\(_2\) 1.90. It has been recrystd from \(*\text{C}_6\text{H}_6\), pet ether or a mixture of both. It sublimes at 50/18mm and can be distd in a vacuum. [IR: Short and Thompson J Chem Soc 168 1952; Boarland and McOmie J Chem Soc 1218 1951].

2-Chloroquinoline [612-62-4] M 163.6, m \(34^\circ\), b \(147-148^\circ/15\text{mm}\), \(d^3_{25} 1.235\), \(n^2_{D} 1.629\), pK\(_{E_{st}}\) -0.3. Purified by crystn of its picrate to constant melting point (123-124\(^\circ\)) from *benzene, regenerating the base and distilling under vacuum [Cumper, Redford and Vogel J Chem Soc 1183 1962]. 2-Chloroquinoline can be crystd from EtOH. Its picrate has m \(122^\circ\) (from EtOH).

4-Chloroquinoline [611-35-8] M 163.6, m \(29-32^\circ\), \(31^\circ\), b \(130^\circ/15\text{mm}\), \(261^\circ/744\text{mm}\), pK 3.72. Possible impurities include the 2-isomer. Best purified by converting to the picrate (m 212-213\(^\circ\) dec) in EtOH and recryst from EtOH (where the picrate of the 2-chloroquinoline stays in soln) or EtOAc. The picrate is decomposed with 5% aqueous NaOH, extracted in CHCl\(_3\), washed with H\(_2\)O, dried (MgSO\(_4\)), evapd and distd in a vacuum. It can be steam distd from slightly alkaline aqueous solns, the aqueous distillate is extracted with Et\(_2\)O, evaporated and distd. The distillate solidifies on cooling. [Bobrowski Chem Ber 71 578 1938].

8-Chloroquinoline [611-33-6] M 163.6, b \(171-171.5^\circ/24\text{mm}\), d \(1.278\), n \(1.644\), pK\(_2\) 3.12. Purified by crystn of its ZnCl\(_2\) complex (m 228\(^\circ\)) from aqueous EtOH.

4-Chlororesorcinol [95-88-5] M 144.6, m \(105^\circ\), pK\(_{E_{st}(1)}\) -9.2, pK\(_{E_{st}(2)}\) -10.1. Crystd from boiling CCl\(_4\) (10g/L, charcoal) and air dried.
5-Chlorosalicaldehyde [635-93-8] M 156.6, m 98.5-99°. Steam distd, then crystd from aq EtOH.


2-Chlorothiophene (2-thienyl chloride) [96-43-5] M 118.6, b 126-128°, d 1.285, n 1.551. Purified by fractional distn at atmospheric pressure or by gas chromatography.

8-Chlorotheophylline [85-18-7] M 214.6, m 311°(dec), pK~~t(1)-5.4, pKSt(-2) -9.1. Crystd from H2O.


2-Chlorotoluene [95-49-8] M 126.6, b 159°, d 1.083, n 1.5255. Dried for several days with CaCl2, then distd from Na using a glass helices-packed column.


4-Chlorotoluene [106-43-4] M 126.6, f 7.2°, b 162.4°, d 1.07, n 1.521. Dried with BaO, fractionally distd, then fractionally crystd by partial freezing.


Chlorotrifluoromethane [75-72-9] M 104.5, m -180°, b -81.5°. Main impurities were CO2, O2, and N2. The CO2 was removed by passage through saturated aqueous KOH, followed by conc H2SO4. The O2 was removed using a tower packed with activated copper on Kieselguhr at 200°, and the gas dried over P2O5.

Chlorotriphenylmethane see triphenylmethyl chloride (trityl chloride).


5β-Cholanic acid [25312-65-6] M 360.6, m 164-165°, [α]D11 +21.7° (CHCl3), pKEst -4.9. Crystd from EtOH. The Ethyl ester has m 93-94° (from 80% EtOH), b 2739/12mm, [α]D20 +21° (CHCl3).


5α-Cholestane [481-21-0] M 372.7, m 80°, [α]D546 +29.5° (c 2, CHCl3). Crystd from diethyl ether/EtOH.

5α-Cholesterol-3β-ol [80-97-7] M 388.7, m 142-143°(monohydrate), [α]D546 +28° (c 1, CHCl3), [α]D0 +27.4° (in CHCl3). Crystd from EtOH or slightly aqueous EtOH, or MeOH. [Mizutani and Whitten J Am Chem Soc 107 3621 1985.]

Cholesterol \([57-88-5]\) M 386.7, m 148.9-149.4°, \([\alpha]_D^{25} -35^\circ\) (hexane). Crystd from ethyl acetate, EtOH or isopropyl ether/MeOH. [Hiromitsu and Kevan J Am Chem Soc 109 4501 1987.] For extensive details of purification through the dibromide, see Fieser [J Am Chem Soc 75 5421 1953] and Schwenk and Werthessen [Arch Biochem Biophys 40 334 1952], and by repeated crystn from acetic acid, see Fieser [J Am Chem Soc 75 4395 1953].

Cholesteryl acetate \([604-35-3]\) M 428.7, m 112-115°, \([\alpha]_{546}^{20} -51^\circ\) (c 5, CHCl₃). Crystd from n-pentanol.


Cholesteryl oleate \([303-43-5]\) M 651.1, m 48.8-49.4°. Purified by chromatography on silica gel.

Cholic acid \([81-25-4]\) M 408.6, m 198-200°, \([\alpha]_{546}^{20} +41^\circ\) (c 0.6, EtOH), pK₂ 4.98. Crystd from EtOH. Dried under vacuum at 94°.

Choline chloride \([67-48-1]\) M 139.6, m 302-305°(dec). Extremely deliquescent. Purity checked by AgNO₃ titration or by titration of free base after passage through an anion-exchange column. Crystd from absolute EtOH, or EtOH-diethyl ether, dried under vacuum and stored in a vacuum desiccator over P₂O₅ or Mg(CIO₄)₂.

4-Chromanone \([491-37-2]\) M 148.2, m 35-37°, 39°, 41°, b 92-93°/3mm, 130-132°/15mm, 160°/50mm. It has been recryst from pet ether, or purified by dissolving in *C₆H₆ washing with H₂O, drying (MgSO₄), evaporate and dist in a vacuum, then recryst the residue. The liquid has a pleasant lemon-like odour. The *semicarbazone* has m 227°. [Loudon and Razdan J Chem Soc 4299 1954.] The oxime is prepared from 3g of chromanone, 3g NH₂OH.HCl in EtOH (50mL), 6g K₂CO₃ and refluxed on a water bath for 6h. The soln is poured into H₂O, the solid is filtered off, dried and dissolved in hot *C₆H₆ which on addition of pet ether yields the oxime as glistening needles m 140°. Decomposition of this gives very pure chromanone. The *benzal derivative* is prepared from 3g of chromanone, 4g PhCHO in 50mL EtOH, heated to boiling, 10mL of conc HCl are added dropwise and set aside for several days. The derivative separates and is recrystd from EtOH to give yellow needles, m 112° [J Am Chem Soc 45 2711 1923]. Reaction with Pb(OAc)₄ yields the 3-acetoxy derivative m 74° (from pet ether + trace of EtOAc) [Cavill et al. J Chem Soc 4573 1954].

Chrysene \([218-01-9]\) M 228.3, m 255-256°. Purified by chromatography on alumina from pet ether in a darkened room. Its soln in *C₆H₆ was passed through a column of decolorising charcoal, then crystd by concentration of the eluate. Also purified by crystn from *C₆H₆ or *C₆H₅-pet ether, and by zone refining. [Gorman et al. J Am Chem Soc 107 4404 1985]. It was freed from 5H-benzo[b]carbazole by dissolving in N,N-dimethylformamide and successively adding small portions of alkali and iodomethane until the fluorescent colour of the carbazole anion no longer appeared when alkali was added. The chrysene (and alkylated 5H-benzo[b]carbazole) separated on addition of water. Final purification was by crystn from ethylcyclohexane and from 2-methoxyethanol [Bender, Sawicki and Wilson Anal Chem 36 1011 1964]. It can be sublimed in a vacuum.

Chrysoidine G (4-phenylazo-1,3-benzenediamine monohydrochloride) \([532-82-1]\) M 248.7, m 118-118.5°, pK₁ 3.32, pK₂ 5.21. Red-brown powder which is recrystd from H₂O. It gives a yellow soln in conc H₂SO₄ which turns orange on dilution. Its solubility at 15° is 5.5% (H₂O), 4.75% (EtOH), 6.0% (cellosolve), 9.5% (ethylene glycol) and insol in *C₆H₆. The *hydroiodide* has m 184° (from EtOH) and the *picrate* forms red needles m 196°. [Bull Chem Soc Jpn 31 864 1958; Chem Ber 10 213 1877.]

1,8-Cineole (1,8-epoxy-p-menthane) \([470-82-6]\) M 154.2, f 1.3°, b 176.0°, d 0.9251. See eucaliptol on p. 242.
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trans-Cinnamaldehyde [14271-10-9] M 132.2, m -4°, -7.5°, -9°, b 80°/0.4 mm, 85.8°/1.1 mm, 125-128°/11 mm, 152.2°/40 mm, 163.7°/60 mm, 199.3°/200 mm, 246°/760 mm dec, d²⁰ 1.0510, n²⁰ 1.623. Purified by steam distn (soln 1 in 700 parts H₂O) followed by distn in vacuo. The cis-isomer has b 67-69°/40 mm and e 1.0436 and n₂⁰ 1.5937. The trans-semicarbazone has m 210° dec from CHCl₃-MeOH (cis-semicarbazone has m 196°); the trans-phenylsemicarbazone has m 177° from CHCl₃-MeOH (the cis-phenylsemicarbazone has m 146°); the trans-2,4-dinitrophenylhydrazone has m 250° dec from MeOH as the cis-isomer [Gamboni et al. Helv Chim Acta 38 255 1955; Peine Chem Ber 17 2117 1884; J Org Chem 26 4814 1961; J Am Chem Soc 86 198 1964].

cis-Cinnamic acid (2-3-phenyl-2-propenoic acid) [102-94-3] M 148.2, m 68° (for ah-form), pK₂ 3.93. The cis-acid is prepared by catalytic reduction of phenylpropiolic acid and after distn in high vacuum at -95° gives the most stable allo-isomer m 68°. Recryst from pet ether yields Liebermann's iso-cinnamic acid m 58°. When the allo-acid (m 68°) is heated at 20° above its melting point in a sealed capillary for 0.5h and allowed to cool slowly Erlenmayer's iso-cinnamic acid m 42° is formed. This form can also be obtained in larger amounts by heating the allo-acid at 80° for 3h and on cooling it remains liquid for several weeks but gives the 42° acid on inoculation with the crystals from the capillary tube. This form is unchanged in 6 weeks when kept in a dark cupboard. All three forms have the same pK values and the same rate of bromination. There is also a very labile form with m 32°. [Liebermann, Chem Ber 26 1572 1893; Clausen and Crismer Justus Liebigs Ann Chem 218 135 1883; Robinson and James J Chem Soc 143 1833; Berthoud and Urech Helv Chim Acta 13 437 1930; McCoy and McCoy J Org Chem 33 2354 1968].

trans-Cinnamic (E-3-phenyl-Z-propenoic) acid [140-10-3; 621-82-9 for E-Z mixture] M 148.2, m 134.5-135°, pK₂ 4.42 (4.50). Crystd from *benzene, CCl₄, hot water, water/EtOH (3:1), or 20% aqueous EtOH. Dried at 60° in vacuo. Steam volatile.

Cinnamic anhydride [538-56-7] M 278.4, m 136°. Crystd from *C₆H₅ or toluene/pet ether (b 60-80°).

N-Cinnamoyl-N-phenylhydroxylamine [7369-44-0] M 239.3, m 158-163°. Recrystd from EtOH.

Cinnamyl alcohol [104-54-1] M 134.2, m 33°, b 143.5°/14 mm, λmax 251nm (e 18,180 M⁻¹ cm⁻¹). Crystd from diethyl ether/pentane.


Citraconic anhydride [616-02-4] M 112.1, m 8-9°, b 47°/0.03 mm, 213°/760 mm, d²⁰ 1.245, n₂⁰ 1.472. Possible contamination is from the acid formed by hydrolysis. If the IR has OH bands then reflux with Ac₂O for 30 min, evaporate then distil the residue in a vacuum; otherwise distil in a vacuum. Store in a dry atmosphere. [Biochem J 191 269 1980.]

Citrazinic acid (2,6-dihydroxyisonicotinic acid) [99-11-6] M 155.1, m >300°, pK₁ 3.0, pK₂ 4.76. Yellow powder with a greenish shade, but is white when ultra pure and turns blue on long standing. It is insoluble in H₂O but slightly soluble in hot HCl and soluble in alkali or carbonate solutions. Purified by precipitation from alkaline solutions with dilute HCl, and dry in a vacuum over P₂O₅. The ethyl ester has m 232° (evacuated tube) and a pKa of 4.81 in MeOCH₂CH₂OH [IR: Pitha Coll Czech Chem Comm 28 1408 1963].

Citric acid (H₂O) [5949-29-1; 77-92-9 (anhydric)] M 210.1, m 156-157°, 153° (anhyd), pK₁ 2.96, pK₂ 4.38, pK₃ 5.68. Cryst from water.
Citronellal (3,7-dimethyloctan-6-al) \(\{R(+)\}: 2385-77-5; S(-): 5949-05-3\} M 154.3, b 67°/4mm, 89°/14mm, 104-105°/21mm, 207°/760mm, \([\alpha]_D^{25} +20^0\) and (-) 20°, \([\alpha]_D^{20} (+)\) and (-) 16.5° (neat). Fractionally distd. Alternatively extracted with NaHSO3 solution, washed with Et2O then acidified to decompose the bisulfite adduct and extracted with Et2O, dried (Na2SO4), evaporated and distd. Check for purity by hydroxylamine titration. The ORD in MeOH (c 0.167) is: \([\alpha]_D^{25} +90^0\), \([\alpha]_D^{20} +110^0\), \([\alpha]_D^{25} +120^0\) and \([\alpha]_D^{20} +120^0\) (neat). The semicarbazone has \(m 85^0\), and the 2,4-dinitrophenylhydrazone has \(m 79-80^0\). [IR: J Chem Soc 3457 1950; Djerassi and Krakower J Am Chem Soc 81 237 1959.]

\(\beta\)-Citronellene (2,6-dimethylocta-2,7-diene) \{S(+): 2436-90-0; R(-): 10281-56-8\} M 138.3, b 153-154°/730mm, 155°/atm, \(d_D^{24} 0.757\), \(n_D^{12} 1.431\), \([\alpha]_D^{25} (+)\) and (-) 6.3°, \([\alpha]_D^{20} (+)\) and (-) 5.4° (neat). Purified by distillation over Na three times and fractionation. [(-)-Arigoni and Jeager Helv Chim Acta 37 881 1954; (+)-Eschenmoser and Schinz Helv Chim Acta 33 171 1950.]

\(\beta\)-Citronellol (3,7-dimethyloctan-6-ol) \{R(+): 11171-61-9; S(-): 106-22-9\} M 156.3, b 47°/1mm, 102-104(10°)/10mm, 112-113°/12mm, 221-224°/atm, 225-226°/atm, \(d_D^{24} 0.8551\), \(n_D^{12} 1.4562\), \([\alpha]_D^{25} (+)\) and (-) 7.9°, \([\alpha]_D^{20} (+)\) and (-) 8.1° (neat). Purified by distillation through a column packed (Ni) and the main cut collected at 84°/14mm and redistilled. Also purified via the benzoate. [IR: Eschenazi J Org Chem 26 3072 1961; Bull Soc Chim Fr 505 1951.]

S-Citrulline (2-amino-5-ureidopentanoic acid) \{372-75-8\} M 175.2, \(m 222^0\). \([\alpha]_D^{25} +24.2^0\) (in 5M HCl), \(pK_a 9.71\). Likely impurities are arginine, and ornithine. Crystd from water by adding 5 volumes of EtOH. Also crystd from water by addn of MeOH.

Clofazimine [2-(4-chloroanilino)-3-isopropylimino-5-(4-chlorophenyl)-3,4-dihydrophenazine] \{2030-63-9\} M 473.5, m 210-212°. Recrystd from acetone.

Coenzyme Qo (2,3-Dimethoxy-5-methyl-1,4-benzoquinone, 3,4-dimethoxy-2,5-toluquinone, fumigatin methyl ether), colchicine and colchicoside see entries in Chapter 6.

Conessine \{546-06-5\} M 356.6, m 125°, 127-128.5°, \([\alpha]_D^{20} -1.9^0\) (in CHCl3) and +25.3° (in EtOH), \(pK_{sh} 10.4\), \(pK_{sh} 10.7\). Crystd from acetone. The dihydrochloride has m >340° and \([\alpha]_D^{20} +9.3^0\) (c 0.9, H2O).

Coniferyl alcohol [4-hydroxy-3-methoxy-cinnamyl alcohol, 3-(4-hydroxy-3-methoxy-phenyl)-2-propen-1-ol] It is soluble in EtOH and insoluble in H2O. It can be recrystd from EtOH and distd in a vacuum. It polymerises in dilute acid. The benzoyl derivative has m 95-96° (from pet ether), and the tosylate has m 66°. [Derivatives: Freudenberg and Achtzehn Chem Ber 88 10 1955; UV: Herzog and Hillmer Chem Ber 64 1288 1931.]

Congo Red \{573-58-0\} M 696.7, \(\lambda_{max}^{max} 497nm\), \(pK_2^{25} 4.19\). Crystd from aq EtOH (1:3). Dried in air.

\((-\)-\(\alpha\)-Copaene \{1R,2S,6S,7S,8S-8-isopropyl-1,3-dimethyltricyclo[4.4.0.02~7]<3-ene\} \{3856-25-5\} M 204.4, b 119-120°/10mm, 246-251°, d 0.908, n 1.489, \([\alpha]_D^{20} -6.3^0\) (c 1.2, CHCl3). Purified by distillation, preferably under vacuum.

4,5-Coprosten-3-ol (cholest-4-ene-3β-ol) \{517-10-2\} M 386.7, m 132°. Crystd from MeOH/diethyl ether.

Coprosterol (5α-cholestan-3β-ol, dihydrocholesterol) \{80-97-7\} M 388.7, m 101°, 139-140°, \([\alpha]_D^{20} +24^0\) (c 1, CHCl3). See entry on p. 169.

Coronene \{191-07-1\} M 300.4, m 438-440°, \(\lambda_{max}^{max} 345nm\) (log ε 4.07). Crystd from *benzene or toluene, then sublimed in vacuum.

Cortisol, corticosterone, cortisone and cortisol-21-acetate see entries in Chapter 6.
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Coumalic acid (2-pyrone-5-carboxylic acid) [500-05-0] M 140.1, m 205-210°(dec), pK<sub>est</sub> ~0. Crystd from MeOH. Methyl ester, from pet ether, has m 74-74° and b 178-180°/60 mm. 


Coumarin-3-carboxylic acid [531-81-7] M 190.2, m 188°(dec), pK<sub>est</sub> ~1.5. Crystd from water.

Creatine (H<sub>2</sub>O) and creatinine see entries in Chapter 6.

(o-)Cresol [95-48-7] M 108.1, m 30.9°, b 191°, n<sub>d1</sub> 1.536, n<sub>d6</sub> 1.534, pK<sup>25</sup> 10.22. Can be freed from m- and p-isomers by repeated fractional distn, Crystd from *benzene by addition of pet ether. Fractional crystd by partial freezing of its melt.

m-Cresol [108-39-4] M 108.1, f 12.0°, b 202.7°, d 1.034, m 1.544, pK<sup>25</sup> 10.09. Separation of the m- and p-cresols requires chemical methods, such as conversion to their sulfonates [Br"uchner Anal Chem 75 289 1928]. An equal volume of H<sub>2</sub>SO<sub>4</sub> is added to m-cresol, stirred with a glass rod until soln is complete. Heat for 3h at 103-105°. Dilute carefully with 1-1.5 vols of water, heat to boiling point and steam distil until all unsulfonated cresol has been removed. Cool and extract residue with ether. Evaporate the soln until the boiling point reaches 140° and steam distil off the m-cresol. Another purification involves distn, fractional crystn from the melt, then redistn. Freed from p-cresol by soln in glacial acetic acid and bromination by about half of an equivalent amount of bromine in glacial acetic acid. The acetic acid was distd off, then fractional distn of the residue under vac gave bromocresols from which 4-bromo-m-cresol was obtained by crystn from hexane. Addn of the bromocresol in glacial acetic acid slowly to a reaction mixture of HI and red phosphorus or (more smoothly) of HI and hypophosphorus acid, in glacial acetic acid, at reflux, removed the bromine. After an hour, the soln was distd at atmospheric pressure until layers were formed. Then it was cooled and diluted with water. The cresol was extracted with ether, washed with water, NaHCO<sub>3</sub> soln and again with water, dried with a little CaCl<sub>2</sub> and distd [Baltzly, Ide and Phillips J Am Chem Soc 77 2522 1955].

p-Cresol [106-44-5] M 108.1, m 34.8°, b 201.9°, n<sub>d1</sub> 1.531, n<sub>d6</sub> 1.529, pK<sup>25</sup> 10.27. Can be separated from m-cresol by fractional crystn of its melt. Purified by distn, by pptn from *benzene soln with pet ether, and via its benzoate, as for phenol. Dried under vacuum over P<sub>2</sub>O<sub>5</sub>. Has also been crystd from pet ether (b 40-60°) and by conversion to sodium p-cresoxyacetate which, after crystn from water was decomposed by heating with HCl in an autoclave [Savard Ann Chim (Paris) 11 287 1929].

o-Cresolphthalein complexon [2411-89-4] M 636.6, m 186°(dec), λ<sub>max</sub> 575nm, pK<sub>1</sub> 2.2, pK<sub>2</sub> 2.9, pK<sub>3</sub> 7.8, pK<sub>4</sub> 11.4, pK<sub>5</sub> 12.0. o-Cresolphthalein (a complexone precursor without the two bis-carboxymethylamino groups) is a contaminant and is one of the starting materials. It can be removed by dissolving the reagent in water and adding a 3-fold excess of sodium acetate and fractionally precipitating it by dropwise addition of HCl to the clear filtrate. Wash the ppte with cold H<sub>2</sub>O and dry the monohydrate at 30° in a vacuum. The pure material gives a single spot on paper chromatography (eluting solvent EtOH/water/phenol, 6:3:1; and developing with NaOH). [Anderegg et al. Helv Chim Acta 37 113 1954.] Complexes with Ba, Ca, Cd, Mg and Sr.


o-Cresotic acid (methylsalicylic acid) [83-40-9] M 152.2, m 163-164°, pK<sup>25</sup> 3.32. Crystd from water.

m-Cresotic acid [50-85-1] M 152.2, m 177°, pK<sub>1</sub><sup>25</sup> 3.15, pK<sub>2</sub><sup>25</sup> 13.35. Crystd from water.

Crocetin diethyl ester [5056-14-4] M 384.5, m 218-219°, 222.5°, A₁cm (λmax) 2340 (400 nm), 3820 (422 nm), 3850 (450 nm) in pet ether. Purified by chromatography on a column of silica gel G. Crystd from *benzene. Stored in the dark, under an inert atmosphere, at 0°.

Crotonaldehyde (2-butenal) [123-73-9] M 70.1, b 104-105°, d 0.851, n 1.437. Fractionally distd under N₂, through a short Vigreux column. Stored in sealed ampoules. Stabilised with 0.01% of 2.6-di-tert-butyl-p-cresol.

trans-Crotonic acid [107-93-7] M 86.1, m 72-72.5°, pK₁ 5.17 (aq H₂SO₄), pK₂ 4.71. Distd under reduced pressure. Crystd from pet ether (b 60-80°) or water, or by partial freezing of the melt.


γ-Crotonolactone [2(5H)-furanone] [497-23-4] M 84.1, m 3-4°, 76-77°/3.5 mm, 90.5-91°C/11.5 mm, 92-93°C/14 mm, 107-109°C/760 mm, d₁5 1.197, n₂D 1.470. Fractionally distd under reduced pressure. IR: (CCl₄) 1784 and 1742 cm⁻¹, W no max above 205 nm (E 1160 cm⁻¹ M⁻¹) and 'H NMR: (CCl₄) 2: 2.15 (pair of triplets 1H), 3.85 (pair of triplets 1H) and 5.03 (triplet 2H).

Crotyl bromide [29576-14-5] M 135.0, b 103-105°/740 mm, n₂5 1.4792. Dried with MgSO₄, CaCO₃ mixture. Fractionally distd through an all-glass Todd column. [Todd column. A column (which may be a Dufton type, fitted with a Monel metal rod and spiral, or a Hempel type, fitted with glass helices) which is surrounded by an open heating jacket so that the temperature can be adjusted to be close to the distillation temperature (Todd Ind Eng Chem (Anal Ed) 17 175 1945)].


Cryptopine 1482-74-6 M 369.4, m 220-221°. Crystd from *benzene.

Cryptoxanthin [472-70-8] M 552.9, A₁cm 2370 (452 nm), 2080 (480 nm) in pet ether. Purified by chromatography on MgO, CaCO₃ or deactivated alumina, using EtOH or diethyl ether to develop the column. Crystd from CHCl₃/EtOH. Stored in the dark, under inert atmosphere, at -20°.

Crystal Violet Chloride (Gentian violet, N-4[bis[4-(dimethylaminophenyl)methylene]-2,5-cyclohexadien-1-ylidene]-N-methylmethaninium chloride) [548-62-9] M 408.0, pK 9.36. Crystd from water (20 mL/g), the crystals being separated from the chilled soln by centrifugation, then washed with chilled EtOH (sol 1 g in 10 mL of hot EtOH) and diethyl ether and dried under vac. It is sol in CHCl₃ but insol in Et₂O. The carbinol was ppted from an aqueous soln of the HCl dye, using excess NaOH, then dissolved in HCl and recrystd from water as the chloride [UV and kinetics: Turgeon and La Mer J Am Chem Soc 74 5988 1952]. The carbinol base has m 195° (needles from EtOH). The diphthalate (blue and turns red in H₂O) crystallises from H₂O, m 153-154° (dec 185-187°) [Chamberlain and Dull J Am Chem Soc 50 3089 1928].

Cumene (isopropyl benzene) [98-82-8] M 120.2, b 69-70°/41 mm, 152.4°/760 mm, d 0.864, n 1.49146, n²D 1.48892. Usual purification is by washing with several small portions of conc H₂SO₄ (until the acid layer is no longer coloured), then with water, 10% aq Na₂CO₃, again with water, and drying with MgSO₄, MgCO₃ or Na₂SO₄, followed by fractional distn. It can then be dried with, and distd from, Na, NaH or CaH₂. Passage through columns of alumina or silica gel removes oxidation products. Has also been steam
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distd from 3% NaOH, and azeotropically distd with 2-ethoxyethanol (which was subsequently removed by washing out with water).

**Cumene hydroperoxide** [80-15-9] M 152.2, b 60°/0.2mm, d 1.028, n^2^4 1.5232. Purified by adding 100mL of 70% material slowly and with agitation to 300mL of 25% NaOH in water, keeping the temperature below 30°. The resulting crystals of the sodium salt were filtered off, washed twice with 25mL portions of *benzene, then stirred with 100mL of *benzene for 20min. After filtering off the crystals and repeating the washing, they were suspended in 100mL of distilled water and the pH was adjusted to 7.5 by addn of 4M HCl. The free hydroperoxide was extracted into two 20mL portions of n-hexane, and the solvent was evaporated under vacuum at room temperature, the last traces being removed at 40-50° and 1mm [Fordham and Williams *Canad J Res* 27B 943 1949]. Petroleum ether, but not diethyl ether, can be used instead of *benzene, and powdered solid CO₂ can replace the 4M HCl. The material is potentially EXPLOSIVE.

**Cuminaldehyde** (4-isopropylbenzaldehyde) [122-03-2] M 148.2, b 82-84°/3.5mm, 120°/23mm, 131-135°/35mm, 235-236°/760mm, d^2^0 0.978, n^2^0 1.5301. Likely impurity is the benzoic acid. Check the IR for the presence of OH from CO₂H and the CO frequencies. If acid is present then dissolve in Et₂O, wash with 10% NaHCO₃ until effervescence ceases, then with brine, dry over CaCl₂, evap and distil the residual oil, preferably under vacuum. It is almost insoluble in H₂O, but soluble in EtOH and Et₂O.

**Cuprein** (6'-hydroxycinchonidine) [524-63-0] M 310.4, m 202°, [α]_D^2^° -176° (in MeOH), pK^1^5 7.63. Crystd from EtOH.

**Curcumin** [bis-(4-hydroxy-3-methoxycinnamoyl)methane] [458-37-7] M 368.4, m 183°. Crystd from EtOH or acetic acid.

**Cyanamide** [420-04-2] M 42.0, m 41°, pK^1^5 -0.36, pK^2^5 10.27. See cyanamide on p. 416 in Chapter 5.


**Cyanoaacetic acid** [372-09-8] M 85.1, m 70.9-71.1°, pK^2^ 2.47. Crystd to constant melting point from *benzene/acetone (2:3), and dried over silica gel.

**Cyanoaacetic acid hydrazide** [140-87-4] M 99.1, m 114.5-115°. Crystd from EtOH.


**4-Cyanobenzoyl chloride** [6068-72-0] M 165.6, m 68-70°, 69-70°, 73-74°, b 132°/8mm, 150-151°/25mm. If the IR shows presence of OH then treat with SOCl₂ boil for 1h, evaporate and distil in
vacuum. The distillate solidifies and can be recrystallised from pet ether. It is moisture sensitive and is an IRRITANT. [Ashley et al. J Chem Soc 103 1942; Fison et al. J Org Chem 16 648 1951.]

Cyanoguanidine (dicyanodiamide) [461-58-5] M 84.1, m 209.5°, pK -0.4. Crystd from water or EtOH.


3-Cyanopyridine [100-54-9] M 104.1, m 50°, pK25 1.38. Crystd to constant melting point from o-xylene/hexane.


Cyanuric acid (2,4,6-trichloro-1,3,5-triazine) [108-80-5] M 120.1, m >300°, pK 6.78. Crystd from water. Dried at room temperature in a desiccator under vacuum.

Cyanuric chloride (TCT, 2,4,6-trichloro-1,3,5-triazine) [108-77-0] M 184.4, m 146-149°, 154°, b 190°. Crystd from CCl4 or pet ether (b 90-100°), and dried under vacuum. Recrystd twice from anhydrous *benzene immediately before use [Abuchowski et al. J Biol Chem 252 3582 1977].

Cyclobutane carboxylic acid [3721-95-7] M 100.1, m 3-4°, -5.4°, b 84-84.5°/10 mm, 110°/25 mm, 135-138°/110 mm, 194°/760 mm, δ20 1.061, δD 1.453, pK25 4.79. Dissolve in aqueous HCO; and acidify with HCl and extract into Et2O, wash with H2O, dry (Na2SO4), concentrate to a small volume, then distil through a glass helices packed column. The S-benzylrhiouronium salt has m 176° (from EtOH), and the anilide has m 112.5-113°, and the p-toluide has m 123°. [Payne and Smith J Org Chem 22 1680 1957; Kantaro and Gunning J Am Chem Soc 73 480 1951.]
	rans-Cyclobutane-1,2-dicarboxylic acid [1124-13-6] M 144.1, m 131°, pK1 4.11, pK2 5.15. Crystd from *benzene.

Cyclobutanone [1191-95-3] M 70.1, b 96-97°, d 0.931, nD 1.4189. Treated with dilute aqueous KMnO4, dried with molecular sieves and fractionally distd. Purified via the semicarbazone, then regenerated, dried with CaSO4, and distd in a spinning-band column. Alternatively, purified by preparative gas chromatography using a Carbowax 20-M column at 80°. (This treatment removes acetone).

Cyclobutylamine [2516-34-9] M 71.1, b 82-83°/atm, 83.2-84.2°/760mm, δ20 0.839, nD 1.437, pK25 10.04 (9.34 in 50%aq EtOH). It has been purified by steam distn. The aqueous distillate (e.g. 2L) is acidified with 3N HCl (90mL) and evapd to dryness in a vacuum. The hydrochloride is treated with a few mL of H2O, cooled in ice and a slush of KOH pellets ground in a little H2O is added slowly in portions and keeping the soln very cold. The amine separates as an oil from the strongly alkaline soln. The oil is collected dried over solid KOH and distd using a vac jacketed Vigreux column and protected from CO2 using a soda lime tube. The fraction boiling at 79-83° is collected, dried over solid KOH for 2 days and redistd over a few pellets of KOH (b 80.5-81.5°). Best distil in a dry N2 atmosphere. The purity can be checked by GLC using a polyethylene glycol on Teflon column at 72°, 15 psi, flow rate of 102 mL/min of He. The sample can appear homogeneous but because of tailing it is not possible to tell if H2O is present. The NMR in CCl4 should show no signals less than 1 ppm from TMS. The hydrochloride has a multiplet at ca 1.5-2.6 ppm (H 2,2,4,3,3,4,4), a quintet at 3.8 ppm (H 1) and a singlet at 4.75 for NH2 [Roberts and Chambers J Am Chem


α-Cyclodexrin (H_2O) [10016-20-3] M 972.9, m >280°(dec), [α]_{546}^20 175° (c 10, H_2O). See entry on p. 524 in Chapter 6.

β-Cyclodextrin (H_2O) [7585-39-9, 68168-23-0] M 1135.0, m >300°(dec), [α]_{546}^20 170° (c 10, H_2O). See entry on p. 524 in Chapter 6.

trans-cis-cis-1,5,9-Cyclododecatriene (cyclododec-1c,5c,9t-triene) [2765-29-9] M 162.3, m -9°, -8°, b 117.5°/2mm, 237-239°/atm, 244°/760mm, d_4^2 0.907, n_4^2 1.5129. Purified by fractional distn, preferably in a vacuum under N_2, and forms an insoluble AgNO_3 complex. [Breil et al. Makromol Chemie 69 28 1963.]


Cycloheptanol [502-41-0] M 114.2, b 77-81°/11mm, 185°/atm, d 0.951, n 1.477. Purified as described for cyclohexanol.

Cycloheptanone [502-42-1] M 112.2, b 105°/80mm, 172.5°/760, d 0.952, n_2^24 1.4607. Shaken with aq KMnO_4 to remove material absorbing around 230-240nm, then dried with Linde type 13X molecular sieves and fractionally distd.


Cycloheptylamine [5452-35-7] M 113.2, b 50-52°/11mm, 60°/18mm, d_4^28 0.887, n_2^20 1.472, pK_{Et} −10.5 (H_2O), pK_{24} 9.99 (in 50% aq methyl cellosolve). It can be purified by conversion to the hydrochloride m 242-246°, and the free base is distd under dry N_2 in a vacuum [Cope et al. J Am Chem Soc 75 3212 1953; Prelog et al. Helv Chim Acta 33 365 1950].

1,3-Cyclohexadiene [592-57-4] M 80.1, b 83-84°/atm, d_4^2 0.840, n_2^3 1.471. Distd from NaBH_4.
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1,4-Cyclohexadiene  [628-41-1] M 80.1, b 83-86°/174mm, 88.3°/741mm, 86-88°/atm, 88.7-89°/760mm, d\textsuperscript{2}0 0.8573, n\textsuperscript{D}4 1.4725. Dry over CaCl\textsubscript{2} and distil in a vacuum under N\textsubscript{2}. [Hückel and Wörfel Chem Ber 88 338 1953; Giovanniini and Wegmüller Helv Chim Acta 42 1142 1959.]

Cyclohexane [110-82-7] M 84.2, f 6.6°, b 80.7°, d\textsubscript{24} 0.77410, n\textsubscript{25} 1.42623, n\textsubscript{25} 1.42354. Commonly, washed with conc H\textsubscript{2}SO\textsubscript{4} until the washings are colourless, followed by water, aq Na\textsubscript{2}CO\textsubscript{3} or 5% NaOH, and again water until neutral. It is next dried with P\textsubscript{2}O\textsubscript{5}, Linde type 4A molecular sieves, CaCl\textsubscript{2}, or MgSO\textsubscript{4} then Na and distd. Cyclohexane has been refluxed with, and distd from Na, CaH\textsubscript{2}, LiAl& (which also removes peroxides), sodium/potassium alloy, or P\textsubscript{2}O\textsubscript{5}. Traces of benzene can be removed by passage through a column of silica gel that has been freshly heated: this gives material suitable for ultraviolet and infrared spectroscopy. If there is much benzene in the cyclohexane, most of it can be removed by a preliminary treatment with nitrating acid (a cold mixture of 30mL conc H\textsubscript{2}SO\textsubscript{4} and 70mL of conc H\textsubscript{2}SO\textsubscript{4}) which converts benzene into nitrobenzene. The impure cyclohexane and the nitrating acid are placed in an ice bath and stirred vigorously for 15min, after which the mixture is allowed to warm to 25° during 1h. The cyclohexane is decanted, washed several times with 25% NaOH, then water dried with CaCl\textsubscript{2}, and distd from sodium. Carbonyl-containing impurities can be removed as described for chloroform. Other purification procedures include passage through columns of activated alumina and repeated crystn by partial freezing. Small quantities may be purified by chromatography on a Dowex 710-Chromosorb W gas-liquid chromatographic column.

Rapid purification: Distil, discarding the forerun. Stand distillate over Grade I alumina (5% w/v) or 4A molecular sieves.

Cyclohexane butyric acid [4441-63-8] M 170.3, m 31°, 26.5-28S0, b 136-139°/4mm. 169°/20mm, 188.50/46rm, pK\textsubscript{25} 4.95. Distil through a Vigreux column, and the crystalline distillate is recrystd from pet ether. The S-benzylthiouronium salt has m 154-155° (from EtOH) [Acta Chem Scand 9 1425 1955; English and Dayan J Am Chem Soc 72 4187 1950].

Cyclohexane-1,2-diaminetetraacetic acid (H\textsubscript{2}O; CDTA) [13291 -61 -71 M 364.4, pK\textsubscript{l} 1.34, pK\textsubscript{2} 3.20, pK\textsubscript{3} 5.75 (6.12), pK\textsubscript{4} 9.26 (12.35). Dissolved in aq NaOH as its disodium salt, then pptd by adding HCl. The free acid was filtered off and boiled with distd water to remove traces of HCl [Bond and Jones Trans Faraday Soc 55 1310 19591. Recrystd from water and dried under vacuum.

trans-Cyclohexene-1,2-dicarboxylic acid [2305-32-0] M 172.2, m 227.5-228°, 228-230°, pK\textsubscript{25} 4.30, pK\textsubscript{3} 6.06 [cis , pK\textsubscript{4} 4.25, pK\textsubscript{5} 6.74]. It is purified by recrystn from EtOH or H\textsubscript{2}O. The dimethyl ester has m 95-96° (from *C\textsubscript{6}H\textsubscript{6}-pet ether). [Abell J Org Chem 22 769 1957; Smith and Byrne J Am Chem Soc 72 4406 1950; Linstead et al. J Am Chem Soc 64 2093 1942.]

(±)-trans-1,2-Cyclohexanediol [1460-57-7] M 116.2, m 104°, 105°, 120°/14mm. Crystd from Me\textsubscript{2}CO and dried at 50° for several days. It can also be recrystd from CCl\textsubscript{4} or EtOAc and can be distilled. The 2,4-dinitrobenzoyl derivative has m 179°. [Winston and Buckles J Am Chem Soc 64 2780 1942.]


cis-1,4-Cyclohexanediol [556-58-9] M 116.2, m 102.5°. Crystd from acetone (charcoal), then dried and sublimed under vacuum.


Cyclohexane-1,4-dione [637-88-7] M 116.2, m 76-77°, 78°, 79.5°, 79-80°, b 130-133°/20mm, d^21 1.0861, n^21 1.4576. Crystd from water, then *benzene. It can also be recrystd from CHCl_3/pet ether or Et_2O. It has been purified by distn in a vacuum and the pale yellow distillate which solidified is then recrystd from CCl_4 (14.3 g/100 mL) and has m 77-79°. The *di-semicarbazonen has m 231°, the *dioxime HCl has m 150° (from MeOH-^*C&), and the *bis-2,4-dinitrophenylhydrazinen has m 240° (from PhN_2). [Org Synth Coll Vol V 288 1973; IR: LeFevre and LeFevre J Chem Soc 3549 1956.]


1,4-Cyclohexanedione monoethylene acetal (1,4-dioxaspiro[4.5]decan-8-one) [4746-97-8] M 156.2, m 70-73°, 73.5-74.5°. Recrystd from pet ether and sublimes slowly on attempted distillation. Also purified by dissolving in Et_2O and adding pet ether (b 60-80°) until turbid and cool. [Gardner et al. J Am Chem Soc 22 1206 1957; Britten and Lockwood J Chem Soc Perkin Trans 1 1824 1974.]

cis,cis-1,3,5-Cyclohexane tricarboxylic acid [16526-68-4] M 216.2, m 216-218°, pK_a 4.1, pK_a 5.4, pK_a 6.8. Purified by recrystn from toluene + EtOH or H_2O. It forms a 1.5 hydraten with m 216-218°, and a dihydron at 110°. Purified also by conversion to the triethyl ester b 217-218°/10mm, 151°/1mm and distillate solidifies on cooling, m 36-37° and is hydrolysed by boiling in aq HCl. The trimethyl estern can be distd and recrystd from Et_2O, m 48-49°. [Newman and Lawrie J Am Chem Soc 76 4598 1954, Lukes and Galik Czech Chem Comm 19 712 1954.]

Cyclohexanol [108-93-0] M 100.2, m 25.2°, b 161.1°, d 0.946, n 1.466, n^25 1.437, n^30 1.462. Refluxed with freshly ignited CaO, or dried with Na_2CO_3, then fractionally distd. Redistd from Na. Further purified by fractional crystn from the melt in dry air. Peroxides and aldehydes can be removed by prior washing with ferrous sulfate and water, followed by distillation under nitrogen from 2,4-dinitrophenylhydrazine, using a short fractionating column: water distils as the azeotrope. Dry cyclohexanol is very hygroscopic.

Cyclohexanone oxime [100-64-1] M 113.2, m 90°. Crystd from water or pet ether (b 60-80°).

Cyclohexanone phenylhydrazone [946-82-7] M 173.3, m 77°. Crystd from EtOH.

(±)-2-Cyclohexen-1-ol (3-hydroxycyclohex-1-ene) [822-67-3] M 242.2, b 63-65°/12 mm, 65-66°/13 mm, 67°/15 mm, 74°/25 mm, 85°/35 mm, 166°/atm, dD2 0.9865, nD2 1.4720. Purified by distillation through a short Vigreux column. The 2,4-dinitrobenzoyl derivative has m 120°, and the phenylurethane has m 107°. [Org Synth 48 18 1968, Cook J Chem Soc 1774 1938; Deiding and Hartman J Am Chem Soc 75 1953.]

Cyclohexene oxide [286-20-4] M 98.2, b 131-139°/atm, dD2 0.971, nD2 1.452. Fractionated through an efficient column. The main impurity is probably H2O. Dry over MgSO4, filter and distil several times (b 129-134°/atm). The residue is sometimes hard to remove from the distilling flask. To avoid this difficulty, add a small amount of a mixture of ground NaCl and Celite (1:1) to help break the residue particularly if H2O is added. [Org Synth Coll Vol I 185 1948.]

Cycloheximide [68-81-9] M 281.4, m 119.5-121°, [α]D 20 +9.5° (c 2, H2O). Crystd from water/MeOH (4:1), amyl acetate, isopropyl acetate/isopropyl ether or water.

Cyclohexylamine [108-91-8] M 99.2, b 134.5°, d 0.866, dD2 0.863, n 1.4593, nD2 1.456, pK2 10.63. Dried with CaCl2 or LiAlH4, then distd from BaO, KOH or Na, under N2. Also purified by conversion to the hydrochloride, several crystns from water, then liberation of the amine with alkali and fractional distn under N2.


Cyclohexyl bromide [108-85-0] M 156.3, b 72°/29 mm, d 0.902, nD2 1.4935. Shaken with 60% aqueous HBr to remove the free alcohol. After separation from excess HBr, the sample was dried and fractionally distd.

Cyclohexyl chloride [542-18-7] M 118.6, b 142-142°, d 1.000, n 1.462. See chlorocyclohexane on p. 162.

1-Cyclohexylethylamine [S(+): 17430-98-7; R(-): 5913-13-3] M 127.2, b 177-178°/atm, dD2 0.866, nD2 1.446, [α]D 15 (+) and (+) 3.2° (neat), pKEm ~10.6. Purified by conversion to the bitartrate salt (m 172°), then decomposing with strong alkali and extracting into Et2O, drying (KOH), filtering, evaporating and distilling. The hydrochloride salt has m 242° (from EtOH-Et2O), [α]D 5 -5.0° (c 10 H2O; from (+) amine). The oxalate salt has m 132° (from H2O). The (±)-base has b 176-178°/760 mm, and HCl has m 237-238°. [Reihlen, Knöpfle and Sapper Justus Liebigs Ann Chem 532 247 1938; Chem Ber 65 660 1932.]


Cyclohexyl mercaptan (cyclohexane thiol) [1569-69-3] M 116.2, b 38-39°/12 mm, 57°/23 mm, 90°/100 mm, 157°/763 mm, dD2 0.949, nD2 1.493, pKEm ~10.8. Possible impurities are the sulfide and the disulfide. Purified by conversion to the Na salt by dissolving in 10%aq NaOH, extract the sulfide and disulfide with Et2O, and then acidify the aq soln with HCl, extract with Et2O, dry MgSO4, evaporate and distil in a vacuum (b 41°/12 mm). The sulfide has b 74°/0.2 mm, nD 1.5162 and the disulfide has b 110-112°/0.2 mm, nD 1.5557. The Hg-mercaptide has m 77-78° (needles from EtOH). [Naylor J Chem Soc 1532 1947.]

Cyclohexyl methacrylate [101-43-9] M 168.2, b 81-86°/0.1 mm, d 0.964, n 1.458. Purification as for methyl methacrylate.
1-Cyclohexyl-5-methyltetrazole [7707-57-5] M 166.2, m 124-124.5°. Cryst from absolute EtOH, then sublimed at 115°/3mm.

Cyclonanone [3350-30-9] M 140.2, m 142.0-142.8°, b 220-222°. Repeatedly sublimed at 0.05-0.1 mm pressure.

cis,cis-1,3-Cyclooctadiene [29965-97-7] M 108.2, m -5°, -49°, b 55°/34 mm, 142-144°/760 mm, δd 0.8690, nD 1.48921. Purified by GLC. Fractionally distd through a Widmer column [as a mobile liquid and redistilled with a Claisen flask or through a semi-micro column [Gould, Holzman and Neiman Anal Chem 20 361 1948]. NB: It has a strong characteristic disagreeable odour detectable at low concentrations and causes headaches on prolonged exposure. [IR: Cope and Estes J Am Chem Soc 72 1128 1950; UV: Cope and Baumgardner J Am Chem Soc 78 2812 1956.] [Widmer column. A Dulton column, modified by enclosing within two concentric tubes the portion containing the glass spiral. Vapour passes up the outer tube and down the inner tube before entering the centre portion. In this way flooding of the column, especially at high temperatures, is greatly reduced (Widmer Helv Chim Acta 7 59 1924).]

cis,cis-1,5-Cyclooctadiene, [1552-12-1] M 108.2, m -69.5°, -70°, b 51-52°/25 mm, 97°/144 mm, 150.8°/757 mm, δd 0.880, nD 1.4935. Purified by GLC. It has been purified via the AgNO3 salt. This is prepared by shaking with a soln of 50% AgNO3 w/w several times (e.g. 3 x 50 mL and 4 x 50 mL) at 70° for ca 20 min to get a good separation of layers. The upper layers are combined and further extracted with AgNO3 at 40° (2 x 20 mL). The upper layer (19 mL) of original hydrocarbon mixture gives colourless needles AgNO3 complex on cooling. The adduct is recrystd from MeOH (and cooling to 0°). The hydrocarbon is recovered by steam distilling the salt. The distillate is extracted with Et2O, dried (MgSO4), evaporated and distd. [Jones J Chem Soc 312 1954.]


1,3,5,7-Cyclooctatetraene [629-20-9] M 104.2, b 141-141.5°, δ 1.537, nD 1.535. Purified by shaking 3 mL with 20 mL of 10% aqueous AgNO3 for 15 min, then filtering off the silver nitrate complex as a ppte. The ppte was dissolved in water and added to cold conc ammonia to regenerate the cyclooctatetraene which was fractionally distd under vacuum onto molecular sieves and stored at 0°. It was passed through a dry alumina column before use [Broadley et al. J Chem Soc, Dalton Trans 737 1986].

cis-Cyclooctene [931-88-4] M 110.2, b 32-34°/12 mm, 66.5-67°/60 mm, 88°/141 mm, 140°/170 mm, 143°/760 mm, δd 0.84843, nD 1.4702. The cis-isomer was freed from the trans-isomer by fractional distn through a spinning-band column, followed by preparative gas chromatography on a Dowex 710-Chromosorb W GLC column. It was passed through a short alumina column immediately before use [Collman et al. J Am Chem Soc 108 2588 1986]. It has also been distd in a dry nitrogen glove box from powdered fused NaOH through a Vigreux column and then passed through activated neutral alumina before use [Wong et al. J Am Chem Soc 109 4328 1987]. Alternatively it can be purified via the AgNO3 salt. This salt is obtained from crude cyclooctene (40 mL) which is shaken at 70-80° with 50% w/w AgNO3 (2 x 15 mL) to remove cyclooctadienes (aq layer). Extraction is repeated at 40° (4 x 20 mL, of 50% AgNO3). Three layers are formed each time. The middle layer contains the AgNO3 adduct of cyclooctene which crystallises on cooling the layer to room temperature. The adduct (complex 2:1) is highly soluble in MeOH (at least 1 g/mL) from which it crystallises in large flat needles when cooled at 0°. It is dried under slight vacuum for 1 week in the presence of CaCl2 and paraffin wax soaked in the cyclooctene. It has m 51° and loses hydrocarbon on exposure to air. cis-Cyclooctene can be recovered by steam distn of the salt, collected, dried (CaCl2) and distilled in vacuum. [Braude et al. J Chem Soc 4711 1957; AgNO3: Jones J Chem Soc 1808 1954; Cope and Estes J Am Chem Soc 72 1128 1950.]

cis-Cyclooctene oxide ([1R,8c]-9-oxabicyclo[6.1.0]nonane) [286-62-4] M 126.7, m 56-57°, 57.5-57.8°, 50-60°, b 85-88°/17 mm, 82.5°/22 mm, 90-93°/37 mm, 189-190°/atm. It can be distd in vacuum and the solidified distillate can be sublimed in vacuum below 50°. It has a characteristic odour.
Cyclopentadecanone [502-72-7] M 224.4, m 63°. Sublimation is better than crystn from aq EtOH.

Cyclopentadiene [542-92-7] M 66.1, b 41-42°. Dried with Mg(ClO₄)₂ and distd.

Cyclopentane [287-92-3] M 70.1, b 49.3°, d 0.745, n₁40645, n₂5 1.4340. Freed from cyclopentene by two passages through a column of carefully dried and degassed activated silica gel.

Cyclopentane carbonitrile [5802-65-3] M 95.2, m -75.2°, -76°, b 43-44°/7mm, 50-62°/10mm, 67-68°/14mm, 74.5-75°/30mm, d₂⁰ 0.912, n₂⁰ 1.441. Dissolve in Et₂O, wash thoroughly with saturated aqueous K₂CO₃, dry (MgSO₄) and distil through a 10 cm Vigreux column.


1,3-Cyclopentanedione [3859-41-4] M 98.1, m 149-150°, 151-152°, 151-154°, 151-153°. Purified by Soxhlet extraction with CHCl₃. The CHCl₃ is evaporated and the residue is recrystd from EtOAc and/or sublimed at 120°/4mm. It has an acidic pKa of 4.5 in H₂O. [IR: Boothe et al. J Am Chem Soc 75 1732 1953; DePuy and Zaweski J Am Chem Soc 81 4920 1959.]

Cyclopentanone [120-92-3] M 84.1, b 130-130.5°, d 0.947, n 1.4370, n₂5 1.4340. Shaken with aq KMnO₄ to remove materials absorbing around 230 to 240nm. Dried with Linde type 13X molecular sieves and fractionally distd. Has also been purified by conversion to the NaHSO₃ adduct which, after crystallising four times from EtOAc/water (4:1), was decomposed by adding to an equal weight of Na₂CO₃ in hot H₂O. The free cyclopentanone was steam distd from the soln. The distillate was saturated with NaCl and extracted with benzene which was then dried and evaporated; the residue was distd [Allen, Ellington and Meakins J Chem Soc 1909 1960].

Cyclopentene [142-29-0] M 68.1, b 45-46°, d 0.772, n 1.4228. Freed from hydroperoxide by refluxing with cupric stearate. Fractionally distd from Na. Chromatographed on a Dowex 710-Chromosorb W GLC column. Methods for cyclohexene should be applicable here. Also washed with 1M NaOH soln followed by water. It was dried over anhydrous Na₂SO₄, distd over powdered NaOH under nitrogen, and passed through neutral alumina before use [Woon et al. J Am Chem Soc 108 7990 1986]. It was distd in a dry nitrogen atmosphere from powdered fused NaOH through a Vigreux column, and then passed through activated neutral alumina before use [Wong et al. J Am Chem Soc 109 3428 1987].

1-Cyclopentene-1,2-dicarboxylic anhydride [3205-94-5] M 138.1, m 42-54°, 46-47°, b 130°/5mm, 133-135°/5mm, n₁⁰ 1.497. If IR has OH peaks then some hydrolysis to the diacid (m 178°) must have occurred. In this case reflux with an appropriate volume of Ac₂O for 30min, evaporate the Ac₂O and distil in vacuo. The distillate solidifies and can be recrystd from EtOAc-hexane (1:1). The diacid distils without dec due to formation of the anhydride. The dimethyl ester has m 120-125°/11mm. [Askain Chem Ber 98 2322 1965.]

Cyclopentylamine [1003-03-8] M 85.2, m -85.7°, b 106-108°/760mm, 108.5°/760mm, d₂⁰ 0.869, n₂⁰ 1.452, pK₂⁵ 10.65, (pK₂⁵ 4.05 in 50% aq EtOH). May contain H₂O or CO₂ in the form of carbamate salt. Dry over KOH pellets and then distil from a few pellets of KOH. Store in a dark, dry CO₂-free atmosphere. It is characterised as the thiocyanate salt m 94.5°. The benzenesulfonyl derivative has m 68.5-69.5°. [Roberts and Chambers J Am Chem Soc 73 5030 1951; Bollinger et al. J Am Chem Soc 75 1729 1953.]

Cyclopropane [75-19-4] M 42.1, b -34°. Washed with a so1n of HgSO₄, and dried with CaCl₂, then Mg(ClO₄)₂.
Cyclopropanecarbonyl chloride \([4023-34-1]\) M 104.5, b 117.9-118.0°/723mm, 119.5-119.6°/760mm, \(d_2^0\) 1.142, \(n_d^0\) 1.453. If the IR shows OH bands then some hydrolysis to the free acid must have occurred. In this case heat with oxalyl chloride at 50° for 2h or \(\text{SOCl}_2\) for 30min, then evap and distil three times using a Dufton column. Store in an inert atm, preferably in sealed tubes. Strong IRRITANT. If it is free from OH bands then just distil in \textit{vacuo} and store as before. [Jeffrey and Vogel \textit{J Chem Soc} 1804 1948.]

Cyclopropane-1,1-dicarboxylic acid \([598-10-7]\) M 130.1, m 140°, \(pK^1_2\) 1.8, \(pK^2_2\) 5.42. Recrystd from CHCl₃.

Cyclopropylamine \([765-30-0]\) M 57.1, b 49-49.5°/760mm, 48-50°/atm, 49-50°/750mm, \(d_4^0\) 0.816, \(n_d^0\) 1.421, \(pK^2_2\) 9.10 (\(pK^2_2\) 5.33 in \(40\%\) aq EtOH). It has been isolated as the \textit{benzamide} m 100.6-101.0° (from aqueous EtOH). It forms a \textit{picrate} m 149° (from EtOH-pet ether) from which the free base can be recovered using a basic ion exchange resin and can then be distd through a Todd column (see p. 174) using an automatic still head which only collects products boiling below 51°/atm. Polymeric materials if present will boil above this temperature. The \textit{hydrochloride} has m 85-86° [Roberts and Chambers \textit{J Am Chem Soc} 73 5030 1951; Jones \textit{J Org Chem} 9 484 1944; Emmons \textit{J Am Chem Soc} 79 6522 1957].

Cyclopropyldiphenylcarbinol \([5785-66-0]\) M 224.3, m 86-87°. Crystd from n-heptane.

Cyclopropyl methyl ketone \([765-43-5]\) M 84.1, b 111.6-111.8°/752mm, d \(0.850\), \(n 1.4242\). Stored with anhydrous CaSO₄, distd under nitrogen. Redistd under vacuum.

Cyclooctadecane \([295-17-0]\) M 192.3, m 56°. Recrystd twice from aq EtOH then sublimed \textit{in vacuo} [Dretloff et al. \textit{J Am Chem Soc} 109 7797 1987].

Cyclooctadecanone \([3603-99-4]\) M 206.3, m 25°, b 145°/10mm, d 0.926, n 1.480. It was converted to the semicarbazone which was recrystd from EtOH and reconverted to the free cyclooctadecanone by hydrolysis [Dretloff et al. \textit{J Am Chem Soc} 109 7797 1987].

Cyclotrimethylenetrinitramine (RDX, 1,3,5-trinitrohexahydro-1,3,5-triazine) \([121-82-4]\) M 222.2, m 203.8°(dec). Crystd from acetone. EXPLOSIVE.

\(p\)-\textit{Cymene} \([99-87-6]\) M 134.2, b 177.1°, d 0.8569, n 1.4909, \(n^2\) 1.4885. Washed with cold, conc H₂SO₄ until there is no further colour change, then repeatedly with H₂O, 10% aqueous Na₂CO₃ and H₂O again. Dried with Na₂SO₄, CaCl₂ or MgSO₄, and distd. Further purification steps include steam distn from 3% NaOH, percolation through silica gel or activated alumina, and a preliminary refluxing for several days over powdered sulfur. Stored over CaH₂.

Cystamine dihydrochloride, \(S,S-(L,L)\)-\textit{Cystathionine}, \textit{Cysteamine}, \textit{Cysteamine hydrochloride}, \((\pm)\)-\textit{Cysteic acid, S-Cysteic acid (H₂O), L-Cysteine hydrochloride (H₂O), (±)-Cysteine hydrochloride and L-Cystine, Cytidine, see entries in Chapter 6.}

Cytisine \([7R,9S-7,9,10,11,12,13\text{-hexahydro-7,9-methano-12H-pyrido}[1,2-a][1,5]diazocin-8-one, Laburnine, Ulexine] \([485-35-8]\) M 190.3, m 152-153°, 155°, b 218°/2mm, \([\alpha]_D^{17}\) -120° (H₂O), \([\alpha]_D^{25}\) -115° (c 1, H₂O), \(pK^1_1\) 1.20, \(pK^2_2\) 8.12 [also stated are \(pK_1 6.11, pK_2 13.08\)]. Crystd from acetone and sublimed in a vacuum. Its solubilities are: 77% (H₂O), 7.7% (Me₂CO), 28.6% (EtOH), 3.3% (\(\text{C}_6\text{H}_5\text{H}_2\)), 50% (CHCl₃) but is insoluble in pet ether. The \textit{tartrate} has m 206-207° \([\alpha]_D^{17}\) +45.9°, the \(N\)-tosylate has m 206-207°, and the \(N\)-acetate has m 208°. [Bohlmann et al. \textit{Angew Chem} 67 708 1955; van Tamelen and Baran \textit{J Am Chem Soc} 77 4944 1955; Isolation: Ing \textit{J Chem Soc} 2200 1931; Govindachari et al. \textit{J Chem Soc} 3839 1957; Abs config: Okuda et al. \textit{Chem Ind (London)} 1751 1961.] TOXIC.
Cytosine  see entry in Chapter 6.

**cis-Decahydroisoquinoline** [2744-08-3] M 139.2, b 97-98°/15mm, 208-209°/730mm, pK\(^+\) 11.32. The free base is treated with satd aq picric acid, allowed to stand for 12h, filtd, washed with MeOH to remove the more soluble trans isomer and recrystd from MeOH to give pure cis-picrate m 149-150°. The picrate (–5g) is shaken with 5M aq NaOH (50mL) and Et\(_2\)O (150mL) while H\(_2\)O is added to the aq phase to dissolve insoluble Na picrate. The Et\(_2\)O extract is dried over solid NaOH and then shaken with Al\(_2\)O\(_3\) (Merck for chromatography) until the yellow color of traces of picric acid disappears (this color cannot be removed by repeated shaking with 5-10 M aq NaOH). The extract is concentrated to 50mL and dry HCl is bubbled through until separn of the white crysts of the cis-HCl is complete. These are washed with Et\(_2\)O, dried at 100° and recrystd from EtOH + EtOAc to yield pure cis-Hydrochloride m 182-183° (dried in a vac desiccator over KOH) with IR (KBr) V\(_{\text{max}}\) 2920, 2820, 1582, 1470, 1445, 1410, 1395, 1313, 1135, 1080, 990, 870 cm\(^{-1}\). The pure free base is prepared by dissolving the hydrochloride in 10 M aq NaOH, extracted with Et\(_2\)O, dried over solid KOH, filtd and distd in vac. It has IR (film) V\(_{\text{max}}\) 2920, 2820, 2720, 2560, 1584, 1470, 1445, 1415, 1395, 1315, 1300, 1135, 1080, 1020, 990, 873 cm\(^{-1}\). The pure free base is available as a cis-trans-mixture (b 70-73°/10mm, Aldrich, ~18% cis-isomer [2051-28-7], but the isomers can be fractionated in a spinning band column (1-1.5 metre, type E) at atmospheric pressure and collecting 2mL fractions with a distillation rate of 1 drop in 8-10sec. The lower boiling fraction solidifies and contains the trans-isomer (see below, m 48°). The higher boiling fraction b 207-208°/708mm, remains liquid and is mostly the cis-isomer. This is reacted with PhCOCl and M aq NaOH to yield the N-benzoyl derivative m 96° after recryst from pet ether (b 80-100°). It is hydrolysed with 20% aq HCl by refluxing overnight. PhC\(_2\)O\(_3\)/H is filtd off, the filtrate is basified with 5M aq NaOH, and then recrystd from Et\(_2\)O. The dried extract (Na\(_2\)SO\(_4\)) is satd with dry HCl gas and the cis-decahydroquinoline hydrochloride which separates has m 222-224° after washing with Et\(_2\)O and drying at 100°; and has IR (KBr) V\(_{\text{max}}\) 2900, 2780, 2560, 1580, 1445, 1432, 1403, 1165, 1080,
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1036, 990, 867 cm\(^{-1}\). The free base is obtained by dissolving the hydchloride salt in 5M aq NaOH, extracting with Et\(_2\)O and drying the extract (Na\(_2\)SO\(_4\)), evaporating and distilling the residue; it has IR (film) \(v_{\text{max}} \) 2900, 2840, 2770, 1445, 1357, 1330, 1305, 1140, 1125, 1109, 1068, 844 cm\(^{-1}\). The \(^1\)H NMR in CDCl\(_3\) is characteristically different from that of the trans-isomer. [Armarego J Chem Soc (C) 377 1967; Hückel and Stepf Justus Liebigs Ann Chem 453 163 1927; Bailey and McElvain J Am Chem Soc 52 4013 1930.]

**trans-Decahydroquinoline [767-92-0]** M 139.2, m 48°, b 205-206\(^\circ\)/708mm, \(\rho K_\text{Z} 0 11.29\). The lower boiling fraction from the preceding spinning band column fractionation of the commercial cis-trans-mixture (\(-20:60\); see the cis-isomer above) solidifies readily \((m 48\degree)\) and the receiver has to be kept hot with warm water. It is further purified by conversion to the Hydrochloride \(m 285-286\degree\) after recrystn from EtOH/AcOEt. This has IR (KBr) \(v_{\text{max}} 2920, 2760, 2578, 2520, 1580, 1455, 1070, 975, 950, 833\) cm\(^{-1}\). The free base is prepared as for the cis-isomer above and distd; and has IR (film, at ca 50\(^\circ\)) \(v_{\text{max}} 2905, 2840, 2780, 1447, 1335, 1305, 1240, 1177, 1125, 987, 900, 835\) cm\(^{-1}\). The \(^1\)H NMR in CDC\(_13\) is characteristically different from that of the cis-isomer. [Armarego J Chem Soc (C) 377 1967; Hückel and Stepf Justus Liebigs Ann Chem 453 163 1927; Bailey and McElvain J Am Chem Soc 52 4013 1930; Prelog and Szpilfogel Helv Chim Acta 28 1684 1945.]

**n-Decane [124-18-5]** M 142.3, b 174.1\(^\circ\), d 0.770, n 1.41189, n\(^2\) 1.40967. It can be purified by shaking with conc H\(_2\)SO\(_4\), washing with water, aqueous NaHCO\(_3\), and more water, then drying with MgSO\(_4\), refluxing with Na and distilling. Passed through a column of silica gel or alumina. It can also be purified by preparative GLC, and by passage through alumina before use. Further purification can be achieved by preparative gas chromatography on a column packed with 30% SE-30 (General Electric methyl-silicone rubber) on 42/60 Chromosorb P at 150\(^\circ\) and 40psig, using helium [Chu J Chem Phys 41 226 1964]. Also purified by zone refining.

**Decan-1,10-diol [112-47-0]** M 174.3, m 72.5-74\(^\circ\). Crystd from dry ethylene dichloride.

**n-Decanol (n-decyl alcohol) [112-30-1]** M 158.3, f 6.0\(^\circ\), b 110-119\(^\circ\)/0.1mm, d 0.823, n 1.434. Fractionally distd in an all-glass unit at 10mm pressure (b 110\(^\circ\)), then fractionally crystd by partial freezing. Also purified by preparative GLC, and by passage through alumina before use.

**n-Decyl bromide [112-29-8]** M 221.2, b 117-118\(^\circ\)/15.5mm, d 1.066. Shaken with H\(_2\)SO\(_4\), washed with water, dried with K\(_2\)CO\(_3\), and fractionally distd.

Deocyltrimethylammonium bromide [2082-84-0] M 280.3, m 239-242\(^\circ\). Crystd from 50\% (v/v) EtOH/diethyl ether, or from acetone and washed with ether. Dried under vacuum at 60\(^\circ\). Also recrystd from EtOH and dried over silica gel. [McDonnell and Kraus J Am Chem Soc 73 2170 1952; Dearden and Wooley J Phys Chem 91 2404 1987.]

**(+)-Dehydroabietylamine (abieta-8,11,13-triene-18-ylamine) [1446-61-3]** M 285.5, m 41\(^\circ\), 42.5-45\(^\circ\), b 192-193\(^\circ\)/1mm, 250\(^\circ\)/12mm, \(n_\rho 1.546, [\alpha]_546^\circ +51^\circ\) (c 1, EtOH), \(pK_{\text{gm}} -10.3\). The crude base is purified by converting 2g of base in toluene (3.3mL) into the acetate salt by heating at 65-70\(^\circ\) with 0.46g of AcOH and the crystals are collected and dried (0.96g from two crops; m 141-143\(^\circ\)). The acetate salt is dissolved in warm H\(_2\)O, basified with aqueous NaOH and extracted with \(\text{CH}_2\text{Cl}_2\). The dried extract (MgSO\(_4\)) is evaporated in vacuum leaving a viscous oil which crystallises and can be distd. [Gottstein and Cheney J Org Chem 30 2072 1965.] The picrate has m 234-236\(^\circ\) (from aq MeOH), and the formate has m 147-148\(^\circ\) (from heptane).

**Dehydro-L(+)-ascorbic acid [490-83-5]** M 174.1, m 196\(^\circ\) (dec), \([\alpha]_546^\circ +42.5^\circ\) (c 1, H\(_2\)O), \(pK 3.90\). Crystd from MeOH

**7-Dehydrocholesterol [434-16-2]** M 384.7, m 142-143\(^\circ\), \([\alpha]_D^\circ -122^\circ\) (c 1, CHCl\(_3\)). Crystd from MeOH.

Dehydroepiandrosterone [54-43-0] M 288.4, m 140-141° and 152-153° (dimorphic), \([\alpha]^2_{D} +13°\) (c 3, EtOH). Crystd from MeOH and sublimed in vacuum.

Delphinine [561-07-9] M 559.7, m 197-199°, \([\alpha]^2_{D} +26°\) (EtOH). Crystd from EtOH.

3-Deoxy-D-allose [6605-21-6] M 164.2, \([\alpha]^2_{D} +8°\) (c 0.25 in H₂O). Obtained from diethyl ether as a colourless syrup.

Deoxybenzoin [451-40-1] M 196.3, m 60°, b 177°/12mm, 320°/760mm. Crystd from EtOH.

Deoxycholic acid [83-44-3] M 392.6, m 171-174°, 176°, 176-178°, \([\alpha]^2_{546} +64°\) (c 1, EtOH), \([\alpha]^2_{D} +55°\) (c 2.5, EtOH), pK 6.58. Refluxed with CCl₄ (50mL/g), filtered, evaporated under vacuum at 25°, recrystd from acetone and dried under vacuum at 155° [Trenner et al. J Am Chem Soc 76 1196 1954]. A soln of (cholic acid-free) material (100mL) in 500mL of hot EtOH was filtered, evaporated to less than 500mL on a hot plate, and poured into 1500mL of cold diethyl ether. The ppt, filtered by suction, was recrystd twice from 1-2 parts of absolute EtOH, to give an alcoholate, m 118-120°, which was dissolved in EtOH (100mL for 60g) and poured into boiling water. After boiling for several hours the ppt was filtered off, dried, ground and dried to constant weight [Sobotka and Goldberg Biochem J 26 555 1932]. Deoxycholic acid was also freed from fatty acids and cholic acid by silica gel chromatography by elution with 0.5% acetic acid in ethyl acetate [Tang et al. J Am Chem Soc 107 4058 1985]. It can also be recrystd from butanone. Its solubility in H₂O at 15° is 0.24gL but in EtOH it is 22.07gL/ll.

11-Deoxycorticosterone (21-hydroxyprogesterone) [64-85-7] M 330.5, m 141-142°, \([\alpha]^2_{546} +178°\) and \([\alpha]^2_{D} +223°\) (c 1, EtOH). Crystd from diethyl ether.


2-Deoxy-α-D-glucose [154-17-6] M 164.2, m 146°, \([\alpha]^2_{D} +46°\) (c 0.5, H₂O after 45h). Crystd from MeOH/acetonitrile.

6-Deoxy-D-glucose (D-quinovose) [7658-08-4] M 164.2, m 146°, \([\alpha]^2_{D} +73°\) (after 5 min) and +30° (final, after 3h) (c 8.3, H₂O). It is purified by recryst from EtOAc and is soluble in H₂O, EtOH but almost insoluble in Et₂O and Me₂CO. [Srivastava and Lerner Carbohydr Res 64 263 1978; NMR: Angyal and Pickles Aust J Chem 25 171 1972.]

2-Deoxy-β-L-ribose [18546-37-7] M 134.1, m 77°, 80°, \([\alpha]^2_{D} +91.7°\) (c 7, pyridine, 40° final). Crystd from diethyl ether.

2-Deoxy-β-D-ribose [533-67-5] M 134.1, m 86-87°, 87-90°, \([\alpha]^2_{D} -56°\) (c 1, H₂O after 24h). Crystd from diethyl ether.

Desyl bromide (α-bromo-desoxybenzoin, ω-bromo-ω-phenyl acetophenone) [484-50-0] M 275.2, m 57.1-57.5°. Crystd from 95% EtOH.

Desyl chloride (α-chloro-desoxybenzoin, ω-chloro-ω-phenyl acetophenone) [447-31-4] M 230.7, m 62-64°, 66-67°, 67.5°, 68°. For the purification of small quantities recrystallise from pet ether (b 40-60°), but use MeOH or EtOH for larger quantities. For the latter solvent, dissolve 12.5g of chloride in 45mL of boiling EtOH (95%), filter and the filtrate yields colourless crystalls (7.5g) on cooling. A further crop (0.9g) can be obtained by cooling in an ice-salt bath. It turns brown on exposure to sunlight but it is
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stable in sealed dark containers. [Henley and Turner J Chem Soc 1182 1931; Org Synth Coll Vol II 159 1943.]

Dexamethasone (9-α-fluoro-16-α-methylprednisolone) [50-02-2] M 392.5, m 262-264°, 268-271°, [α]D25 +77.5° (c 1, dioxane). It has been recrystallised from Et2O or small volumes of EtOAc. Its solubility in H2O in 10 mg/100mL at 25°; and is freely soluble in Me2CO, EtOH and CHCl3. [Arth et al. J Am Chem Soc 80 3161 1958; for the β-methyl isomer see Taub et al. J Am Chem Soc 82 4025 1960.]

Dexamethasone 21-acetate (9-α-fluoro-16-α-methylprednisolone-21-acetate) [1177-87-3] M 434.5, m 215-225°, 229-231°, [α]D5 +77.6° (c 1, dioxane), +73° (c 1, CHCl3). Purified on neutral Al2O3 using CHCl3 as eluent, fraction evaporated, and recrystd from CHCl3. UV has λmax at 239nm. [Oliveto et al. J Am Chem Soc 80 4431 1958.]


Diacetoxyiodobenzene (iodobenzenediacetate) [3240-34-4] M 322.1, m 163-165°. Purity can be checked by treatment with H2SO4 then KI and the liberated I2 estimated with standard thiosulfate. It has been recrystd from 5M acetic acid and dried overnight in a vac desiccator over CaCl2. The surface of the crystals may become slightly yellow but this does not affect its usefulness. [Sharefkin and Saltzman Org Synth Coll Vol V 600 1973.]

1,2-Diacetyl benzene [704-00-7] M 162.2, m 39-41°, 41-42°, b 110°/0.1mm, 148°/20mm. Purified by distn and by recrystn from pet ether. The bis-2,4-dinitrophenyl hydrazone has m 221° dec. [Halford and Weissmann J Org Chem 17 1646 1952; Riemschneider and Kassahn Chem Ber 92 1705 1959.]


(+)-Di-O-acetyl-L-tartaric anhydride [(R,R)-2,3-diacetoxysuccinic anhydride] [6283-74-5] M 216.2, m 129-132°, 133-134°, 135°, 137.5°, [α]D20 +97.2° (c 0.5, dry CHCl3). If the IR is good, i.e. no OH bands, then keep in a vacuum desiccator overnight (over P2O5/paraffin) before use. If OH bands are present then reflux 4g in Ac2O (12.6mL) containing a few drops of conc H2SO4 for 10min (use a relatively large flask), pour onto ice, collect the crystals, wash with dry *C6H6 (2 x 2mL), stir with 17mL of cold Et2O, filter and dry in a vacuum desiccator as above, and store in dark evacuated ampoules under N2 in small aliquots. It is not very stable in air; the melting point of the crystals drop one degree in the first four days then remains constant (132-134°). If placed in a stoppered bottle it becomes gummy and the m falls 100° in three days. Recrystn leads to decomposition. If good quality anhydride is required it should be prepared fresh from tartaric acid. It sublimes in a CO2 atmosphere. [Org Synth Coll Vol IV 600 1973.]


(+)-N,N'-Diallyl tartrimide (DATD) [58477-85-3] M 228.3, m 184°, [α]D546 +141° (c 3, MeOH). Wash with Et2O containing 10% EtOH until the washings are clear and colourless, and dry in vacuo. [FEBS Lett 7 293 1970.]

Diamantane [2292-79-7] M 188.3, m 234-235°. Purified by repeated crystn from MeOH or pentane. Also dissolved in CH2Cl2, washed with 5% aq NaOH and water, and dried (MgSO4). The soln was concentrated to a small volume, an equal weight of alumina was added, and the solvent evaporated. The residue was placed on
an activated alumina column (ca 4 x weight of diamantane) and eluted with pet ether (b 40-60°). Eight sublimations and twenty zone refining experiments gave material m 251° of 99.99% purity by differential analysis [Tetrahedron Lett 3877 1970; J Chem Soc (C) 2691 1972].

3,6-Diaminoacridine hydrochloride [952-23-8] M 245.7, m 270°(dec), ε456 4.3 x 10^4, pK1 1.5, pK2 9.60 (9.65 free base). First purified by pptn of the free base by adding aq NH3 soln to an aq soln of the hydrochloride or hydrogen sulfate, drying the ppte and subliming at 0.01mm Hg [Müller and Crothers Eur J Biochem, 54 267 1975].

3,6-Diaminoacridine sulfate (proflavin sulfate) [1811-28-5] M 516.6, m >300°(dec), λmax 456nm. An aqueous soln, after treatment with charcoal, was concentrated, chilled overnight, filtered and the ppte was rinsed with a little diethyl ether. The ppte was dried in air, then overnight in a vacuum oven at 70°.

1.3-Diaminoadamantane [10303-95-4] M 164.3, m 52°, pK(Est(1))-8.6, pK(Est(2))-10.6. Purified by zone refining.

1.4-Diaminoanthraquinone [128-95-0] M 238.3, m 268°. Purified by thin-layer chromatography on silica gel using toluene/acetone (9:1) as eluent. The main band was scraped off and extracted with MeOH. The solvent was evaporated and the quinone was dried in a drying pistol [Land, McAlpine, Sinclair and Truscott J Chem Soc, Faraday Trans 1 72 2091 1974]. Crystd from EtOH in dark violet crystals.

1.5-Diaminoanthraquinone [129-44-2] M 238.3, m 319°. Recrystd from EtOH or acetic acid [Flom and Barbara J Phys Chem 89 4481 1985].

2,6-Diaminoanthraquinone [131-14-6] M 238.3, m 310-320°. Crystd from pyridine. Column-chromatographed on Al2O3 / toluene to remove a fluorescent impurity, then recrystd from EtOH.

3,3’-Diaminobenzidine tetrahydrochloride (2H2O) [7411-49-6] M 396.1, m >300°(dec), pK(Est(1))-3.3, pK(Est(2))-4.7 (free base). Dissolved in water and ppted by adding conc HCl, then dried over solid NaOH.


4,4’-Diaminobenzophenone [611-98-3] M 212.3, m 242-244°, 243-245°, 246.5-247.5° (after sublimation at 0.0006 mm), pK1 1.37, pK2 2.92. Purified by recrystn from EtOH and by sublimation in high vacuum. The dihydrochloride has m 260° dec (from EtOH) and the thiosemicarbazone has m 207-207.5° dec (from aq EtOH). [Kuhn et al. Chem Ber 75 711 1942.]


1,2-Diamino-4,5-dichlorobenzene [5348-42-5] M 177.0, m 163°, pK(Est(1))-0, pK(Est(3))-2.9. Refluxed with activated charcoal in CH2Cl2, followed by recrystn from diethyl ether/pet ether or pet ether [Koolar and Koch J Org Chem 52 4545 1987].

2,2’-Diaminodiethylamine (diethylenetriamine) [111-40-0] M 103.2, b 208°, d 0.95, n 1.483, pK1 4.34, pK2 9.13, pK3 9.94. Dried with Na and distd, preferably under reduced pressure, or in a stream of N2. § Polymer-bound diethylenetriamine is commercially available.

4,5-Diamino-2,6-dihydroxypyrimidine (diamino uracil) sulfate [32014-70-3] M 382.3, m >300°, pK1 1.7, pK2 3.20, pK3 4.56. The salt is quite insoluble in H2O but can be converted to the
free base which is recrystd from H2O and converted to the sulfate by addition of the required amount of H2SO4. The hydrochloride has m 300-305° dec and can be used to prepare the sulfate by addition of H2SO4; it is more soluble than the sulfate. The perchlorate has m 252-254°. The free base has \( \lambda_{max} \) 260nm (log e 4.24) in 0.1M HCl. [Bogert and Davidson J Am Chem Soc 86 1668 1933; Bredereck et al. Chem Ber 86 850 1953; Org Synth Coll Vol IV 247 1963; Barlin and Pfleiderer J Chem Soc (B) 1425 1971.]

5,6-Diamino-1,3-dimethyluracil hydrate (5,6-diamino-1,3-dimethyl-2-pyrimidine-2,4-dione hydrate) [5440-00-6] M 188.2, m 205-208° dec, 209° dec, 210° dec, pK1 1.7, pK2 4.6. Recryst from EtOH. The hydrochloride has m 310° (from MeOH) and the perchlorate has m 246-248°. [UV: Bredereck et al. Chem Ber 92 583 1959; Taylor et al. J Am Chem Soc 77 2243 1955.]

4,4'-Diamino-3,3'-dinitrobiphenyl [6271-79-0] M 274.2, m 275°, pK\textsubscript{H+} ~0.2. Crystd from aqueous EtOH.

4,4'-Diaminodiphenylamine [537-65-5] M 199.3, m 158°, pK\textsubscript{H+} ~5.0. Crystd from water.

4,4'-Diaminodiphenylmethane [101-77-9] M 198.3, m 91.6-92°, pK\textsubscript{H+} ~4.9. Crystd from water, 95% EtOH or *benzene.

3,3'-Diaminodipropylamine [56-18-8] M 131.2, b 152°/50mm, d 0.938, n 1.481, pK\textsubscript{1} 7.72, pK\textsubscript{2} 9.57, pK\textsubscript{3} 10.65. Dried with Na and distd under vacuum.

6,9-Diamino-2-ethoxyacridine (Ethacridine) [442-16-0] M 257.3, m 226°, pK\textsubscript{H+} ~11.5. Crystd from 50% EtOH.

2,7-Diaminofluorene [524-64-4] M 196.3, m 165°, pK\textsubscript{H+} ~4.6. Recrystd from H2O.

2,4-Diamino-6-hydroxypyrimidine [56-06-4] M 126.1, m 260-270°(dec), pK\textsubscript{1} 1.34, pK\textsubscript{2} 3.27, pK\textsubscript{3} 10.83. Recrystd from H2O.


1,5-Diaminonaphthalene [2243-62-1] M 158.2, m 190°, pK\textsubscript{2} 4.12. Recrystd from boiling H2O, but is wasteful due to poor solubility. Boil in chlorobenzene (charcoal), filter hot and cool the filtrate. This gives colourless crystals. Dry in a vac till free from chlorobenzene (odour), and store away from light.

1,8-Diaminonaphthalene [479-27-6] M 158.2, m 66.5°, b 205°/12mm, pK 4.44. Crystd from water or aqueous EtOH, and sublimed in a vacuum. N,N'-DiMe deriv [20734-56-9] has m 103-104° and pK 5.61; N,N,N'-TriMe deriv [20734-57-0] has m 29-30° and pK 6.43. [Hodgson et al. J Chem Soc 202 1945.]

2,3-Diaminonaphthalene [771-97-1] M 158.2, m 199°, pK\textsubscript{2} 3.54 (in 50% aq EtOH). Crystd from water, or dissolved in 0.1M HCl, heated to 50°. After cooling, the soln was extracted with decalin to remove fluorescent impurities and centrifuged.

2,4-Diamino-5-phenylthiazole (Amiphenazole) [490-55-1] M 191.3, m 163-164°(dec). Crystd from aqueous EtOH or water. Stored in the dark under N2.
1,5-Diaminopentane [462-94-2] M 102.2, m 14-16°, b 78-80°/12mm, 101-103°/35mm, 178-180°/750mm, d^21 0.869, n^D 1.458, pK_a^2 10.02, pK_b^2 10.96. Purified by distn, after standing over KOH pellets (at room temp; i.e. liquid form). It has pKa values of 10.02 and 10.96 in H_2O. Its dihydrochloride has m 275° (sublimes in vac), and its tetraphenyl boronate has m 164°. [Schwarzenbach et al. Helv Chim Acta 35 2333 1952.]


1,3-Diaminopropane dihydrochloride [10517-44-9] M 147.1, m 243°, pK_a^5 8.29, pK_b^5 10.30. Crystd from EtOH/water.

1,3-Diaminopropan-2-ol [616-29-5] M 90.1, m 38-40°, pK_a^5 7.94, pK_b^5 9.57. Dissolved in an equal amount of water, shaken with charcoal and vacuum distd at 68°/0.1mm. It is too viscous to be distd through a packed column.


2,6-Diaminopyridine [141-86-6] M 109.1, m 121.5° pK_a^7 (-6.0, pK_b^7 7.3. Crystd from benzene and sublimed in vacuo.

3,4-Diaminopyridine [54-96-6] M 109.1, m 218-219°, pK_a^5 0.49, pK_b^5 9.14. Crystd from benzene and stored under H_2 because it is deliquescent and absorbs CO_2.


Diaminotoluene see toluenediamine.

3,5-Diamino-1,2,4-triazole (Guanazole) [1455-77-2] M 99.1, m 206° pK_a 4.43, pK_b 12.12. Crystd from water or EtOH.

2,5-Di-tert-amylhydroquinone [79-74-3] M 250.4, m 185.8-186.5°. Crystd under N_2 from boiling glacial acetic acid (7mL/g) plus boiling water (2.5mL/g) [Stolow and Bonaventura J Am Chem Soc 85 3636 1963].

Di-n-amyl phthalate [131-18-0] M 306.4, b 204-206°/11mm, d^25 1.023, n 1.489. Washed with aqueous Na_2CO_3, then distilled water. Dried with CaCl_2 and distd under reduced pressure. Stored in a vacuum desiccator over P_2O_5.

1,3-Diazazulene (cycloheptimidazole) [275-94-5] M 130.1, m 120°. Recrystd repeatedly from deaerated cyclohexane in the dark.

1,5-Diazabiciclo[4.3.0]non-5-ene (DBN, 2,3,4,6,7,8-hexahydropyrollo[1,2-a]-pyrimidine) [3001-72-2] M 124.2, b 96-98°/11mm, 100-102°/12mm, 118-121°/32mm, d^25 1.040, n^20 1.520, pK >13.0. Distd from BaO. It forms a hydroiodide by addn of 47% HI, dry and dissolve in MeCN, evaporate and repeat, recrystallise from EtOH then dry at 25°/1mm for 5h, then at 80°/0.03mm for 12h and store and dispense in a dry box, m 154-156° [Jaeger et al. J Am Chem Soc 101 717 1979]. The methiodide is recrystd from CHCl_3 + Et_2O, m 248-250°, and hydrogen fumarate has m 159-160° and is crystd from iso-
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1,4-Diazabicyc[2.2.2]octane (DABCO, triethylenediamine TED) [280-57-9] M 112.2, m 156-157°C (sealed tube), pK<sub>1</sub> 2.97, pK<sub>2</sub> 8.82. Crystd from 95% EtOH, pet ether or MeOH/diethyl ether (1:1). Dried under vacuum over CaCl<sub>2</sub> and BaO. It can be sublimed in vacuo, and readily at room temperature. Also purified by removal of water during azeotropic distn of a benzene soln. It was then recrystd twice from anhydrous diethyl ether under argon, and stored under argon [Blackstock et al. J Org Chem 52 1451 1987].

1,8-Diazabicyclo[5.4.0]undec-7-ene (DBU, 2,3,4,6,7,8,9,10-octahydropyrimidino[1,2-a]-azepine) [6674-22-2] M 152.2, b 115°/11mm, d 1.023, n 1.522, pK<sub>m</sub> >13. Fractionally dist under vac. Also purified by chromatography on Kieselgel and eluting with CHCl<sub>3</sub>/EtOH/25% aq NH<sub>3</sub> (1:5:2) and checked by IR and MS. [Oediger et al. Chem Ber 99 2012 1962; Angew Chem, Int Ed Engl 6 76 1967; Guggisberg et al. Helv Chim Acta 61 1057 1978].

1,8-Diazabiphenylene [259-84-7] M 154.2, pK<sub>Et</sub> ~4.4. Recrystd from cyclohexane, then sublimed in a vacuum.

2,7-Diazabiphenylene [31857-42-8] M 154.2, pK<sub>Et</sub> ~4.5. Recrystd from cyclohexane, then sublimed in a vacuum.

Diazoaminobenzene (1,3-diphenyltriazene) [136-36-6] M 197.2, m 99°. Crystd from pet ether (b 60-80°), 60% MeOH/water or 50% aqueous EtOH (charcoal) containing a small amount of KOH. Also purified by chromatography on alumina/toluene and toluene-pet ether. Stored in the dark.

6-Diazo-5-oxo-L-norleucine [157-03-9] M 171.2, m 145-155°(dec), [α]<sub>D</sub> +21° (c 5, EtOH) pK<sub>1</sub> 2.1, pK<sub>2</sub> 8.95. Crystd from EtOH, aq EtOH or MeOH.

Dibenzoalacetone [538-58-9] M 234.3, m 112°. Crystd from hot ethyl acetate (2.5mL/g) or EtOH.

Dibenzo[a,h]anthracene [53-70-3] M 278.4, m 266-267°. The yellow-green colour (due to other pentacyclic impurities) has been removed by crystn from *benzene or by selective oxidation with lead tetraacetate in acetic acid [Moriconi et al. J Am Chem Soc 82 3441 1960].


Dibenzo[b]furan [132-64-9] M 168.2, m 82.4°. Dissolved in diethyl ether, then shaken with two portions of aqueous NaOH (2M), washed with water, separated and dried (MgSO<sub>4</sub>). After evaporating the ether, dibenzofuran was crystd from aq 80% EtOH and dried under vacuum. [Cass et al. J Chem Soc 1406 1958.] High purity material was obtained by zone refining.

Dibenzyopyran (xanthene) [92-83-1] M 182.2, m 100.5°, b 310-312°. See entry on p. 386.

Dibenzoithiophene [132-65-0] M 184.3, m 99°. Purified by chromatography on alumina with pet ether, in a darkened room. Crystd from water or EtOH.

Dibenzoylmethane (1,3-diphenyl-1,3-propanedione) [120-46-7] M 224.3, m 80°. Crystd from pet ether or MeOH.

Di-O-benzoyl-(R and S)-tartaric acid (H₂O) [R(+) - 17026-42-5; S(+) - 2743-38-6] M 376.3, m 88-89° (hydrate), 173° (anhydrous), [α]D²⁰ (+) and (-) 136° (c 2, EtOH), [α]D²⁰ (++) and (-) 117° (c 5, EtOH), pHₑₓ₄ (H₂O) ~ 2.9, pHₑₓ₄ (EtOH) ~ 4.2. Crystd from water (18g from 400 mL boiling H₂O) and stir vigorously while cooling in order to obtain crystals; otherwise an oil will separate which solidifies on cooling. Dry in a vacuum desiccator over KOH·H₂SO₄ (yield 16.4g) as monohydrate, m 88-89°. It crystallizes from xylene as the anhydrous acid, m 173° (150-153°). It does not cryst from *C₆H₅, toluene, *CH₂Cl₂-pet ether (oil), or CHCl₃-pet ether. [Butler and Cretcher J Am Chem Soc 55 2605 1933; Tetrahedron 41 2465 1085.]

2,3,6,7-Dibenzophenanthrene [222-93-5] M 276.3, m 257°. Crystd from xylene.

Dibenzyl amine [103-49-1] M 197.3, m -26°, b 113-114°/0.1mm, 174-175°/6mm, 270°/250mm, 300° (partial dec), d²⁰ 1.027, n₂⁰ 1.576, pKₐ 8.52. Purified by distn in a vacuum. It causes burns to the skin. The hydrochloride has m 265-266° after recrystn from MeOH·HCl, and the tetrabenzyl borinate has m 129-133°. [Bradley and Maisey J Chem Soc 247 1954; Hall J Phys Chem 60 63 1956; Donetti and Bellora J Org Chem 37 3352 1972.]


Dibenzylethylenediamine (benzathine, DBED) [140-28-3] M 240.4, m 26°, b 195°/4mm, d 1.02, n 1.565, pKₑₓ₂(1) ~ 5.9, pKₑₓ₂(2) ~ 8.9. Dissolve in acid, extract with toluene, basify, extract with Et₂O, dry over solid KOH, evap and fractionate in vucuo. The diacetate cryst from H₂O by addn of EtOH, has m 110° (sol in H₂O is -25%). [Frost et al., J Am Chem Soc 71 3842 1949.]

1,3,4,6-Di-O-benzylidene-D-mannitol [28224-73-9] M 358.4, m 192-195°, 193°, [α]D²⁰ -11.9° (c 0.7, Me₂CO). Recryst from Et₂O in long fine needles. hmax 256nm (E 435) in 95% EtOH, RF 0.21 (1:1 CCl₄-EtOAc) on TLC Silica Gel G. [Sinclair Carbohydr Res 12 150 1970; ORD, CD, NMR, IR, MS: Brecknell et al. Aust J Chem 29 1749 1976.]

Dibenzyl ketone (1,3-diphenyl-2-propanone) [102-04-5] M 210.3, m 34.0°. Fractionally crystd from its melt, then crystd from pet ether. Stored in the dark.


Dibenzyl sulfide [538-74-9] M 214.3, m 48.5°, 50°. Crystd from EtOH/water (10:1), or repeatedly from Et₂O. Also chromatographed on Al₂O₃ (pentine as eluent), then recrystd from EtOH [Kice and Bowers J Am Chem Soc 84 2390 1962]. Vacuum dried at 30° over P₂O₅, fused under nitrogen and re-dried.

2,4-Dibromoaniline [615-57-6] M 250.9, m 79-80°, pK²⁵ 1.87. Crystd from aqueous EtOH.


2,5-Dibromobenzoic acid [610-71-9] M 279.9, m 157°, pKₑₓ ~ 1.5. Crystd from water or EtOH.

4,4'-Dibromobiphenyl [92-86-4] M 312.0, m 164°, b 355-360°/760mm. Crystd from MeOH.

trans-1,4-Dibromobut-2-ene [821-06-7] M 213.9, m 54°, b 85°/10mm. Crystd from ligroin.
α,α-Dibromodeoxybenzoin [15023-99-1] M = 354.0, m = 111.8-112.7° Crystd from acetic acid.


1,3-Dibromo-5,5-dimethylhydantoin [77-48-5] M = 285.9, m = 190-192° dec, 190-193° dec. Recrystd from H₂O. Solubility in CCl₄ is 0.003 mol/L at 25° and 0.024 mol/L at 76.5°.

1,2-Dibromomethane [106-93-4] M = 187.9, f = 10.0°, b = 29.1°/10mm, 131.7°/760mm, d = 2.179, n = 1.54160. Washed with conc HCl or H₂SO₄, then water, aqueous NaHCO₃ or Na₂CO₃, more water, and dried with CaCl₂. Fractionally distd. Alternatively, kept in daylight with excess bromine for 2 hours, then extracted with aqueous Na₂SO₃, washed with water, dried with CaCl₂, filtered and distd. It can also be purified by fractional crystallization by partial freezing. Stored in the dark.

4',5'-Dibromofluorescein [596-03-2] M = 490.1, m = 285°. Crystd from aqueous 30% EtOH.

5,7-Dibromo-8-hydroxyquinoline [521-74-4] M = 303.0, m = 196°, pKₐ = 5.84, pKₐ = 9.56. Crystd from acetone/EtOH. It can be sublimed.

Dibromomaleic acid [608-37-7] M = 273.9, m = 123.5°, 125° dec, pKₐ = 1.45, pKₐ = 4.62. It has been recrystd from Et₂O or Et₂O-CHCl₃. It is slightly soluble in H₂O, soluble also in AcOH but insoluble in *C₆H₆ and CHCl₃. [Salmony and Simonis Chem Ber 38 2583 1905; Ruggli Helv Chim Acta 3 566 1929.]

2,5-Dibromonitrobenzene [3460-18-2] M = 280.9, m = 84°. Crystd from acetone.

2,6-Dibromo-4-nitrophenol [99-28-5] M = 280.9, m = 143-144°, pKₐ = 3.39. Crystd from aq EtOH.

2,4-Dibromophenol [615-58-7] M = 251.9, m = 37°, 41-42°, b = 154°/10mm, 239°/atm, pKₐ = 7.79. Crystd from CHCl₃ at -40°.

2,6-Dibromophenol [608-33-3] M = 251.9, m = 56-57°, b = 138°/10mm, 255-256°/740mm, pKₐ = 6.67. Vacuum distd (at 18mm), then crystd from cold CHCl₃ or from EtOH/water.

1,3-Dibromopropane [110-64-8] M = 201.9, f = -34.4°, b = 63-63.5°/26mm, 76-77°/40mm, 90°/80mm, 165°/atm, d = 1.977, n = 1.522. Washed with dilute aqueous Na₂CO₃, then water. Dried and fractionally distilled under reduced pressure.

2,6-Dibromopyridine [626-05-1] M = 236.9, m = 117-119°, 118.5-119°, b = 249°/757.5mm, pKₐ < 0. Purified by steam distillation then twice recrystd from EtOH. Does not form an HgCl₂ salt. [den Hertog and Wibaut Rec Trav Chim Pays Bas 51 381 1932.]


1,2-Dibromotetrafluoroethane [124-73-2] M = 259.8, b = 47.3°/760mm. Washed with water, then with weak alkali. Dried with CaCl₂ or H₂SO₄ and distd. [Locke et al. J Am Chem Soc 56 1726 1934.] Also purified by gas chromatography on a silicone DC-200 column.

α,α'-Dibromo-o-xylene [91-13-4] M = 264.0, m = 95°, b = 129-130°/4.5mm. Crystd from CHCl₃

α,α'-Dibromo-m-xylene [626-15-3] M = 264.0, m = 77°, b = 156-160°/12mm. Crystd from acetone.

α,α'-Dibromo-p-xylene [623-24-5] M = 264.0, m = 145-147°, b = 155-158°/12-15mm, 245°/760mm. Crystd from *benzene or chloroform.

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Di-n-butylamine [111-92-2] M 129.3, b 159°, n 1.41766, d 0.761, pK25 11.25. Dried with LiAlH4, CaH2 or KOH pellets, filtered and distd from BaO or CaH2.

α-Dibutylamino-α-(p-methoxyphenyl)acetamide (Ambucetamide) [519-88-0] M 292.4, m 134°. Crystd from EtOH containing 10% diethyl ether.

2,5-Di-tert-butyl aniline [21860-03-7] M 205.4, m 134°. Crystd from EtOH containing 10% diethyl ether.

2,5-Di-tert-butyl aniline [21860-03-7] M 205.4, m 134°. Crystd from EtOH containing 10% diethyl ether.

2,6-Di-tert-butyl-1,4-benzoquinone [719-22-2] M 220.3, m 66-67°. It can be recrystd from MeOH and sublimed in a vacuum.

3,5-Di-tert-butyl-o-benzoquinone [3383-21-9] M 220.3, m 112-114°, 113-114°. It can be recrystd from MeOH or pet ether, and forms fine red plates or rhombs. [Flaig et al. Justus Liebigs Ann Chem 597 1955; IR: Ley and Muller Chem Ber 89 1402 1956.]


Dibutylcarbitol [di(ethyleneglycol)dibutyl ether] [111-73-2] M 218.3, b 125-130°/0.1mm, d 0.883, n 1.424. Freed from peroxides by slow passage through a column of activated alumina. The eluate was shaken with Na2CO3 (to remove any remaining acidic impurities), washed with water, and stored with CaCl2 in a dark bottle [Tuck J Chem Soc 3202 1957].

2,6-Di-tert-butyl-4-dimethylaminomethylphenol [88-27-7] M 263.4, m 93-94°, b 172°/30mm, pK2 ~12.0. Crystd from n-hexane.

Di-tert-butyl dicarbonate (di-tert-butyl pyrocarbonate) [24424-99-5] M 218.3, m 23°(21-22°), b 55-56°/0.15mm, 62-65°/0.4mm, d 0.950, n 1.409. Melt by heating at ~35°, and distil in vac. If IR and NMR (ν 1810m 1765 cm⁻¹, δ in CCl4 1.50 singlet) suggest very impure then wash with equal vol of H2O containing citric acid to make the aqueous layer slightly acidic, collect the organic layer and dry over anhyd MgSO4 and distil in vac. [Pope et al. Org Synth 57 45 1977.] FLAMMABLE.

2,6-Di-tert-butyl-4-dimethylaminomethylphenol [88-27-7] M 263.4, m 93-94°, b 172°/30mm, pK2 ~12.0. Crystd from n-hexane.

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2,6-Di-tert-butyl-4-ethylphenol [4130-42-1] M 234.4, m 42-44°, pK_{Em} \sim 12.3. Cryst from aqueous EtOH or n-hexane.

2,6-Di-tert-butyl-4-methylpyridine [38222-83-2] M 205.4, m 31-32°, 33-36°, b 148-153°/95mm, 223°/760mm, d^2 1.476, pK_{Em} \sim 5.7. Possible impurity is 2,6-di-tert-butyl-4-neopentylpyridine. Attempts to remove coloured impurities directly by distn, acid-base extraction or treatment with activated charcoal were unsuccessful. Pure material can be obtained by dissolving 0.3mole of the alkylpyridine in pentane (150mL) and introducing it at the top of a water jacketed chromatographic column (40 x 4.5cm) the cooling is necessary because the base in pentane reacts exothermically with alumina) containing activated and acidic alumina (300g). The column is eluted with pentane using a 1L constant pressure funnel fitted at the top of the column to provide slight press. All the pyridine is obtained in the first two litres of eluent (the progress of elution is monitored by spotting a fluorescent TLC plate and examining under short wave UV light - a dark blue spot is evidence for the presence of the alkylpyridine). Elution is complete in 1h. Pentane is removed on a rotovap with 90-93% recovery yielding a liquid which solidifies on cooling, m 31-32°, and the base can be distilled. The HPTCl_6 salt has m 213-314° (dec), and the CF_3SO_3H salt has m 202.5-203.5° (from CH_2Cl_2). [Org Synth 60 34 1981.]

Di-tert-butyl peroxide (tert-butyl peroxide) [110-05-4] M 146.2, d 0.794, n 1.389. Washed with aqueous AgNO_3 to remove olefinic impurities, water and dried (MgSO_4). Freed from tert-butyl hydroperoxide by passage through an alumina column [Jackson et al. J Am Chem Soc 107 208 1985], and if necessary two high vacuum distns from room temp to a liquid-air trap [Offenbach and Tobolsky J Am Chem Soc 79 278 1957]. The necessary protection from EXPLOSION should be used.

Dibutyl phthalate [84-74-2] M 278.4, b 206°20mm, 340°760mm, d 1.4929, d^5 1.0426, n^25 1.490. Washed with dilute NaOH (to remove any butyl hydrogen phthalate), aqueous NaHCO_3 (charcoal), then distd water. Dried with CaCl_2, distd under vacuum, and stored in a desiccator over P_2O_5. (See also p. 151.)

Di-n-butyl sulfide [544-40-1] M 146.3, α-form b 182°, β-form 190-230°(dec). Washed with aq 5% NaOH, then water. Dried with CaCl_2 and distd from sodium.

Di-n-butyl sulfone [598-04-9] M 162.3, m 43.5°. Purified by zone melting.

Dichloramine-T \((N,N\text{-dichloro-p-toluenesulfonamide})\) \([473-34-7]\) M 240.1, m 83°. Crystd from pet ether (b 60-80°) or CHCl₃/pet ether. Dried in air. (see also chloramine-T in Chapter 5).

Dichloroacetic acid \([79-43-6]\) M 128.9, m 13.5°, b 95.0-95.5°/17-18mm, d 1.563, n 1.466, pK² 1.35. Crystd from benzene or pet ether. Dried with MgSO₄ and fractionally distd. [Bernasconi et al. J Am Chem Soc 107 3612 1985.]

Sym-Dichloroacetone \((1,3\text{-dichloropropan-2-one})\) \([534-07-6]\) M 127.0, m 41-43°, b 86-88°/12mm, 75-77°/22mm, 172-172.5°/atm, 170-175° /atm, d 1.383. Crystd from CCl₄, CHCl₃ and benzene. Distd under vacuum. [Conant and Quayle Org Synth Coll Vol 2 1941; Hall and Sirel J Am Chem Soc 74 6156 1952]. It is dimorphic [Daasch and Kagarise J Am Chem Soc 77 6156 1955]. The oxime has m 130-131°, b 106°/25mm [Arzneimittel-Forsch 8 638 1958].

Dichloroacetonitrile \([3018-12-0]\) M 110.0, b 110-112°, d 1.369, n 1.440. Purified by distn and by gas chromatography. FLAMMABLE.


3,4-Dichloroaniline \([95-76-1]\) M 162.0, m 71.5°, pK² 2.97. Crystd from MeOH.


2,4-Dichlorobenzaldehyde \([874-42-0]\) M 175.0, m 72°. Crystd from EtOH or ligroin.

2,6-Dichlorobenzaldehyde \([83-38-5]\) M 175.0, m 70.5-71.5°. Crystd from EtOH/water or pet ether (b 30-60°).

\(\alpha\)-Dichlorobenzene \([95-50-1]\) M 147.0, b 81-82°/31-32mm, 180.5°/760mm, d 1.306, n 1.551, n² 1.549. Contaminants may include the p-isomer and trichlorobenzene [Suslick et al. J Am Chem Soc 106 4522 1984]. It was shaken with conc or fuming H₂SO₄, washed with water, dried with CaCl₂, and distd from CaH₂ or sodium in a glass-packed column. Low conductivity material (ca 10⁻¹⁰ mhos) has been obtained by refluxing with P₂O₅, fractionally distilled and passed through a column packed with silica gel or activated alumina: it was stored in a dry-box under N₂ or with activated alumina.

\(\beta\)-Dichlorobenzene \([541-73-1]\) M 147.0, b 173.0°, d 1.289, n 1.54586, n² 1.54337. Washed with aqueous 10% NaOH, then with water until neutral, dried and distd. Conductivity material (ca 10⁻¹⁰ mhos) has been prepared by refluxing over P₂O₅ for 8h, then fractionally distilling, and storing with activated alumina. \(\alpha\)-Dichlorobenzene dissolves rubber stoppers.

\(\beta\)-Dichlorobenzene \([541-73-1]\) M 147.0, b 173.0°, d 1.289, n 1.54586, n² 1.54337. Washed with aqueous 10% NaOH, then with water until neutral, dried and distd. Conductivity material (ca 10⁻¹⁰ mhos) has been prepared by refluxing over P₂O₅ for 8h, then fractionally distilling, and storing with activated alumina. \(\alpha\)-Dichlorobenzene dissolves rubber stoppers.

2,2'-Dichlorobenzidine \([84-68-4]\) M 253.1, m 165°, pKₑ₇(1) ~3.0, pKₑ₇(2) ~4.0. Crystd from EtOH.

3,3'-Dichlorobenzidine \([91-94-1]\) M 253.1, m 132-133°, pKₑ₇(1) ~4.8, pKₑ₇(2) ~5.7. Crystd from EtOH or benzene. CARCINOGEN.

2,4-Dichlorobenzoic acid \([50-84-0]\) M 191.0, m 163-164°, pK² 2.68. Crystd from aqueous EtOH (charcoal), then benzene (charcoal). It can also be recrystd from water.
2,5-Dichlorobenzoic acid [50-79-3] M 191.0, m 154°, b 301°/760mm, \( \text{pK}_2 \, 2.47 \). Crystd from water.

2,6-Dichlorobenzoic acid [50-30-6] M 191.0, m 141-142°, \( \text{pK}_2 \, 1.59 \). Crystd from EtOH and sublimed in vacuo.

3,4-Dichlorobenzoic acid [51-44-5] M 191.0, m 206-207°, \( \text{pK}_2 \, 3.64 \). Crystd from aqueous EtOH (charcoal) or acetic acid.

3,5-Dichlorobenzoic acid [51-36-5] M 191.0, m 188°, \( \text{pK}_2 \, 3.54 \). Crystd from EtOH and sublimed in a vacuum.


2,6-Dichloro-1,4-benzoquinone [697-91-6] M 177.0, m 122-124°. Recrystd from pet ether (b 60-70°) [Carlson and Miller J Am Chem Soc 107 419 1985].

2,6-Dichlorobenzoyl chloride [4659-45-4] M 209.5, m 15-17, b 122-124°/15mm, d 1.464. Reflux for 2h with excess of acetyl chloride (3 vols), distil off AcCl followed by the benzoyl chloride. Store away from moisture. It is an IRRITANT.


2,3-Dichloro-1,3-butadiene [1653-19-6] M 123.0, b 41-43°/85mm, 98°/760mm. Crystd from pentane to constant melting point about -40°. A mixture of meso and \( \text{d,l} \) forms was separated by gas chromatography on an 8m stainless steel column (8mm i.d.) with 20% DEGS (diethyleneglycolsilyl chloride) on Chromosorb W (60-80 mesh) at 60° and 80mL Helmin. [Su and Ache J Phys Chem 80 659 1976].

(\(+\) and \(-\) (8,8-Dichlorocamphorylsulfonyl)oxaziridine [127184-05-8] M 298.2, m 178-180°, 183-186°, \([\alpha]_D \, (+) \) and \(-\) \( 88.3° \) (c 1.3, CHCl₃), \( +\) and \(-\) \( 91° \) (c 5, CHCl₃). Recrystd from EtOH [Davis and Weismiller J Org Chem 55 3715 1990].

\( \text{cis-3,4-Dichlorocyclobutene} \) [2957-95-1] M 123.0, b 70-71°/55mm, 74-76°/55mm, \( d_4 \, 1.297, n_D \, 1.499 \). Distd at 55mm through a 36-in platinum spinning band column, a fore-run b 58-62°/55mm is mainly 1,4-dichlorobutadiene. When the temperature reaches 70° the reflux ratio is reduced to 10:1 and the product is collected quickly. It is usually necessary to apply heat frequently with a sun lamp to prevent any dichlorobutadiene from clogging the exit in the early part of the distn [Pettit and Henery Org Synth 50 36 1970].

2,3-Dichloro-5,6-dicyano-p-benzoquinone (DDQ) [84-58-2] M 227.0, m 203° (dec). Crystd from CHCl₃, CHCl₃/benzene (4:1), or *benzene and stored at 0°. [Pataki and Harvey J Org Chem 52 2226 1987].

\( \text{b,8'-Dichlorodiethyl ether} \) [111-44-4] M 143.0, b 79-80°/20mm, 176-177.0°/743mm, n 1.457, d 1.219. See bis-(b-dichloroethyl)ether on p. 134.

1,2-Dichloro-1,2-difluoroethane [431-06-1] M 134.9, b 59°, n 1.376. Purified by frct dist [Hazeldine J Chem Soc 4258 1952]. For purification of diastereoismeric mixture, with resolution into \( \text{meso} \) and \( \text{rac} \) forms, see Macrilla and Stocklin [J Phys Chem 78 658 1974].
Dichlorodifluoromethane (Freon 12) \[75-71-8\] M 120.9, b -158°, d -29.8°/atm, 42.5°/10atm. Passage through saturated aqueous KOH then conc H\textsubscript{2}SO\textsubscript{4}, and a tower packed with activated copper on Kieselguhr at 200° removed CO\textsubscript{2} and O\textsubscript{2}. A trap cooled to -29° removed a trace of high boiling material. It is a non-flammable propellant.  

1,3-Dichloro-5,5’-dimethylhydantoin \[118-52-5\] M 197.0, m 132-134°, 136°. Purified by dissolving in conc H\textsubscript{2}SO\textsubscript{4} and diluting with ice H\textsubscript{2}O, dry and recrystd from CH\textsubscript{2}Cl\textsubscript{2}. It sublimes at loo in a vacuum. Exhibits time dependent hydrolysis at pH 9. [Petterson and Grzeskowiak \textit{J Org Chem} 24 1414 1959.]  

4,5-Dichloro-3H-1,2-dithiol-3-one \[1192-52-5\] M 187.1, m 52-56°, 61°, b 87°/0.5mm, 125°/11mm. Distd in vacuo and then recrystd from pet ether. IR: v 1650 cm\textsuperscript{-1} [Boberg \textit{Justus Liebigs Ann Chem} 693 212 1966].  

1,1-Dichloroethane (ethylidene dichloride) \[75-34-3\] M 99.0, b 57.3°, d\textsubscript{15} 1.18350, d\textsubscript{1.177} 1.177, n\textsubscript{15} 1.41975. Shaken with conc H\textsubscript{2}SO\textsubscript{4} or aqueous KMnO\textsubscript{4}, then washed with water, saturated aqueous NaHC\textsubscript{O}\textsubscript{3}, again with water, dried with K\textsubscript{2}CO\textsubscript{3} and distd from CaH\textsubscript{2} or CaSO\textsubscript{4}. Stored over silica gel.  

1,2-Dichloroethane \[107-06-2\] M 99.0, b 83.4°, d\textsubscript{1.256} 1.44759. Usually prepared by chlorinating ethylene, so that likely impurities include higher chloro derivatives and other chloro compounds depending on the impurities originally present in the ethylene. It forms azeotropes with water, MeOH, EtOH, trichloroethylene, CCl\textsubscript{4} and isopropanol. Its azeotrope with water (containing 8.9% water, and b 77°) can be used to remove gross amounts of water prior to final drying. As a preliminary purification step, it can be steam distd, and the lower layer was treated as below. Shaken with conc H\textsubscript{2}SO\textsubscript{4} (to remove alcohol added as an oxidation inhibitor), washed with water, then dilute KOH or aqueous Na\textsubscript{2}CO\textsubscript{3} and again with water. After an initial drying with CaCl\textsubscript{2}, MgSO\textsubscript{4} or by dista, it is refluxed with P\textsubscript{2}O\textsubscript{5}, CaSO\textsubscript{4} or CaH\textsubscript{2} and fractionally distd. Carbonyl-containing impurities can be removed as described for chloroform.  

1,2-Dichloroethylene \[cis + trans 540-59-0\] M 96.9, b 60° (cis), d\textsubscript{1.284} 1.284, d\textsubscript{1.48} 1.48° (trans), d\textsubscript{1.257} 1.257. Shaken successively with conc H\textsubscript{2}SO\textsubscript{4}, water, aqueous NaHC\textsubscript{O}\textsubscript{3} and water. Dried with MgSO\textsubscript{4} and distn separated the cis- and trans-isomers.  

cis-1,2-Dichloroethylene \[156-59-2\] M 96.9, b 60.4°, d\textsubscript{1.2830} 1.44903, n\textsubscript{1.177} 1.44975. Purified by careful fractional distn, followed by passage through neutral activated alumina. Also by shaking with mercury, drying with K\textsubscript{2}CO\textsubscript{3} and distn from CaSO\textsubscript{4}.  

trans-1,2-Dichloroethylene \[156-60-5\] M 96.9, b 47.7°, n\textsubscript{1.45189} 1.45189, n\textsubscript{1.4462} 1.4462, d\textsubscript{1.2551} 1.255. Dried with MgSO\textsubscript{4}, and fractionally distd under CO\textsubscript{2}. Fractional crystn at low temperatures has also been used.  

5,7-Dichloro-8-hydroxyquinoline \[773-76-2\] M 214.1, m 180-181°, pK\textsubscript{1} 1.89, pK\textsubscript{2} 7.62. Crystd from acetone/EtOH.  

2,3-Dichloromaleic anhydride \[1122-17-4\] M 167.0, m 105-115°, 120°, 121-121.5°. Purified by sublimation in vacuo [Katakis et al. \textit{J Chem Soc, Dalton Trans} 1491 1986]. It has also been purified by Soxhlet extraction with hexane, recrystd from CH\textsubscript{3}Cl\textsubscript{3} and sublimed [MS, Relles \textit{J Org Chem} 37 3630 1972].  

Dichloromethane (methylene dichloride) \[75-09-2\] M 84.9, b 40.0°, d\textsubscript{1.325} 1.325, n\textsubscript{251.4201} 1.42456, n\textsubscript{251.4201} 1.42456. Shaken with portions of conc H\textsubscript{2}SO\textsubscript{4} until the acid layer remained colourless, then washed with water, aqueous 5% Na\textsubscript{2}CO\textsubscript{3}, NaHC\textsubscript{O}\textsubscript{3} or NaOH, then water again. Pre-dried with CaCl\textsubscript{2}, and distd from CaSO\textsubscript{4}, CaH\textsubscript{2} or P\textsubscript{2}O\textsubscript{5}. Stored away from bright light in a brown bottle with Linde type 4A molecular sieves, in an atmosphere of dry N\textsubscript{2}. Other purification steps include washing withaq Na\textsubscript{2}S\textsubscript{2}O\textsubscript{3}, passage through a column of silica gel, and removal of carbonyl-containing impurities as described under Chloroform. It has also been purified by treatment with basic alumina, distd, and stored over molecular sieves under nitrogen [Puchot et al. \textit{J Am Chem Soc} 108 2353 1986].
Dichloromethane from Japanese sources contained MeOH as stabiliser which is not removed by distn. It can, however, be removed by standing over activated 3A Molecular Sieves (note that 4A Sieves cause the development of pressure in bottles), passed through activated Al₂O₃ and distd [Gao et al. *J Am Chem Soc* **109**, 5771, 1987]. It has been fractionated through a platinum spinning band column, degassed, and distd onto degassed molecular sieves, Linde 4A, heated under high vacuum at over 450°C until the pressure readings reached the low values of 10⁻⁶ mm — ~1-2 h [Mohammad and Kosower *J Am Chem Soc* **93**, 2713, 1971].

**Rapid purification:** Reflux over CaH₂ (5% w/v) and distil. Store over 4A molecular sieves.


5,7-Dichloro-2-methyl-8-hydroxyquinoline (5,7-dichloro-8-hydroxyquinaldine) [72-80-0] M 228.1, m 114-115°C, pKₑₒₙ(1) ~2.0, pKₑₒₙ(2)~8.4. Crystd from EtOH.


2,4-Dichloro-1-naphthol [2050-76-2] M 213.1, m 106-107°C, pKₑₒₙ ~7.7. Crystd from MeOH.

2,3-Dichloro-1,4-naphthoquinone [117-80-6] M 227.1, m 193°C. Crystd from EtOH.

2,5-Dichloro-4-nitroaniline [6627-34-5] M 207.0, m 157-158°C, pKₑₒₙ -1.74 (aq H₂SO₄). Crystd from EtOH, then sublimed.

2,6-Dichloro-4-nitroaniline [99-30-9] M 207.0, m 193°C. Crystd from acq EtOH or *benzene/EtOH.

2,5-Dichloro-1-nitrobenzene [89-61-2] M 192.0, m 56°C. Crystd from absolute EtOH.

3,4-Dichloro-1-nitrobenzene [99-54-7] M 192.0, m 43°C. Crystd from absolute EtOH.

2,4-Dichloro-6-nitrophenol [609-89-2] M 208.0, m 122-123°C, pKₑₒₙ ~5.0. Crystd from AcOH.

2,6-Dichloro-4-nitrophenol [618-00-4] M 208.0, m 125°C, pKₑₒₙ 3.55. Crystd from EtOH and dried in vacuo over anhydrous MgSO₄.

4,6-Dichloro-5-nitropyrimidine [4316-93-2] M 194.0, m 100-103°C, 101-102°C, pKₑₒₙ <0. If too impure then dissolve in Et₂O, wash with H₂O, dry over MgSO₄, evaporate to dryness and recrystallise from pet ether (b 85-105°C) as a light tan solid. It is sol in ca 8 parts of MeOH [Boon et al, *J Chem Soc* 96 1951; Montgomery et al. in *Synthetic Procedures in Nucleic Acid Chemistry* (Zorbach and Tipson eds) Wiley & Sons, NY, p76 1968].

**Dichlorophen (2,2'-methylenebis(4-chlorophenol)) [97-23-4] M 269.1, b 177-178°C, pKₑₒₙ ~9.7.** Crystd from toluene.

2,3-Dichlorophenol [576-24-9] M 163.0, m 57°C, pKₑₒₙ 7.70. Crystd from ether.

2,4-Dichlorophenol [120-83-2] M 163.0, m 42-43°C, pKₑₒₙ 7.89. Crystd from pet ether (b 30-40°C). Purified by repeated zone melting, using a P₂O₅ guard tube to exclude moisture. Very hygroscopic when dry.

2,5-Dichlorophenol [583-78-8] M 163.0, m 58°C, b 211°/744mm, pKₑₒₙ 7.51. Crystd from ligroin and sublimed.

3,4-Dichlorophenol [95-77-2] M 163.0, m 68°C, b 253.5°/767mm, pKₑₒₙ 8.58. Crystd from pet ether/*benzene mixture.
3,5-Dichlorophenol \([591-35-5]\) M 163.0, m 68°, b 122-124°/8mm, 233-234°/760mm, pK\textsuperscript{25} 8.81. Crystd from pet ether/benzene mixture.

2,4-Dichlorophenoxyacetic acid (2,4-D) [94-75-7] M 221.0, m 146°, pK\textsuperscript{25} 2.90. Crystd from MeOH. TOXIC.

\(\alpha-(2,4\text{-Dichlorophenoxy})\text{-propionic acid} (2,4\text{-DP, Dichloroprop}) [120-36-5] M 235.1, m 117°, pK\textsuperscript{20} 2.86, Crystd from MeOH. TOXIC.

2,4-Dichlorophenolacetic acid [19719-28-9] M 205.0, m 131°, 132-133°, pK\textsubscript{est} 4.0. Crystd from aqueous EtOH.

2,6-Dichlorophenolacetic acid [6575-24-2] M 205.0, m 157-158°, pK\textsubscript{est} 3.8. Crystd from aqueous EtOH.


4,5-Dichloro-o-phenylenediamine [5348-42-5] M 177.1, m 162°, 162-163°, pK\textsubscript{est(1)} -1.0, p\textsubscript{b}\textsubscript{St(2)}-2.9. Recrystd from hexane, \(*_{_{_{_{\text{C}_6\text{H}_6}, \text{pet ether or H}_2\text{O (Na}_2\text{SO}_4)}} \) and sublimed at 150°/15mm.

4,5-Dichlorophthalic acid [56962-08-4] M 235.0, m 200° (dec to anhydride), pK\textsubscript{est(1)} 2.2, p\textsubscript{b}\textsubscript{St(2)}-4.7. Crystd from water. Can be purified by converting to the anhydride, reacting with boiling EtOH to form the monoethyl ester (m 133-134°) and hydrolysing back to the diacid.

3,6-Dichlorophthalic anhydride [4466-59-5] M 189-191°, 191-191.5°, b 339°. Boil in xylene (allowing any vapours which would contain H\textsubscript{2}O to be removed, e.g. Dean and Stark trap), which causes the acid to dehydrate to the anhydride and cool. Recryst from xylene [Villiger Chem Ber 42 3539 1909; Fedoorow Izv Akad Nauk SSSR Otd Khim Nauk 397 1948, Chem Abstr 1585 1948].

1,2-Dichloropropane [78-87-5] M 113°, b 95.9-96.2°, d 1.158, n 1.439. Distd from CaH\textsubscript{2}.

2,2-Dichloropropane [594-20-7] M 113.0, b 69.3°, d 1.090, n 1.415. Washed with aqueous Na\textsubscript{2}CO\textsubscript{3} soln, then distilled water, dried over CaCl\textsubscript{2} and fractionally distd.

2,6-Dichloropurine [5451-40-1] M 189.0, m 180-181.5°, 181°, 185-195° (dec), 188-189°, pK\textsubscript{b} 1.16 (aq H\textsubscript{2}SO\textsubscript{4}), pK\textsubscript{b} 7.06. It can be recrystd from 150 parts of boiling H\textsubscript{2}O and dried at 100° to constant weight. Soluble in EtOAc. The HgCl\textsubscript{2} salt separates from EtOH soln. UV: \(\lambda\text{max} 275\text{nm (}\varepsilon 8.9K\) at pH 1; and 280nm (8.5K) at pH 11 [Elion and Hitchings J Am Chem Soc 78 3508 1956; Schaeffer and Thomas J Am Chem Soc 80 3738 1958; Beaman and Robins J Appl Chem (London) 12 432 1962; Montgomery J Am Chem Soc 78 1928 1956].

2,6-Dichloropyridine [2402-78-0] M 148.0, m 87-88°, pK -2.86 (aq H\textsubscript{2}SO\textsubscript{4}). Crystd from EtOH.

3,5-Dichloropyridine [2457-47-8] M 148.0, m 64-65°, pK\textsuperscript{25} 0.67. Crystd from EtOH.

4,7-Dichloroquinoline [86-98-6] M 198.1, m 86-87.4°, b 148°/10mm, pK\textsuperscript{25} 2.80. Crystd from MeOH or 95% EtOH.

2,3-Dichloroquinoxaline [2213-63-0] M 199.0, m 152-153°, 152-154°, pK\textsubscript{est} <0. Recrystd from \(*_{_{_{_{\text{C}_6\text{H}_6}}} \) and dried in a vacuum [Cheeseman J Chem Soc 1804 1955].

2,6-Dichlorostyrene [28469-92-3] M 173.0, b 72-73°/2mm, d 1.4045, n 1.5798. Purified by fractional crystn from the melt and by distn.
2,4-Dichlorotoluene [95-73-8] M 161.1, m -13.5°, b 61-62°/3mm, d 1.250, n 1.5513. Recrystd from EtOH at low temperature or fractionally distd.

2,6-Dichlorotoluene [118-69-4] M 161.1, b 199-200°/760mm, d 1.254, n 1.548. Fractionally distd and collecting the middle fraction.

3,4-Dichlorotoluene [95-75-0] M 161.1, m -16°, b 205°/760mm, d 1.254, n 1.549. Recrystd from EtOH at very temperature or fractionally distd.

α,α’-Dichloro-p-xylene [623-25-6] M 175.1, m 100°. Crystd from *benzene and dried under vacuum.

Dicinnamalacetone (1,9-diphenyl-1,3,6,8-nonatetraen-5-one) [622-21-9] M 314.4, m 146°.

Dicumyl peroxide [80-43-3] M 270.4, m 39-40°. Crystd from *benzene and dried under vacuum. Stored at 0°. Potentially EXPLOSIVE.


1,2-Dicyanobenzene [91-15-6] M 128.1, m 141°. (See phthalonitrile on p. 334.)

1,4-Dicyanobenzene [623-26-7] M 128.1, m 222°. Crystd from EtOH.

1,4-Dicyanonaphthalene [3029-30-9] M 178.2, m 206°. Purified by crystn and sublimed in vacuo.

1,3-Dicyclohexylcarbodiimide (DCC) [538-75-0] M 206.3, m 34-35°, b 95-97°/0.2mm, 120-121°/0.6mm, 155°/11mm. It is sampled as a liquid after melting in warm H2O. It is sensitive to air and it is a potent skin irritant. It can be distd in a vacuum and stored in a tightly stoppered flask in a freezer. It is very soluble in CH2Cl2 and pyridine where the reaction product with H2O, after condensation, is dicyclohexyl urea which is insoluble and can be removed by filtration. Alternatively dissolve in CH2Cl2 add powdered anhyd MgSO4 shake 4h, filter, evaporate and distil at 0.6 mm press and oil bath temperature 145°. [Biochem Prep 10, 122 1963; Justus Liebigs Ann Chem 571 83 1951; Justus Liebigs Ann Chem 612 11 1958.]

cis-Dicyclohexyl-18-crown-6 [16069-36-6] M 372.5, m 47-50°. Purified by chromatography on neutral alumina and eluting with an ether/hexane mixture [see Inorg Chem 14 3132 1975]. Dissolved in ether at ca 40°, and spectroscopic grade MeCN was added to the solution which was then chilled. The crown ether ptted and was filtered off. It was dried in vacuo at room temperature [Wallace J Phys Chem 89 1357 1985]. SKIN IRITANT.

Di-n-decylamine [1120-49-6] M 297.6, m 34°, b 153°/1mm, 359°/760mm, pKEm ~11.0. Dissolved in *benzene and pptd as its bisulfate by shaking with 4M H2SO4. Filtered, washed with *benzene, separating by centrifugation, then the free base was liberated by treating with aqueous NaOH [McDowell and Allen J Phys Chem 65 1358 1961].


Dienestrol [4,4'-(diethylidene-ethylene)diphenol, Dienol] \[84-17-3\] M 266.3, m 227-228°, 231-233°, pK\textsubscript{acet} -9.8. Crystd from EtOH or dilute EtOH, sublimes at 130°/1mm. The diacetate has m 119-120° (from EtOH) [Hobday and Short \textit{J Chem Soc} 609 1943].

Diethanolamine (2,2'-iminodiethanol) \[111-42-2\] M 105.1, m 28°, b 154-155°/10 mm, 270°/760 mm pK\textsubscript{2} 8.88. Fractionally distd twice, then fractionally crystd from its melt.

3,4-Diethoxy-3-cyclobutene-1,2-dione (diethyl squarate) \[5321-87-8\] M 170.2, b 89-91°/0.4 mm, 88-92°/0.4 mm, d\textsubscript{4} 1.162, n\textsubscript{D}² 1.5000. Dissolve in Et\textsubscript{2}O, wash with Na\textsubscript{2}CO\textsubscript{3}, H\textsubscript{2}O and dry (Na\textsubscript{2}SO\textsubscript{4}), filter, evaporate and distil using a Kugelrohr or purify by chromatography. Use a Kieselgel column and elute with 20% Et\textsubscript{2}O-Pet ether (b 40-60°) then with Et\textsubscript{2}O-pet ether (1:1), evaporate and distil in vacuo. [Dehmlow and Schell \textit{Chem Ber} 113 1 1980; Perri and Moore \textit{J Am Chem Soc} 112 1897 1990; IR: Cohen and Cohen \textit{J Am Chem Soc} 88 1533 1966.] It can cause severe dermatitis [Foland et al. \textit{J Am Chem Soc} 111 975 1989].

N,N-Diethylacetamide \[685-91-6\] M 157.2, b 86-88°, n 1.474, d 0.994. Dissolved in cyclohexane, shaken with anhydrous BaO and then filtered. The procedure was repeated three times, and the cyclohexane was distd off at 1 atmosphere pressure. The crude amide was also fractionally distd three times from anhydrous BaO.

Diethyl acetamidomalonate \[1068-90-2\] M 217.2, m 96°. Crystd from *benzene/pet ether.

Diethyl acetylenedicarboxylate \[762-21-0\] M 170.2, b 60-62°/0.3 mm, 107-110°/11 mm, 118-120°/20 mm, d\textsubscript{4}² 1.0735, n\textsubscript{D}² 1.4428. Dissolve in \textit{C}_{6}\textit{H}_{6}, wash with NaHCO\textsubscript{3}, H\textsubscript{2}O, dry over Na\textsubscript{2}SO\textsubscript{4}, filter, evaporate and distil in a vacuum [IR: Walton and Hughes \textit{J Am Chem Soc} 79 3985 1957; Truce and Kruse \textit{J Am Chem Soc} 81 5372 1959].

Diethylamine \[109-89-7\] M 73.1, b 55.5°, d 0.707, n 1.38637, pK\textsubscript{15} 11.38. Dried with LiAlH\textsubscript{4} or KOH pellets. Refluxed with, and distd from, BaO or KOH. Converted to the p-toluenesulfonamide and crystd to constant melting point from dry pet ether (b 90-120°), then hydrolysed with HCl, excess NaOH was added, and the amine passed through a tower of activated alumina, redistd and dried with activated alumina before use [Swift \textit{J Am Chem Soc} 64 115 1942]. § A polystyrene diethylaminomethyl supported version is commercially available.

Diethylamine hydrochloride \[660-68-4\] M 109.6, m 223.5°. Crystd from absolute EtOH. Also crystd from dichloroethane/MeOH. Hygroscopic.

trans-4-(Diethylamino)azobenzene \[3588-91-8\] M 320.5, m 171° pK\textsubscript{Est(1)} --5.4, pK\textsubscript{Est(2)}--3.0. Purified by column chromatography [Flamigni and Monti \textit{J Phys Chem} 89 3702 1985].

N,N-Diethylaniline \[91-66-7\] M 149.2, b 216.5°, d 0.938, n 1.5409 pK\textsubscript{2} 6.57. Refluxed for 4h with half its weight of acetic anhydride, then fractionally distd under reduced pressure (b 92°/10 mm).

Diethyl azodicarboxylate (DEAD) \[1972-28-7\] M 174.2, b 104.5°/12 mm, 211-213°/atm, d\textsubscript{4}² 1.110, n\textsubscript{D}² 1.420. Dissolve in toluene, wash with 10% NaHCO\textsubscript{3} till neutral (may require several washes if too much hydrolysis had occurred (check IR for OH bands), then wash with H\textsubscript{2}O (2 x), dry over Na\textsubscript{2}SO\textsubscript{4}, filter, evaporate the toluene and distil through a short Vigreux column. Main portion boils at 107-111°/15 mm [\textit{Org Synth} Coll Vol III 376 1953]. § A polystyrene supported DEAD version is commercially available.

5,5-Diethylbarbituric acid (Barbital) \[57-44-3\] M 184.2, m 188-192°, pK\textsubscript{1} 8.02, pK\textsubscript{2} 12.7. Crystd from water or EtOH. Dried in a vacuum over P\textsubscript{2}O\textsubscript{5}.
Diethyl bromomalonate [685-87-0] M 239.1, b 116-118°/10mm, 122-123°/20mm, d^2_4 1.420, n^2_0 1.4507. Purified by fractional distn in a vacuum. IR: 1800 and 1700-1600. [Abramovitch Can J Chem 37 1146 1959; Bretschneider and Karpitschka Monatsh Chem 84 1091 1953].

Diethyl tert-butylmalonate [759-24-0] M 216.3, b 40-42°/0.03, 102-104°/11mm, 109.5-110.5°/17mm, 205-210°/760mm, d^2_4 0.980, n^2_0 1.425. Dissolve in Et_2O, wash with aqueous NaHCO_3, H_2O, dry (MgSO_4), filter, evaporate and distil residue. Identified by hydrolysis to the acid and determining the neutralisation equiv (theor: 80.0). The acid has m 155-157° efferv [Hauser, Abramovitch and Adams J Am Chem Soc 64 2715 1942; Bush and Beauchamp J Am Chem Soc 75 2949 1953].

N,N'-Diethylcarbanilide (sym-Diethyldiphenylurea) [85-98-3] M 268.4, m 79°. Crystd from EtOH.

Diethyl carbonate [105-58-8] M 118.1, b 126.8°, d 0.975, n^25 1.38287. It was washed (100mL) with an aqueous 10% Na_2CO_3 (20mL) solution, saturated CaCl_2 (20mL), then water (30mL). After drying by standing over solid CaCl_2 for 1h (note that prolonged contact should be avoided because slow combination with CaCl_2 occurs), it should be fractionally distd. Also dried over MgSO_4 and distd.

1,1'-Diethyl-2,2'-cyanine iodide [977-96-8] M 454.4, m 274° (dec). Crystd from EtOH and dried in a vacuum oven at 80° for 4h.


Diethylene glycol [111-46-6] M 106.1, f -10.5°, b 244.3°, d 1.118, n^15 1.4490, n 1.4475. Fractionally distd under reduced pressure (b 133°/14mm), then fractionally crystd by partial freezing.


Diethylene glycol mono-n-butyl ether (butyl carbitol) [112-34-5] M 162.2, b 69-70°/0.3mm, 230.5°/760mm, d 0.967, n 1.4286. Dried with anhydrous K_2CO_3 or CaSO_4, filtered and fractionally distd. Peroxides can be removed by refluxing with stannous chloride or a mixture of FeSO_4 and KHSO_4 (or, less completely, by filtration under slight pressure through a column of activated alumina).

Diethylene glycol monoethyl ether [111-90-0] M 134.2, b 201.9°, d 0.999, n 1.4273, n^25 1.4254. Ethylene glycol can be removed by extracting 250g in 750mL of *benzene with 5mL portions of water, allowing for phase separation, until successive aqueous portions show the same volume increase. Dried, and freed from peroxides, as described for diethylene glycol mono-n-butyl ether.

Diethylene glycol monomethyl ether [111-77-3] M 120.2, b 194°, d 1.010, n 1.423. Purified as for diethylene glycol mono-n-butyl ether.

Diethyl ether (ethyl ether) [60-29-7] M 74.1, b 34.6°/760mm, d 0.714, n\(^{15}\) 1.3555, n\(^{1.3527}\). Usual impurities are water, EtOH, diethyl peroxide (which is explosive when concentrated), and aldehydes. Peroxides [detected by liberation of iodine from weakly acid (HCl) solutions of KI, or by the blue colour in the ether layer when 1mg of Na\(_2\)Cr\(_2\)O\(_7\) and 1 drop of dil H\(_2\)SO\(_4\) in 1mL of water is shaken with 10mL of ether] can be removed in several different ways. The simplest method is to pass dry ether through a column of activated alumina (80g Al\(_2\)O\(_3\)/700mL of ether). More commonly, 1L of ether is shaken repeatedly with 5-10mL of a sol comprising 6.0g of ferrous sulfate and 6mL of conc H\(_2\)SO\(_4\) in 1LmL of water. Aqueous 10% Na\(_2\)S\(_2\)O\(_3\) or stannous chloride can also be used. The ether is then washed with water, dried for 24h with CaCl\(_2\), filtered and dried further by adding sodium wire until it remains bright. The ether is stored in a dark cool place, until distd from sodium before use. Peroxides can also be removed by wetting the ether with a little water, then adding excess LiAlH\(_4\) or CaH\(_2\) and leaving to stand for several hours. This also dried the ether. Werner [Analyst 58 335 1933] removed peroxides and aldehydes by adding 8g AgNO\(_3\) in 60mL of water to 1L of ether, then 100mL of 4% NaOH and shaking for 6min. Fierz-David [Chimia 1 246 1947] shook 1L of ether with a couple. This reagent was prepared by suspending zinc dust in 50mL of hot water, adding 5mL of 2M HCl and decanting after 20sec, washing twice with water, covering with 50mL of water and 5mL of 5% cuprous sulfate with swirling. The liquid was decanted and discarded, and the residue was washed three times with 20mL of ethanol and twice with 20mL of diethyl ether). Aldehydes can be removed from diethyl ether by distn from hydrazine hydrogen sulfate, phenyl hydrazine or thiosemicarbazide. Peroxides and oxidisable impurities have also been removed by shaking with strongly alkaline satd KMnO\(_4\) (with which the ether was left to stand in contact for 24h), followed by washing with water, conc H\(_2\)SO\(_4\), water again, then drying (CaCl\(_2\)) and distn from sodium, or sodium containing benzophenone to form the ketyl. Other purification procedures include distn from sodium triphenylmethyl or butyl magnesium bromide, and drying with solid NaOH or P\(_2\)O\(_5\).

Rapid purification: Same as for 1,4-dioxane.

Diethyl ethoxymethylene malonate [87-13-8] M 216.2, b 014°/0.2mm, 109°/0.5mm, 279-283°/atm, d\(_4\) 1.079, n\(_{D}^{20}\) 1.4623. Likely impurity is diethyl diethoxymethylene malonate which is difficult to separate from diethyl ethoxymethylene malonate by distn and it is necessary to follow the course of the distn by the change in refractive index instead of boiling point. After a low boiling fraction is collected, there is obtained an intermediate fraction (n\(_{D}^{20}\) 1.414-1.458) the size of which depends on the amount of diethoxymethylene compound. This fraction is fractionated through a 5-inch Vigreux column at low pressure avoiding interruption in heating. Fraction b 108-110°/0.25mm was ca 10\(^{\circ}\) lower than the submitters' (b 97.2°/0.25mm (n\(_{D}^{20}\) 1.4612-1.4623) [Org Synth Coll Vol III 395 1955; Fuson et al. J Org Chem 11 197 1946; Duff and Kendall J Chem Soc 893 1948].

N,N'-Diethylformamide [617-84-5] M 101.2, b 29°/0.5mm, 61-63°/10mm, 178.3-178.5°/760mm, d\(_4\) 0.906, n\(_{D}^{20}\) 1.4313. Distd under reduced pressure then at atmospheric pressure [Wintcler et al. Helv Chim Acta 37 2370 1954; NMR: Hoffmann Z Anal Chem 170 177 1959].

Diethyl fumarate [623-91-6] M 172.2, b 218°, d 1.052, n 1.441. Washed with aqueous 5% Na\(_2\)CO\(_3\), then with saturated CaCl\(_2\) soln, dried with CaCl\(_2\) and distd.

Di-(2-ethylhexyl)phthalate (di-iso-octyl phthalate) [117-81-7] M 390.6, b 38°, 256-257°/1mm, d 0.9803, n 1.4863. Washed with Na\(_2\)CO\(_3\) soln, then shaken with water. After the resulting emulsion had been broken, the ethereal soln was washed twice with water, dried (CaCl\(_2\)), and evaporated. The residual liquid was distd several times under reduced pressure, then stored in a vacuum desiccator over P\(_2\)O\(_5\) [French and Singer J Chem Soc 1424 1956].

Diethyl ketone (3-pentanone) [96-22-0] M 86.1, b 102.1°, d 0.8099, n 1.392. Dried with anhydrous CaSO\(_4\) or CuSO\(_4\), and distd from P\(_2\)O\(_5\) under N\(_2\) or under reduced pressure. Further purification by conversion to the semicarbazone (recrystd to constant m 139°, from EtOH) which, after drying under vacuum over CaCl\(_2\) and paraffin wax, was refluxed for 30min with excess oxalic acid, then steam distd and salted out with K\(_2\)CO\(_3\). Dried with Na\(_2\)SO\(_4\) and distd [Cowan, Jeffrey and Vogel J Chem Soc 171 1940].
Diethyl malonate \([105-53-3]\) M 160.2, b 92°/22mm, 198-199°/760mm, d 1.056, d\text{25} 1.0507, n 1.413. If too impure (IR, NMR) the ester (250g) has been heated on a steam bath for 36h with absolute EtOH (125mL) and conc H\text{2SO4} (75mL), then fractionally distd under reduced pressure. Otherwise fractionally distil under reduced pressure and collect the steady boiling middle fraction.

Diethyl phenyl orthoformate (diethoxy phenoxy ethane) \([14444-77-0]\) M 196.3, b 111°/11mm, 122°/13mm, \(d_2^0\) 1.0099, \(n_D\) 1.4799. Fractionated through an efficient column under vacuum [Smith Acta Chem Scand 10 1006 1956].

Diethyl phthalate \([84-66-2]\) M 222.2, b 172°/12mm, b 295°/760mm, \(d_2^5\) 1.1160, n 1.5022. Washed with aqueous Na\text{2CO3}, then distilled water, dried (CaCl\text{2}), and distd under reduced pressure. Stored in a vacuum desiccator over P\text{2O5}.

Diethyl phthalimidomalonate \([56680-61-5]\) M 305.3, m 72-74°, b 73-74°, P\text{K} 9.17. Dissolve in xylene and when the temperature is 30° add pet ether (b 40-60°) and cool to 20° whereby the malonate separates as a pale brown powder [Booth et al. J Chem Soc 666 1944]. Alternatively, dissolve in \(\text{C}6\text{H}6\), dry over CaCl\text{2}, filter, evaporate and the residual oil solidifies. This is ground with Et\text{2}0, filter and wash with Et\text{2}0 until white in colour, and dry in a vacuum. The anion has \(\lambda_{\text{max}} 254\text{nm}\) (\(E 18.5\text{K}\)) [Clark and Murray Org Synth Coll Vol I 271 1941; UV of Na salt: Nnadi and Wang J Am Chem Soc 92 4421 1970].

2,2-Diethyl-1,3-propanediol \([115-76-4]\) M 132.2, m 61.4-61.8°. Crystd from pet ether (b 65-70°).

Diethyl pyrocarbonate (DEP) \([1609-47-8]\) M 162.1, b 38-40°/12mm, 160-163°/atm, \(d_4^0\) 1.119, \(n_D\) 1.398. Dissolve in Et\text{2}O, wash with dilute HCl, H\text{2}O, dry over Na\text{2SO4}, filter, evaporate and distil the residue first \(\text{in vacuo}\) then at atmospheric pressure. It is soluble in alcohols, esters, ketones and hydrocarbon solvents. A 50% w/w soln is usually prepared for general use. Treat with great CAUTION as DEP irritates the eyes, mucous membranes and skin. [Boehm and Mehta Chem Ber 71 1797 1938; Thoma and Rinke Justus Liebigs Ann Chem 624 30 1959.]

Diethylstilboesterol \([56-23-1]\) M 268.4, m 169-172°. Crystd from \(\text{benzene}\).

Diethyl succinate \([123-25-1]\) M 174.2, b 105°/15mm, d 1.047, n 1.4199. Dried with MgSO\text{4}, and distd at 15mm pressure.

Diethyl sulfate \([64-67-5]\) M 154.2, b 96°/15mm, 118°/40mm, d 1.177, n 1.399. Washed with aqueous 3% Na\text{2CO3} (to remove acidic material), then distilled water, dried (CaCl\text{2}), filtered and distd. Causes blisters to the skin.

Diethyl disulfide \([352-93-2]\) M 90.2, m 0°/15mm, 90.1°/760mm, d 0.837, n 1.443. Washed with aq 5% NaOH, then water, dried with CaCl\text{2} and distd from sodium. Can also be dried with MgSO\text{4} or silica gel. Alternative purification is via the Hg(II) chloride complex \([\text{Et}2\text{S.2HgCl2}]\) (see dimethyl sulfide).

Diethyl (-)-D- (from the non-natural) \([13811-71-7]\) and (+)-L- (from the natural acid) \([89-91-2]\) tartrate M 206.2, m 17°, b 80°/0.5mm, 162°/19mm, 278-282°/atm, \(d_4^0\) 1.204, \(n_D\) 1.4476, \([\alpha]_D\) 8.5° (c 1, H\text{2}O) and (-) and (+) 8.5° (neat), \([\alpha]_2^0\) (-) and (+) 30° (c 1, H\text{2}O). Distd under high vacuum and stored under vacuum or in an inert atm in a desiccator in round bottomed flasks equipped with a vac stopcock. Have also been dist by Kügelrohr distn and/or by 'wiped-film' molecular distn. Slightly sol in H\text{2}O but miscible in EtOH and Et\text{2}O. [Gao et al. J Am Chem Soc 109 5770 (1987); IR: Pristera Anal Chem 25 844 1953.]

Diethyl terephthalate \([636-09-0]\) M 222.2, m 44°, 142°/2mm, 302°/760mm. Crystd from toluene and distd under reduced pressure.

Difluoroacetic acid [381-73-7] M 96.0, m -0.35°, b 67-70°/20mm, 134°/760mm, d\textsubscript{2}^{0} 1.530, n\textsubscript{D}^{0} 1.3428, pK\textsubscript{2}^{5} 1.28. Purified by distilling over P\textsubscript{2}O\textsubscript{5}. The acid chloride is a fuming liquid b 25°/atm, and the amide has b 108.6°/atm, m 52° (from *C\textsubscript{6}H\textsubscript{6}), and the anilide has b 90°/1mm, 114°/5mm, m 58° [Henne and Pelley J Am Chem Soc 74 1426 1952; Coffman et al. J Org Chem 14 749 1949; NMR: Meyer et al. J Am Chem Soc 75 4567 1953; pK, Wegscheider Z Phys Chem 69 614 1909].

Diglycolic acid (2-oxapentane-1,5-dioic acid) [10-99-6] M 134.1, m 148° (monohydrate), pK\textsubscript{5} 2.97, pK\textsubscript{11} 4.37. Crystd from water.

Diglycyl glycine or H\textsubscript{2}O/EtOH and dried at 100°. [556-33-2] M 189.2, m 246° (dec), pK\textsubscript{5} 3.30, pK\textsubscript{11} 7.96. Crystd from H\textsubscript{2}O.

Diglyme [bis-(2-methoxyethyl) ether, diethylene glycol dimethyl ether] [I1-96-6] M 134.2, b 62°/17mm, 75°/35mm, 160°/760mm, d 0.917, n 1.4087. Dried with NaOH pellets or CaH\textsubscript{2}, then refluxed with, and distd (under reduced pressure) from Na, CaH\textsubscript{2}, LiAlH\textsubscript{4}, NaBH\textsubscript{4} or NaH. These operations were carried out under N\textsubscript{2}. The amine-like odour of diglyme has been removed by shaking with a weakly acidic ion-exchange resin (Amberlite IR-120) before drying and distillation. Addtn of 0.01% NaBH\textsubscript{4} to the distillate inhibits peroxidation. Purification as for dioxane. Also passed through a 12-in column of molecular sieves to remove water and peroxides.

Digoxin [20830-75-5] M 781.0, m 265° (dec), [α]\textsubscript{546} +14.0° (c 10, pyridine). Crystd from aqueous EtOH or aqueous pyridine.

4,4'-Di-n-heptyloxyazoxybenzene [2635-26-9] M 426.6, m 75°, 95° (smectic → nematic) and 127° (nematic → liquid), pK\textsubscript{Et} ~ 5. Purified by chromatography on AI\textsubscript{2}O\textsubscript{3} (*benzene), recrystd from hexane or 95% EtOH and dried by heating under vacuum. The liquid crystals can be sublimed in vacuo. [Mellifiori et al. Spectrochim Acta Part A 37(A) 605 1981; Dewar and Schroeder J Am Chem Soc 86 5235 1964; Weygand and Glaber J Prakt Chem 155 332 1940].


2,3-Dihydrobenzofuran (coumaran) [496-16-2] M 120.2, m -21.5°, 72-73°/12mm, 84°/17mm, 188°/atm, d\textsubscript{2}^{0} 1.065, n\textsubscript{D}^{0} 1.5524. Suspend in aqueous NaOH and steam distil. Saturate the distillate with NaCl and extract with Et\textsubscript{2}O, dry extract (MgSO\textsubscript{4}), filter, evaporate and dry the residue. It gives a strong violet colour with FeCl\textsubscript{3} + H\textsubscript{2}SO\textsubscript{4} and forms a yellow picrate, m 76°, from EtOH or *C\textsubscript{6}H\textsubscript{6} which loses coumaran in a desiccator [Bennett and Hafez J Chem Soc 287 1941; Baddeley et al. J Chem Soc 2455 1956].

Dihydrochloranil (tetrachloro-1,4-hydroquinone) [87-87-6] M 247.9, m 240.5°. Crystd from EtOH or AcOH+EtOH. Sublimes at 77°/0.6x 10\textsuperscript{-3}mm. The dibenzoyl derivative has m 233°. [Conant and Fieser J Am Chem Soc 45 2207 1923; Rabideau et al. J Am Chem Soc 108 8130 1986.]

Dihydrocodeine [125-28-0] M 301.4, m 112-113°, b 248/14mm\textsuperscript{0}. Crystd from aqueous methanol.

1,4-Dihydro-1,4-epoxyphthalalene [573-57-9] M 144.2, m 53-54°, 53-56°, 55-56°. Dissolve in Et\textsubscript{2}O, wash with H\textsubscript{2}O, dry over K\textsubscript{2}CO\textsubscript{3}, filter, evaporate and dry the residue at 15mm, then recrystallise from pet ether (b 40-60°), dry at 25°/0.005mm and sublime (sublimes slowly at room temp)[Wittig and Pohmer Chem Ber 89 1334 1956; Gilman and Gorsich J Am Chem Soc 79 2625 1957].

Dihydropyran (3,4-dihydro-2H-pyran) [110-87-2] M 84.1, b 84.4°/742mm, 85.4-85.6°/760mm, d\textsubscript{2}^{0} 0.9261, n\textsubscript{D}^{0} 1.4423, pK\textsubscript{Et} ~ 4.2. Partially dried with Na\textsubscript{2}CO\textsubscript{3}, then fractionally distl. The fraction b 84-85°, was refluxed with Na until hydrogen was no longer evolved when fresh Na was
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3,4-Dihydro-2H-pyrido[1,2a]-pyrimidin-2-one [5439-14-5] M 148.2, m 185-187°, 187-188°, 191-191.5°. Dissolve in CHCl3, filter, evaporate then recrystallise the residue from EtOH-Me2CO (needles) which can be washed with Et2O and dried. It can also be recrystd from CHCl3-pet ether or CHCl3-hexane. The hydrochloride has m 295-295° (dec, from EtOH or MeOH-Et2O), the hydrobromide has m 299-300°(dec, from MeOH-Et2O) and the picrate has m 224-226°(corr), m 219-220° from EtOH. [Adams and Pachter J Am Chem Soc 74 4906 1952; Lappin J Org Chem 23 1358 1958; Hurd and Hayao J Am Chem Soc 77 115 1955.]


2,4-Dihydroxyazobenzene (Sudan orange G) [2051-85-6] M 214.2, m 228°, pK\S(1)<0, pK\S(2) -7.3. Crystd from hot EtOH (charcoal).


2,5-Dihydroxybenzoic acid [490-79-9] M 154.1, m 204.5-205°, pK1 2.95. Crystd from hot water or benzene/acetone. Dried in a vacuum desiccator over silica gel.

2,6-Dihydroxybenzoic acid [303-07-1] M 154.1, m 167°(dec), pK1 1.05. Dissolved in aqueous NaHC03 and the soln was washed with ether to remove non-acidic material. The acid was ptted by adding H2SO4, and recrystd from water. Dried under vacuum and stored in the dark [Lowe and Smith J Chem Soc, Faraday Trans I 69 1934 1973].

2,4-Dihydroxybenzenophenone [131-56-6] M 214.2, m 145.5-147° pK\S(1) -7.0, pK\S(2) -12.0. Recrystd from MeOH.

2,5-Dihydroxybenzyl alcohol (Gentisyl alcohol) [495-08-9] M 140.1, m 100° pK\S(1) -9.3, pK\S(2) -11.3. Crystd from CHCl3. Sublimes at ~70° under high vacuum.

2,2'-Dihydroxybiphenyl [1806-29-7] M 186.2, m 108.5-109.5°, pK1 7.56, pK2 11.80. Repeatedly crystd from toluene, then sublimed at 60°/10-4mm.

3α,7α-Dihydroxycholanic acid (Chenodeoxycholic acid) [474-25-9] M 239.6, m 143°, [α]20 +14° (c 2, EtOH), pK\S -4.9. Crystd from ethyl acetate.

7,8-Dihydroxycoumarin (Daphnetin) [486-35-1] M 178.2, m 256°(dec), pK\S(1) -8.5, pK\S(2) -12.3. Crystd from aqueous EtOH. Sublimed.

trans-2,3-Dihydroxy-1,4-dioxane \([4845-50-5]\) M 120.1, m 91-95°, 100°. Recryst from Me₂CO. With phenylhydrazine it gives glyoxal phenylhydrazone m 175° (from Me₂CO-pet ether). The diacetyl derivative has m 105-106° [Head J Chem Soc 1036 1955, Rauñitz Chem Ind (London) 166 1956].

2,5-Dihydroxy-1,4-dithiane \([40018-26-6]\) M 152.2, m (142-147° ?) 150-152°, looO. Recryst from Me₂CO. The 2,5-diethoxy-dithiane has m 91O (92-93O) crystallises from pet ether and can be sublimed at 60°/0.001mm [Hormatka and Haber Monatsh Chem 85 1088 1954; Thiel et al. Justus Liebigs Ann Chem 611 121 1958; Hesse and Jöeder Chem Ber 85 924 1952].

\((N,N\text{-Dihydroxyethy}l)\text{glycine (BICINE)} \([150-25-4]\) M 163.2, m 193O(dec), pK1' 1.81, pK2' 8.27. Dissolved in a small volume of hot water and ppted with EtOH, twice. Repeated once more but with charcoal treatment of the aqueous soln, and filtered before addition of EtOH.

Dihydroxyfumaric (1,2-dihydroxybut-1-ene-1,2-dioic) acid dihydrate \([133-38-0]\) M 184.1, m 155°(dec), pK1' 1.57, pK2' 3.36. Crystd from water.

3,4'-Dihydroxyisoflavone \([578-86-9]\) M 256.3, m 234-236O. Crystd from aqueous 50% EtOH.

5,7-Dihydroxy-4'-methoxyisoflavone \([133-38-0]\) M 184.1, m 261O, pK1' 4.14 (COOH). Crystd from EtOH or \(\text{CHCl}_3\) or \(\text{H}_2\text{O}\) (sol 85% at 25°).

1,8-Dihydroxy-3-methylanthraquinone (chrysophanic acid) \([481-74-3]\) M 245.3, m 196°, pKEst(l) -8.2, pKEst(2) -12.4. Crystd from EtOH or \(*\text{benzene}\) and sublimed in a vacuum.

1,5-Dihydroxynaphthalene \([83-56-7]\) M 160.2, m 260°, 250-261°, pKEst -9.6. Crystd from \(*\text{benzene}\) or \(*\text{benzene/MeOH}\) after treatment with charcoal.

1,6-Dihydroxynaphthalene \([575-44-0]\) M 160.2, m 138-139° (with previous softening), pKEst -9.4. Crystd from *benzene or *benzene/MeOH after treatment with charcoal.

2,5-Dihydroxyphenylacetic acid (homogentisic acid) \([451-13-8]\) M 168.2, m 152°, 154-152°, pK1' 4.14 (COOH). Crystd from EtOH/\(\text{CHCl}_3\) or \(\text{H}_2\text{O}\) (sol 85% at 25°).

3,4-Dihydroxytoluene \([452-86-8]\) M 124.1, m 65-66°, 68° b 112°/3mm, 241°/760mm, pK1' 9.44 (9.7), pK2' 10.90 (11.9). Crystd from *\(\text{C}_6\text{H}_6\). Purity checked by TLC. Crystd from high-boiling pet ether and distd in a vacuum.

1,3-Diminoisoindoline \([3468-11-9]\) M 145.2, m 193-194° (dec), 196° (dec), pK 8.27. It crystallises from \(\text{H}_2\text{O}, \text{MeOH}\) or \(\text{MeOH}-\text{Et}_2\text{O}\) (charcoal) in colourless prisms that become green on heating. [Elvidge and Linstead J Chem Soc 5000 1952]. IR (nujol): 3150 and 690 cm⁻¹, and UV: \(\lambda_{max}\) 251nm (ε 12.5K), 256nm (ε 12.5K) and 303nm (ε 4.6K) [Elvidge and Golden J Chem Soc 700 1957; Clark et al. J Chem Soc 3593 1953]. The thiocyanate has m 250-255° (dec), the monohydrochloride has m 300-301° (turns green) and the dihydrochloride has m 326-328° (turns green) and the picrate cryst from EtOH has m 299° (dec).

1,4-Diiodobenzene \([624-38-4]\) M 329.9, m 132-133°. Crystd from EtOH or boiling MeOH, then air dried.

1,2-Diiodoethane \([624-73-7]\) M 281.9, m 81-84°, d 2.134. Dissolved in ether, washed with satd aq \(\text{Na}_2\text{S}_2\text{O}_3\) drying it over MgSO₄ and evap the ether in vacuo [Molander et al. J Am Chem Soc 109 453 1987].

5,7-Diiodo-8-hydroxyquinoline \([83-73-8]\) M 397.0, m 214-215°(dec) pK1' 3.2, pK2' 8.2. Crystd from xylene and dried at 70° in a vacuum.

Diiodomethane (methylenediiodide) \([75-11-6]\) M 267.8, m 61°, b 66-70°/11-12mm, d 3.325. Fractionally distd under reduced pressure, then fractionally cryst by partial freezing, and stabilized
with silver wool if necessary. It has also been purified by drying over CaCl₂ and fractionally distd from Cu powder.

**S-3,5-Diiodotyrosine (iodogorgic acid)** [300-39-0] M 469.0, m 204°(dec), [α]D +1.5° (in 1M HCl) pK₁ 2.12, pK₂ 6.48, pK₃ 7.82. See 3,5-diido-L-tyrosine dihydrate on p. 530 in Chapter 6.


Diisopropylamine [108-18-9] M 101.2, b 83.5°/760mm, n 1.39236, d 0.720, pK₂ 11.20. Distd from NaOH, or refluxed over Na wire or NaH for three minutes and distd into a dry receiver under N₂. § A polystyrene supported version of diisopropylamine is commercially available.


(-)-2,3:4,6-Di-O-isopropylidene-2-keto-L-gulonic acid monohydrate (- DAG) [18467-77-1] M 292.3, m 100-101°, 103°, [α]D²⁵ -21.6° (c 2.3, MeOH). Dissolve in Et₂O, filter, dry (MgSO₄), filter, evaporate to give a yellow oil. Addition of one drop of H₂O induces crystn to the monohydrate, which also forms rhombic crystals by recrystn from 95% EtOH-H₂O at room temperature. [Flatt et al. *Synthesis* 1979; Reichstein and Grussner *Helv Chim Acta* 17 311 1934; Takagi and Jeffrey *Acta Crystallogr Sect B* 34 2932 1978; cf *Org Synth 55* 80 1976.]


Diisopropyl ketone (2,4-dimethyl-3-pentanone) [565-80-0] M 114.2, b 124°, d 0.801, n 1.400. Dried with CaSO₄, shaken with chromatographic alumina and fractionally distd from P₂O₅ under N₂.

Diketene [674-82-8] M 84.1, m -7°, b 66-68°/90mm, d 1.440, n 1.4376, n²⁵ 1.4348. Diketene polymerizes violently in the presence of alkali. Distd at reduced pressure, then fractionally crystd by partial freezing (using as a cooling bath a 1:1 soh of Na₂S₂O₃ in water, cooled with Dry-ice until slushy, and stored in a Dewar flask). Freezing proceeds slowly, and takes about a day for half completion. The crystals are separated and stored in a refrigerator under N₂. See ketene on p. 276.

Dilauroyl peroxide [105-74-8] M 398.6, m 53-54°. See lauryl peroxide (dodecyl peroxide) on p. 278.

Dimedone (5,5-dimethylcyclohexane-1,3-dione) [126-81-8] M 140.2, m 148-149°, pK₂ 5.27. Crystd from acetone (ca 8mL/g), water or aqueous EtOH. Dried in air.

2,3-Dimercapto-1-propanol (BAL, British Anti-Lewisite) [59-52-9] M 124.2, b 82-84°/0.8mm, d 1.239, n 1.5732, pK₁ 8.62, pK₂ 10.75. Pptd as the Hg mercaptide [see Bjöberg *Chem Ber* 75 13 1942], regenerated with H₂S, and distd at 2.7mm [Rosenblatt and Jean *Anal Chem* 951 1955].

1,3-Dimercapto-2-propanol [584-04-3] M 124.2, b 82°/1.5mm. Purified as for 2,3-dimercapto-1-propanol above.
meso-2,3-Dimercaptosuccinic acid [304-55-2]  M 182.2, m 191-192\(^\circ\) (dec), 210\(^\circ\) (dec), 210-211\(^\circ\) (dec), pK\(_1\)\(^2\) 2.71, pK\(_2\)\(^3\) 3.48, pK\(_3\)\(^3\) 8.89, pK\(_4\)\(^3\) 10.75. Purified by dissolving in NaOH and precipitating with dilute HCl, dry and recrystallise from MeOH. IR has v at 2544 (SH) and 1689 (C=O) cm\(^{-1}\). The bis-S-acetyl deriv has m 183-185\(^\circ\) (from EtOAc or Me\(_2\)CO) and its Me ester has m 119-120\(^\circ\) (from pet ether) [Gerecke et al. *Helv Chim Acta* 44 957 1961; Owen and Sultanbawa *J Chem Soc* 3112 1949].

4,4'-Dimethoxyazobenzene [501-58-6]  M 242.3, m 162.7-164.7\(^\circ\), pK\(_{\text{Ht}}\) -0. Chromatographed on basic alumina, eluted with *benzene. Crystd from 2:2:1 (v/v) methanol/ethanol/*benzene.

4,4'-Dimethoxyazoxybenzene [1562-94-3]  M 258.3, transition temp 118-121\(^\circ\). See p,p'-azoxyanisole on p. 118.

1,2-Dimethoxybenzene (veratrole) [91-16-7]  M 137.2, m 23\(^\circ\), b 208.5-208.7\(^\circ\), d 1.085, n\(^2\)\(^5\) 1.5323. Steam distd. Fractionally distd from BaO, CaH\(_2\) or Na. Crystd from *benzene or low-boiling pet ether at 0\(^\circ\). Fractionally crystd from its melt. Stored over anhydrous Na\(_2\)SO\(_4\).

1,3-Dimethoxybenzene [151-10-0]  M 137.2, b 212-213\(^\circ\), d 1.056, n 1.5215. Extracted with aqueous NaOH, and water, then dried. Fractionally distd from BaO or Na.

1,4-Dimethoxybenzene [150-78-7]  M 137.2, m 57.2-57.8\(^\circ\). Steam distd. Crystd from hexane or *benzene, and from MeOH or EtOH but these are wasteful due to high solubilities. Dried under vacuum. Also sublimes under vacuum.

2,4-Dimethoxybenzoic acid [91-52-1]  M 182.2, m 109\(^\circ\), pK\(_2\)\(^5\) 4.36. Crystd from water and dried in a vacuum desiccator over H\(_2\)SO\(_4\).

2,6-Dimethoxybenzoic acid [1466-76-8]  M 182.2, m 186-187\(^\circ\), pK\(_2\)\(^5\) 3.44. Crystd from water.

3,4-Dimethoxybenzoic acid (veratric acid) [93-07-2]  M 182.2, m 181-182\(^\circ\), pK\(_2\)\(^5\) 4.43. Crystd from water or aq acetic acid.

3,5-Dimethoxybenzoic acid [1132-21-4]  M 182.2, m 185-186\(^\circ\), pK\(_2\)\(^5\) 3.97. Crystd from water, EtOH or aq acetic acid.

p,p'-Dimethoxybenzophenone [90-96-0]  M 242.3, m 144.5\(^\circ\). Crystd from absolute EtOH.

2,6-Dimethoxy-1,4-benzoquinone [530-55-2]  M 168.1, m 256\(^\circ\). Crystd from acetic acid. Sublimes in a vacuum.

1,1-Dimethoxyethane (acetaldehyde dimethyl acetal) [534-15-6]  M 90.1, b 212\(^\circ\)/760mm, d 0.828, n 1.4140. Purification as for acetal on p. 81. Also purified by GLC.

1,2-Dimethoxyethane (glycol dimethyl ether, glyme) [110-71-4]  M 90.1, b 84\(^\circ\), d 0.867, n 1.380. Traces of water and acidic materials have been removed by refluxing with Na, K or CaH\(_2\), decanting and distilling from Na, K, CaH\(_2\) or LiAlH\(_4\). Reaction has been speeded up by using vigorous high-speed stirring and molten potassium. For virtually complete elimination of water, 1,2-dimethoxyethane has been dried with Na-K alloy until a characteristic blue colour was formed in the solvent at Dry-ice/cellosolve temperatures: the solvent was kept with the alloy until distd for use [Ward *J Am Chem Soc* 83 1296 1961]. Alternatively, glyme, refluxed with benzophenone and Na-K, was dry enough if, on distn, it gave a blue colour of the ketyl immediately on addition to benzophenone and sodium [Ayscough and Wilson *J Chem Soc* 5412 1963]. Also purified by distn under N\(_2\) from sodium benzophenone ketyl (see above).

5,6-Dimethoxy-1-indanone [2107-69-9]  M 192.2, m 118-120\(^\circ\). Crystd from MeOH, then sublimed in a vacuum.
Dimethoxymethane (methylal) \([109-87-5]\) M 76.1, \(b\) 42-46°/atm, \(d^2_4\) 0.8608, \(n^2_0\) 1.35335. See formaldehyde dimethyl acetal on p. 245.

1,4-Dimethoxynaphthalene \([10075-62-4]\) M 188.2, \(m\) 87-88°. Crystd from EtOH.

1,5-Dimethoxynaphthalene \([10075-63-5]\) M 188.2, \(m\) 183-184°. Crystd from EtOH.

2,6-Dimethoxyphenol \([91-10-1]\) M 154.2, \(m\) 54-56°, \(pK_{\text{est}}\) ~9.6. Purified by zone melting or sublimation in a vacuum.

3,5-Dimethoxyphenol (phloroglucinol dimethylether) \([500-99-2]\) M 154.2, \(m\) 42-43°, \(b\) 115°/0.04mm, \(pK_{25}\) 9.35. Purified by distn followed by sublimation in a vacuum.

3,4-Dimethoxyphenylacetic acid (homoveratric acid) \([93-40-3]\) M 196.2, \(m\) 97-99°, \(pK_{25}\) 4.33. Crystd from water or benzene/ligroin.


4,4'-Dimethoxythiobenzophenone \([958-80-5]\) M 258.3, \(m\) 120°. Recrystd from a mixture of cyclohexane/dichloromethane (4:1).


4,4'-Dimethoxytrityl chloride (DMT) \([40615-36-9]\) M 338.8, \(m\) 114°. Crysts from cyclohexane-acetyl chloride as the hydrochloride and dry over KOH pellets in a desiccator. When dissolved in \(^{\infty}\)C\(_6\)H\(_6\) and air is blown through, HCl is removed. It crystallises from Et\(_2\)O. [Justus Liebigs Ann Chem 370 142 1909; Chem Ber 36 2774 1903; Smith et al. J Am Chem Soc 84 430 1962; Smith et al. J Am Chem Soc 85 3821 1963.] If it had hydrolysed considerably (see OH in IR) then repeat the crystallisation from cyclohexane-acetyl chloride — excess of AcCl is removed in vac over KOH.

N,N-Dimethylacetamide \([127-19-5]\) M 87.1, \(b\) 58.0-58.5°/11.4mm, \(d\) 0.940, \(n\) 1.437. Shaken with BaO for several days, refluxed with BaO for 1h, then fractionally distd under reduced pressure, and stored over molecular sieves.

\(\beta,\beta\)-Dimethylacrylic acid (senecioic acid) \([541-47-9]\) M 100.1, \(m\) 68°, \(pK_{25}\) -5.4 (aq H\(_2\)SO\(_4\)). Crystd from hot water or pet ether (b 60-80°).

Dimethyl adipate \([627-93-0]\) M 174.2, \(m\) 9-11°, \(b\) 109°/10mm, 121-123°/20mm, 235°/760mm, \(d^2_4\) 1.0642, \(n^2_0\) 1.4292. Dissolve in Et\(_2\)O, wash with NaHCO\(_3\), H\(_2\)O, dry over MgSO\(_4\), filter, evaporate and distil several times until the IR and NMR are consistent with the structure [Lorette and Brown J Org Chem 24 261 1959; Hoffmann and Weiss J Am Chem Soc 79 4759 1957].

Dimethyl adipimidate dihydrochloride \([14620-72-5]\) M 245.1, \(m\) 218-220°, 222-224°. If the salt smells of HCl then wash with MeOH and dry Et\(_2\)O (1:3) under N\(_2\) until the HCl is completely removed. Recryst from MeOH-Et\(_2\)O (it is very important that the solvents are super dry) [Hartman and Wold Biochemistry 6 2439 1967; McElvain and Shroeder J Am Chem Soc 71 40 1949].

Dimethylamine \([124-40-3]\) M 45.1, \(f\) -92.2°, \(b\) 0°/563mm, 6.9°/760mm, \(pK_{25}\) 10.73. Dried by passage through a KOH-filled tower, or by standing with sodium pellets at 0° during 18h. § A dimethylaminomethyl polystyrene supported version is commercially available.
Dimethylamine hydrochloride \([506-59-2]\) M 81.6, \(m\) 171\(^\circ\). Crystd from hot \(\text{CHCl}_3\) or abs \(\text{EtOH}\). Also recrystd from \(\text{MeOH}\)/ether soln. Dried in a vacuum desiccator over \(\text{H}_2\text{SO}_4\), then \(\text{P}_2\text{O}_5\). 

\[4-N,N'\text{-Dimethylaminoazo-benzene-4'-isothiocyanate}\] \(\{\text{DABITC, } 4-[(\text{4-isocyanatophenyl})\text{-azo}]\text{-N,N'\text{-dimethylaniline}}\}\) \([7612-98-8]\) M 282.4, \(m\) 170-171\(^\circ\), \(pK_{\text{et}}\) ~2.5. Crystd by dissolving 1g in 150mL of boiling \(\text{Me}_2\text{CO}\), filtering hot and allowing to cool at -20\(^\circ\) overnight collecting the solid and drying in vac. Solns in pyridine should be used immediately otherwise it dec. Moisture sensitive. [Chang Methods Enzymol 91 79, 455 1983.]

\(4\text{-N,N'\text{-Dimethylaminoazo-benzene} (Methyl Yellow)}\) \([60-11-7]\) M 225.3, \(m\) 118-119\(^\circ\)\(\text{(dec)}\), \(pK_1\) -5.34 (aq \(\text{H}_2\text{SO}_4\)), \(\approx pK_2\) -2.96.

Crystd from acetic acid or isooctane, or from 95\% \(\text{EtOH}\) by adding hot water and cooling. Dried over KOH under vacuum at 50\%. CARCINOGEN.

\(p\text{-Dimethylaminobenzaldehyde (Ehrlich's Reagent)}\) \([100-10-7]\) M 149.2, \(m\) 74-75\(^\circ\), \(pK_{\text{et}}\) ~2.6. Crystd from water, hexane, or from \(\text{EtOH}\) (2mL/g), after charcoal treatment, by adding excess of water. Also dissolved in aqueous acetic acid, filtered, and ppted with ammonia. Finally recrystd from \(\text{EtOH}\).

\(p\text{-Dimethylaminobenzoic acid}\) \([619-84-1]\) M 165.2, \(m\) 242.5-243.5\(^\circ\)\(\text{(dec)}\), \(pK_1\) 2.51, \(pK_2\) 6.03.

Crystd from \(\text{EtOH}/\text{water}\).

\(p\text{-Dimethylaminobenzophenone}\) \([530-44-9]\) M 225.3, \(m\) 92-93\(^\circ\), \(pK_{\text{et}}\) ~2.7. Crystd from \(\text{EtOH}\).

\(N,N\text{-Dimethylamino-p-chlorobenzene (p-chloro-N,N\text{-dimethylaniline)}\} \([698-69-1]\) M 155.6, \(m\) 32-33.5\(^\circ\), 35.5\(^\circ\), \(b\) 231\(^\circ\)/atm. Purified by vacuum sublimation [Guarr et al. J Am Chem Soc 107 5104 1985]. The picrate has \(m\) 126-128\(^\circ\) (from \(\text{methanol}\)).

\(2\text{S,3R-(+)-4-Dimethylamino-1,2-diphenyl-3-methyl-2-butanol}\) \([38345-66-3]\) M 283.4, \(m\) 55-57\(^\circ\), \([\alpha]_{546}^D\) +9.3\(^\circ\) (c 9.6, \(\text{EtOH}\)), \([\alpha]_	ext{p}^D\) +7.7\(^\circ\) (c 9.6, \(\text{EtOH}\)), \(pK_{\text{et}}\) ~10.0. Purification of the hydrochloride by dissolving 1.5g in 13.5 mL of 5N \(\text{HCl}\) heating to boiling and evaporate in a vacuum. Recrystn of the hydrochloride three times from \(\text{MeOH-EtOAc}\) gives \(m\) 189-190\(^\circ\), \([\alpha]_D\) -33.7\(^\circ\) (c 1, \(\text{H}_2\text{O}\)) \(\{\text{enantiomer has } +34.2\(^\circ\}\). The hydrochloride in the minimum volume of water is basified with aqueous 5N \(\text{NaOH}\) and extracted with \(\text{Et}_2\text{O}\). The extract is dried (\(\text{K}_2\text{CO}_3\)) and evap leaving a residue which is stored in a desiccator over solid \(\text{KOH}\) as a low melting solid. It can be recovered with these procedures from asymmetric reductions with \(\text{LAH}\), and reused. [J Am Chem Soc 77 3400 1955; J Org Chem 28 2381 2483 1963.]

\(2\text{-Dimethylamino-2,2-diphenylvaleramide}\) \([60-46-8]\) M 296.4, \(m\) 183-184\(^\circ\), \(pK_{\text{et}}\) ~9.8. Crystd from aqueous \(\text{EtOH}\).

\((-\text{-L-4-Dimethylamino-2,2-diphenylvaleramide}\) \([6078-64-4]\) M 296.4, \(m\) 136.5-137.5\(^\circ\).

Crystd from pet ether or \(\text{EtOH}\).

\(2\text{-Dimethylaminoethanol}\) \([108-01-0]\) M 89.1, \(b\) 134.5-135.5\(^\circ\), \(d\) 1.430, \(n\) 1.4362, \(pK_2\) 9.23. Dried with anhydrous \(\text{K}_2\text{CO}_3\) or \(\text{KOH}\), and fractionally distd.

\(1\text{-((3-Dimethylamino-propyl))-3-ethylcarbodiimide hydrochloride (EDCI, DEC, 1-ethyl-3-(3-dimethylamino-propyl) carbodiimide hydrochloride)}\) \([25952-53-8]\) M 191.7, \(m\) 113.5-114.5\(^\circ\), 114-116\(^\circ\), \(pK_{\text{et}}\) ~10.3. An excellent \(\text{H}_2\text{O}\)-soluble peptide coupling reagent. It is purified by dissolving \((ca 1\text{g})\) in \(\text{CH}_2\text{Cl}_2\) (10mL) at room temperature and then add dry \(\text{Et}_2\text{O}\) (~110mL) dropwise and the crystals that separate are collected, washed with dry \(\text{Et}_2\text{O}\) and recrystd from \(\text{CH}_2\text{Cl}_2\)-\(\text{Et}_2\text{O}\) and dried in a vacuum over \(\text{P}_2\text{O}_5\). It is important to work in a dry atmosphere or work rapidly and then dry the solid as soon as possible. Material is moderately hygroscopic but once it becomes wet it reacts slowly with \(\text{H}_2\text{O}\). Store away from moisture and at -20\(^\circ\) to slow down the hydrolysis process. The free base has \(b\) 47-48\(^\circ\)/0.27mm, 53-54\(^\circ)/0.6mm, \(n\) \(D\) 1.4582. The methiodide is recrystallised from \(\text{CHCl}_3\)-\(\text{EtOAc}\), the crystals are filtered off, washed with dry \(\text{Et}_2\text{O}\) and recrystd from \(\text{CHCl}_3\)-\(\text{Et}_2\text{O}\), and dried in vacuo over \(\text{P}_2\text{O}_5\), \(m\) 93-95\(^\circ\), 94-95\(^\circ\). [Sheehan et al. J Am Chem Soc 87 2492 1965; Sheehan and Cruickshank Org Synth Coll Vol V 555 1973.]

\(2\text{-Dimethyloxirane\} \([108-01-0]\) M 89.1, \(b\) 134.5-135.5\(^\circ\), \(d\) 1.430, \(n\) 1.4362, \(pK_2\) 245 9.23. Dried with anhydrous \(\text{K}_2\text{CO}_3\) or \(\text{KOH}\), and fractionally distd.
A polymer bound version is commercially available.

6-Dimethylaminopurine [938-55-6] M 163.1, m 257.5-258.5°, 259-262°, 263-264°, pK\textsubscript{1} 3.87, pK\textsubscript{2} 10.5. It is purified by recryst from H\textsubscript{2}O, EtOH (0.32g in 10mL) or CH\textsubscript{2}Cl\textsubscript{2}. [Albert and Brown \textit{J Chem Soc} 2060 1954; UV: Mason \textit{J Chem Soc} 2071 1954.]

Monohydrochloride crystallises from EtOH-Et\textsubscript{2}O, m 253° (dec) [Elion et al. \textit{J Am Chem Soc} 74 411 1952], the dihydrochloride has m 225° (dec) and the picrate has m 245° (235-236.5°) [Fryth et al. \textit{J Am Chem Soc} 80 2736 1958].


N,N-Dimethylaniline [121-69-7] M 121.2, f 2°, b 84°/15mm, 193°/760mm, d 0.956, n\textsubscript{25} 1.5556, pK\textsubscript{1} 5.07. Primary and secondary amines (including aniline and monomethylaniline) can be removed by refluxing for some hours with excess acetic anhydride, and then fractionally distilling. Crocker and Jones (\textit{J Chem Soc} 1959) used four volumes of acetic anhydride, then distd off the greater part of it, and took up the residue in ice-cold dil HCl. Non-basic materials were removed by ether extraction, then the dimethylaniline was liberated with ammonia, extracted with ether, dried, and distd under reduced pressure. Metzler and Tobolsky (\textit{J Am Chem Soc} 76 5178 1954) refluxed with only 10% (w/w) of acetic anhydride, then cooled and poured into excess 20% HCl, which, after cooling, was extracted with diethyl ether. (The amine hydrochloride, remains in the aqueous phase.) The HCl soln was cautiously made alkaline to phenolphthalein, and the amine layer was drawn off, dried over KOH and fractionally distd under reduced pressure, under nitrogen. Suitable drying agents for dimethylaniline include NaOH, BaO, CaSO\textsubscript{4}, and CaH\textsubscript{2}. Other purification procedures include the formation of the picrate, prepared in benzene soln and crystd to constant melting point, then decomposed with warm 10% NaOH and extracted into ether: the extract was washed with water, and distd under reduced pressure. The oxalate has also been used. The base has been fractionally crystd by partial freezing and also from aq 80% EtOH then from absolute EtOH. It has been distd from zinc dust, under nitrogen.

2,6-Dimethylaniline [87-62-7] M 121.2, f 2°, b 210-211°/736mm, d 0.974, n\textsubscript{25} 1.5604, pK\textsubscript{2} 3.95. Converted to its hydrochloride which, after recryst, was decomposed with alkali to give the free base. Dried over KOH and fractionally distd.

3,4-Dimethylaniline [95-64-7] M 121.2, m 51°, b 116-118°/25mm, b 226°/760mm, pK\textsubscript{2} 5.17. Crystd from ligroin and distilled under vacuum.


1,3-Dimethylbarbituric acid [769-42-6] M 156.1, m 123°, pK\textsubscript{2} 4.56. Crystd from water and sublimed in a vacuum. Also purified by dissolving 10g in 100mL of boiling CCl\textsubscript{4}/CHCl\textsubscript{3} (8:2) (1g charcoal), filtered and cooled to 25°. Dried in vacuo [Kohn et al. \textit{Anal Chem} 58 3184 1986].

5,6-Dimethylbenzimidazole [582-60-5] M 146.2, m 205-206°, pK\textsubscript{1} 5.96, pK\textsubscript{2} 12.52. Crystd from diethyl ether. Sublimed at 140°/3mm.

2,3-Dimethylbenzoic acid [603-79-2] M 150.2, m 146°, pK\textsubscript{2} 3.72. Crystd from EtOH and is volatile in steam.

2,4-Dimethylbenzoic acid [611-01-8] M 150.2, m 126-127°, b 267°/727mm, pK\textsubscript{2} 4.22. Crystd from EtOH, and sublimed in a vacuum.
2,5-Dimethylbenzoic acid \([610-72-0]\) M 150.2, m 134\(^\circ\), b 268\(^\circ\)/760mm, pK\(_{25}\) 4.00. Steam distd, and crystd from EtOH.

2,6-Dimethylbenzoic acid \([632-46-2]\) M 150.2, m 117\(^\circ\), pK\(_{25}\) 3.35. Steam distd, and crystd from EtOH.

3,4-Dimethylbenzoic acid \([619-04-5]\) M 150.2, m 166\(^\circ\), pK\(_{25}\) 4.50. Crystd from EtOH and sublimed in vacuo.

3,5-Dimethylbenzoic acid \([499-06-9]\) M 150.2, m 170\(^\circ\), pK\(_{25}\) 4.30. Distd in steam, crystd from water or EtOH and sublimed in a vacuum.

4,4'-Dimethylbenzophenone \([611-97-2]\) M 210.3, m 95\(^\circ\), b 333-334\(^\circ\)/725mm. Purified by zone refining.

2,5-Dimethyl-1,4-benzoquinone \([137-18-8]\) M 136.1, m 124-125\(^\circ\). Crystd from EtOH.

2,6-Dimethyl-1,4-benzoquinone \([527-61-7]\) M 136.1, m 72\(^\circ\) (sealed tube). Crystd from water/EtOH (8:1).

2,3-Dimethylbenzothiophene \([31317-17-6]\) M 212.3, b 123-124\(^\circ\)/10mm, n\(_{19}\) 1.6171. Fractionated through a 90cm Monel spiral column, or other efficient fractionating or spinning band column and collecting the middle fraction.

N,N-Dimethylbenzylamine \([103-83-3]\) M 135.2, b 66-67\(^\circ\)/15mm, 181\(^\circ\)/760mm, d\(_{4}^2\) 0.898, n\(_{D}^0\) 1.516, pK\(_{25}\) 8.91. See N-benzyl dimethylamine on p. 128.

4,4'-Dimethyl-2,2'-bipyridine \([1134-35-6]\) M 184.2, m 175-176\(^\circ\), pK\(_{Em(1)}\) -0.2, pK\(_{Em(2)}\)~4.9. Crystd from ethyl acetate. [Elliott et al. \textit{J Am Chem Soc} 107 4647 1985.]

1,1'-Dimethyl-4,4'-bipyridylium dichloride (3H\(_2\)O; Methyl Viologen Dichloride, paraquat dichloride) \([1910-42-5]\) M 311.2, m >300\(^\circ\)(dec). Recrystd from MeOH/acetone mixture. Also crystd three times from absolute EtOH [Bancroft et al. \textit{Anal Chem} 53 1390 1981]. Dried at 80\(^\circ\) in a vacuum.

N,N-Dimethylbiuret \([7710-35-2]\) M 131.1, m 178\(^\circ\). Purified by repeated crystn from the melt, or H\(_2\)O. [Bredereck and Richter \textit{Chem Ber} 99 2461 1966; Dunning and Close \textit{J Am Chem Soc} 75 3615 1953.]

2,3-Dimethyl-1,3-butadiene \([513-81-5]\) M 82.2, m -69-70\(^\circ\), b 68-69\(^\circ\)/760mm, d 0.727, n 1.4385. Distd from NaBH\(_4\), and purified by zone melting.

1,3-Dimethylbutadiene sulfone (1,3-dimethylsulfolene) \([10033-92-8]\) M 145.2, m 40.4-41.0\(^\circ\). Crystd from diethyl ether.

2,2-Dimethylbutane \([75-83-2]\) M 86.2, b 49.7\(^\circ\), d 0.649, n\(_{25}\) 1.36595. Distd azeotropically with MeOH, then washed with water, dried and distd.

2,3-Dimethylbutane \([79-29-8]\) M 86.2, b 58.0\(^\circ\), d 1.375, n\(_{25}\) 1.37231. Distd from sodium, passed through a column of silica gel (activated by heating in nitrogen to 350\(^\circ\) before use) to remove unsaturated impurities, and again distd from sodium. Also distilled azeotropically with MeOH, then washed with water, dried and redistd.

2,3-Dimethylbut-2-ene \([563-79-1]\) M 84.2, b 72-73\(^\circ\)/760mm, d 0.708, n 1.41153. Purified by GLC on a column of 20% squalene on chromosorb P at 50\(^\circ\) [Flowers and Rabinovitch \textit{J Phys Chem} 89 563 1985]. Also washed with 1M NaOH soln followed by H\(_2\)O. Dried over Na\(_2\)SO\(_4\), distd over powdered KOH.

**Dimethylcarbamoyl chloride** [79-44-7] M 107.5, m -33°, b 34°/0.1mm, d 1.172, n 1.4511. Must distil under high vacuum to avoid decomposition.


**Dimethyl carbonate** [616-38-5] M 90.1, m 4.65°, b 90-91°, d 1.070, n 1.369. Contains small amounts of water and alcohol which form azeotropes. Stood for several days in contact with Linde type 4A molecular sieves, then fractionally distd. The middle fraction was frozen slowly at 20°, several times, retaining 80% of the solvent at each cycle.

**cis- and trans-1,4-Dimethylcyclohexane** [589-90-2] M 112.2, b 120°, d 0.788, n 1.427. Freed from olefins by shaking with conc H2SO4, washing with water, drying and fractionally distilling.

**1,2-Dimethylcyclohexene** [1674-10-8] M 110.2, b 135-136°/760mm, d 0.826, n 1.4591. Passed through a column of basic alumina and distd.

**1,5-Dimethyl-1,5-diazaundecamethylene polymethobromide (Hexadimethrene, Polybrene)** [28728-55-4] M 5000—10,000 polymer Purified by chromatography on Dowex 50 and/or by filtration through alumina before use [Frank Hoppe-Seyler’s Z Physiol Chemie 360 997 1979]. Hygroscopic, sol in H2O is 10%.


**Dimethyl disulfide** [624-92-0] M 94.2, f -98°, b 40°/12mm, 110°/760mm, d 1.0605, n 1.5260. Passed through neutral alumina before use.

**2,2-Dimethylethyleneimine** [2658-24-4] M 71.1, b 70.5-71.0°, pK25 8.64. Freshly distd from sodium before use.

**N,N-Dimethylformamide (DMF)** [68-12-2] M 73.1, b 40°/10mm, 61°/30mm, 88°/100mm, 153°/760mm, d 0.948, n25 1.4269, pK -0.3. Decomposes slightly at its normal boiling point to give small amounts of dimethylamine and carbon monoxide. The decomposition is catalysed by acidic or basic materials, so that even at room temperature DMF is appreciably decomposed if allowed to stand for several hours with solid KOH, NaOH or CaH2. If these reagents are used as dehydrating agents, therefore, they should not be refluxed with the DMF. Use of CaSO4, MgSO4, silica gel or Linde type 4A molecular sieves is preferable, followed by distn under reduced pressure. This procedure is adequate for most laboratory purposes. Larger amounts of water can be removed by azeotropic distn with *benzene (10% v/v, previously dried over CaH2), at atmospheric pressure; water and *benzene distil below 80°. The liquid remaining in the distn flask is further dried by adding MgSO4 (previously ignited overnight at 300-400°) to give 25g/L. After shaking for one day, a further quantity of MgSO4 is added, and the DMF distd at 15-20mm pressure through a 3-ft vacuum-jacketed column packed with steel helices. However, MgSO4 is an inefficient drying agent, leaving about 0.01M water in the final DMF. More efficient drying (to around 0.001-0.007M water) is achieved by standing with powdered BaO, followed by decanting before distn, with alumina powder (50g/L; previously heated overnight to 500-600°), and distilling from more of the alumina; or by refluxing at 120-140° for 24h with triphenylchlorosilane (5-10g/L), then distilling at ca 5mm pressure [Thomas and Rochow J Am Chem Soc 79 1843 1957]. Free amine in DMF can be detected by colour reaction with 1-fluoro-2,4-dinitrobenzene. It has also been purified by drying overnight over KOH pellets and then distd from BaO through a 10 cm Vigreux column [Exp Cell Res 100 213 1976]. [For efficiency of desiccants in drying dimethylformamide see Burfield and Smithers J Org Chem 43 3966 1978, and for a review on purification, tests of purity and physical properties, see Juillard Pure Appl Chem 49 885 1977].
It has been purified by distilling from K₂CO₃ under high vac and fractionated in an all-glass apparatus. The middle fraction is collected, degassed (seven or eight freeze-thaw cycles) and redistd under as high a vacuum as possible [Mohammad and Kosower J Am Chem Soc 93 2713 1971].

**Rapid purification:** Stir over CaH₂ (5% w/v) overnight, filter, then distil at 20mmHg. Store the distd DMF over 3A or 4A molecular sieves. For solid phase synthesis, the DMF used must be of high quality and free from amines.

### d,l-2,4-Dimethylglutaric acid [2121-67-7] M 160.2, m 144-145° pKₑₒₓ(M(1)−4.4, pKₑₒₓ(M(2)−5.4. Distd in steam and crystd from ether/pet ether.


**N,N-Dimethylglycinehydrazide hydrochloride** [539-64-0] M 153.6, m 181°. Crystd by adding EtOH to a conc aqueous soln.

### Dimethylglyoxime [95-45-4] M 116.1, m 240°, pK₊ 10.60, pK₋ 11.85. Crystd from EtOH (10mL/g) or aqueous EtOH. TOXIC.

2,5-Dimethyl-2,4-hexadiene [764-13-6] M 110.2, f 14.5°, b 132-134°, d 0.773, n 1.4796. Distd, then repeatedly fractionally crystd by partial freezing. Immediately before use, the material was passed through a column containing Woelm silica gel (activity 1) and Woelm alumina (neutral) in separate layers.

2,2-Dimethylhexane [590-73-8] M 114.2, m -121.2°, b 107°, d 0.695. Dried over type 4A molecular sieves and distd.

2,5-Dimethylhexane [592-13-2] M 114.2, m -91.2°, b 109°, d 0.694. Dried over type 4A molecular sieves and distd.

2,5-Dimethylhexane-2,5-diol [110-03-2] M 146.2, m 88-90°. Purified by fractional crystn. Then the diol was dissolved in hot acetone, treated with activated charcoal, and filtered while hot. The soln was cooled and the diol was filtered off and washed well with cold acetone. The crystn process was repeated several times and the crystals were dried under a vac in a freeze-drying apparatus [Goates et al. J Chem Soc, Faraday Trans 1 78 3045 1982].


1,1-Dimethylhydrazine [57-14-7] M 60.1, b 60.1°/702mm, d 0.790, n 1.408 pK 7.21. Fractionally distd through a 4-ft column packed with glass helices. Pptd as its oxalate from diethyl ether soln. After crystn from 95% EtOH, the salt was decomposed with aqueous saturated NaOH, and the free base was distd, dried over BaO and redistd [McBride and Kruse J Am Chem Soc 79 572 1957]. Distn and storage should be under nitrogen.


1,1-Dimethyl-1H-indene [18636-55-0] M 144.2, b 57°/4.8mm, 115°/20mm. Purified by gas chromatography or by fractional distn.
Dimethyl itaconate [617-52-7] M 158.2, m 38°, b 208°, d 1.124. Crystd from MeOH by cooling to -78°.


Dimethylmalonic acid [595-46-0] M 132.1, m 192-193°, pK\textsubscript{a} 3.03, pK\textsubscript{b} 5.73. Crystd from *benzene/pet ether and sublimed in a vacuum with slight decomposition.

1,5-Dimethylnaphthalene [571-61-9] M 156.2, m 81-82°, b 265-266°. Crystd from 85% aq EtOH.

2,3-Dimethylnaphthalene [581-40-8] M 156.2, m 104-104.5°. Steam distd and crystd from EtOH.

2,6-Dimethylnaphthalene [581-42-0] M 156.2, m 110-111°, b 122.5-123.5°/10mm, 261-262°/760mm. Distd in steam and crystd from EtOH.

3,3'-Dimethylnaphthidine (4,4'-diamino-3,3'-dimethyl-1,1'-binaphthyl) [13138-48-2] M 312.4, m 213°. Recrystd from EtOH or pet ether (b 60-80°).

N,N-Dimethyl-m-nitroaniline [1619-31-8] M 166.1, m 60°, pK\textsubscript{a} 2.63. Crystd from EtOH.

N,N-Dimethyl-p-nitroaniline [100-23-2] M 166.1, m 164.5-165.2°, pK\textsubscript{a} 0.61 (0.92). Crystd from EtOH or aqueous EtOH. Dried under vacuum.


2,6-Dimethyl-2,4,6-octatriene [7216-56-0; cis/trans mixt 673-84-7; trans, trans 3016-19-1] M 136.2, b 80-82°/15mm, ε\textsubscript{278nm} 42,870. Repeated distn at 15mm through a long column of glass helices, the final distn being from sodium under nitrogen. See neo-allocimene on p. 100.

Dimethylolurea [140-95-4] M 120.1, m 137-139°. Crystd from aqueous 75% EtOH.

Dimethyl oxalate [553-90-2] M 118.1, m 54°, b 163-165°, d 1.148. Crystd repeatedly from EtOH. Degassed under nitrogen high vacuum and distd.

3,3-Dimethyloxetane [6921-35-3] M 86.1, b 79.2-80.3°/760mm. Purified by gas chromatography using a 2m silicone oil column.

2,3-Dimethylpentane [565-59-3] M 100.2, b 89.8°, d 0.695, n 1.39197, n\textsuperscript{25} 1.38946. Purified by azeotropic distn with EtOH, followed by washing out the EtOH with water, drying and distn [Streiff et al. J Res Nat Bur Stand 37 331 1946].
2,4-Dimethylpentane [108-08-7] M 100.2, b 80.5°, d 0.763, n 1.3814, n25 1.37882. Extracted repeatedly with conc H2SO4, washed with water, dried and distd. Percolated through silica gel (previously heated in nitrogen to 350°). Purified by azeotropic distn with EtOH, followed by washing out the EtOH with water, drying and distn.


Dimethyl peroxide [690-02-8] M 62.1, b 135°/760mm, d 0.8677, n 1.3503. Purified by repeated trap-to-trap fractionation until no impurities could be detected by gas IR spectroscopy [Haas and Oberhammer J Am Chem Soc 106 6146 1984]. All necessary precautions should be taken in case of EXPLOSION.

2,9-Dimethyl-1,10-phenanthroline [484-11-7] M 208.3, m 162-164°, pK25 5.85. Purified as hemihydrate from water, and as anhydrous from *benzene.

R-(-)-N,N'-Dimethyl-1-phenethylamine [19342-01-9] and S-(+)-N,N'-Dimethyl-1-phenethylamine [17279-31-1] M 149.2, b 81°/16mm, [c]D 25 (+) and (-) 50.2° (c 1, MeOH), [α]D 26 +61.8° and -64.4° (neat l 1), d 0.908, pK6 9.0 (for RS). The amine is mixed with aqueous 10N NaOH and extracted with toluene. The extract is washed with saturated aqueous NaCl and dried over K2CO3, and transferred to fresh K2CO3 until the soln is clear, and filtered. The filtrate is distd. If a short column packed with glass helices is used, the yield is reduced but a purer product is obtained. [Org Synth 25 89 1945; J Am Chem Soc 71 291 3929 3931 4165 1949.] The (-)-picrate has m 140-141° (cryst from EtOH). The racemate [1126-71-2] has b 88-89°/16mm, 92-94°/30mm, 194-195°/atm, d25 0.908.

2,3-Dimethylphenol [526-75-0] M 122.2, m 75°, b 120°/20mm, 218°/760mm, pK25 10.54. Crystd from aqueous EtOH.

2,5-Dimethylphenol [95-87-1] M 122.2, m 73°, b 211.5°/762mm, pK25 10.41. Crystd from EtOH/ether.

2,6-Dimethylphenol [576-26-1] M 122.2, m 49°, b 203°/760mm, pK25 10.61. Fractionally distd under nitrogen, crystd from *benzene or hexane, and sublimed at 38°/10mm.

3,4-Dimethylphenol [95-65-8] M 122.2, m 65°, b 225°/757mm, pK25 10.36. Heated with an equal weight of conc H2SO4 at 103-105° for 2-3h, then diluted with four volumes of water, refluxed for 1h, and either steam distd or extracted repeatedly with diethyl ether after cooling to room temperature. The steam distillate was also extracted and evaporated to dryness. (The purification process depends on the much slower sulfonation of 3,5-dimethylphenol than most of its likely contaminants.). It can also be crystd from water, hexane or pet ether, and vacuum sublimed. [Kester Ind Eng Chem (Anal Ed) 24 770 1932; Bernasconi and Paschalis J Am Chem Soc 108 2969 1986.]


Dimethyl phthalate [131-11-3] M 194.2, b 282°, n 1.5149, d 1.190, d25 1.1865. Washed with aqueous Na2CO3, then distilled water, dried (CaCl2) and distd under reduced pressure (b 151-152°/0.1mm).

2,2-Dimethyl-1,3-propanediol (neopentyl glycol) [126-30-7] M 104.2, m 128.4-129.4°, b 208°/760mm. Crystd from *benzene or acetone/water (1:1).

2,2-Dimethyl-1-propanol (neo-pentyl alcohol) [75-84-3] M 88.2, m 52°, b 113.1°/760mm. Difficult to distil because it is a solid at ambient temperatures. Purified by fractional crystallisation and sublimation.
Purification of Organic Chemicals

N,N-Dimethylpropionamide \[758-96-3] M 101.2, b 175-178°, d 0.920, n 1.440. Shaken over BaO for 1-2 days, then distd at reduced pressure.

2,5-Dimethylpyrazine \[123-32-0] M 108.1, b 156°, d 0.990, n 1.502, pK1^2 4.6 (aq H2SO4), pK2^2 1.85. Purified via its picrate (m 150°) [Wiggins and Wise J Chem Soc 4780 1956].


2,4-Dimethylresorcinol \[634-65-1] M 138.1, m 149-150°, pK1 1.85, pK2 4.16. Crystd from EtOH/ether or EtOH/chloroform.

meso-\(\alpha,\beta\)-Dimethylsuccinic acid \[608-40-2] M 146.1, m 211°, pK1^2 3.77, pK2^2 5.36. Crystd from EtOH/ether or EtOH/chloroform.

2,2-Dimethylsuccinic acid \[597-43-3] M 146.1, m 141°, pK1^2 4.15, pK2^2 6.40. Crystd from EtOH/ether or EtOH/chloroform.

(\(\pm\))-2,3-Dimethylsuccinic acid \[13545-04-5] M 146.1, m 129°, pK1^2 3.82, pK2^2 5.98. Crystd from water.

Dimethyl sulfide \[75-18-3] M 62.1, f -98.27°, b 0°/172mm, 37.5-38°/760mm, d 21 0.8458, n 25 1.4319. Purified via the Hg(II) chloride complex by dissolving 1 mole of Hg(II)Cl2 in 1250mL of EtOH and slowly adding the boiling alcoholic soln of dimethyl sulfide to give the right ratio for 2(CH3)2S.3HgCl2. After recrystn of the complex to constant melting point, 500g of complex is heated with 250mL conc HCl in 750mL of water. The sulfide is separated, washed with water, and dried with CaCl2 and CaSO4. Finally, it is distd under reduced pressure from sodium. Precautions should be taken (efficient fume hood) because of its very UNPLEASANT ODOR.


Dimethyl sulfoxide (DMSO) \[67-68-5] M 78.1, m 18.0-18.5°, b 75.6-75.8°/12mm, 190°/760mm, d 1.100, n 1.479. Colourless, odourless, very hygroscopic liquid, synthesised from dimethyl sulfide. The main impurity is water, with a trace of dimethyl sulfoxide. The Karl-Fischer test is applicable. It is dried with Linde types 4A or 13X molecular sieves, by prolonged contact and passage through a column of the material, then distd under reduced pressure. Other drying agents include CaH2, CaO, BaO and CaSO4. It can also be fractionally crystd by partial freezing. More extensive purification is achieved by standing overnight with freshly heated and cooled chromatographic grade alumina. It is then refluxed for 4h over CaO, dried over CaH2, and then fractionally distd at low pressure. For efficiency of desiccants in drying dimethyl sulfoxide see Burfield and Smithers [J Org Chem 43 3966 1978; Sato et al. J Chem Soc, Dalton Trans 1949 1986].

Rapid purification: Stand over freshly activated alumina, BaO or CaSO4 overnight. Filter and distil over CaH2 under reduced pressure (~ 12 mm Hg). Store over 4A molecular sieves.


N,N-Dimethylthiocarbamoyl chloride \[16420-13-6] M 123.6, m 42-43°, b 64-65°/0.1mm. Crystd twice from pentane.
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\[ N,N\text{-Dimethyl-o-toluidine} \quad \{609-72-3\} \quad M 135.2, b 68^\circ/10\text{mm}, \quad 211-211.5^\circ/760\text{mm}, \quad d 0.937, \quad n 1.53664, \quad \text{pK}^{25} 5.85. \]  Isomers and other bases have been removed by heating in a water bath for 100h with two equivalents of 20\% HCl and two and a half volumes of 40\% aq formaldehyde, then making the sohn alkaline and separating the free base. After washing well with water it was disted at 10mm pressure and redistd at ambient pressure [von Braun and Aust \textit{Chem Ber} 47 260 19141]. Other procedures include drying with NaOH, distilling from zinc in an atmosphere of nitrogen under reduced pressure, and refluxing with excess of acetic anhydride in the presence of conc H\textsubscript{2}SO\textsubscript{4} as catalyst, followed by fractional distn under vacuum.

\[ N,N\text{-Dimethyl-m-toluidine} \quad \{121-72-2\} \quad M 135.2, b 211.5-212.5^\circ, \quad d 0.93, \quad \text{pK}^{25} 5.22. \]  See \textit{m}\text{-}methyl-N,N-dimethylaniline on p. 291.

\[ N,N\text{-Dimethyl-p-toluidine} \quad \{99-97-8\} \quad M 135.2, b 93-94^\circ/11\text{mm}, \quad b 211^\circ, \quad d 0.937, \quad n 1.5469, \quad \text{pK}^{25} 4.76. \]  See \textit{p}-methyl-N,N-dimethylaniline on p. 291.

1,3-Dimethyluracil \quad \{874-14-6\} \quad M 140.1, m 121-122^\circ, \quad \text{pK}^{25} -3.25 \text{ (aq H}\textsubscript{2}\text{SO}\textsubscript{4}). \end{quote}

\[ \text{sym-Dimethylurea} \quad \{96-31-1\} \quad M 88.1, m 106^\circ. \]  Crystd from acetone/diethyl ether by cooling in an ice bath. Also crystd from EtOH and dried at 50^\circ and 5mm for 24h [Bloemendahl and Somsen \textit{J Am Chem Soc} 107 3426 1985].

2,2\'-Dinaphthylamine \quad \{532-18-3\} \quad M 269.3, m 170.5^\circ, \quad \text{pK}_{\text{EtOH}} <0. \]  Crystd from *benzene.

2,4-Dinitroaniline \quad \{97-02-9\} \quad M 183.1, m 180^\circ, \quad \varepsilon_{348} 12,300 \text{ in dil aq HClO}_{4}, \quad \text{pK}^{25} -4.27 \text{ (aq H}\textsubscript{2}\text{SO}\textsubscript{4}). \]  Crystd from boiling EtOH by adding one-third volume of water and cooling slowly. Dried in a steam oven.

2,6-Dinitroaniline \quad \{606-22-4\} \quad M 183.1, m 139-140^\circ, \quad \text{pK}^{25} -5.37 \text{ (aq H}\textsubscript{2}\text{SO}\textsubscript{4}). \]  Purified by chromatography on alumina, then crystd from *benzene or EtOH.

2,4-Dinitroanisole \quad \{5327-44-6\} \quad M 198.1, m 94-95^\circ. \]  Crystd from aq EtOH.

3,5-Dinitroanisole \quad \{119-27-7\} \quad M 198.1, m 105-106^\circ. \]  Purified by repeated crystn from water and dried in a vacuum desiccator over P\textsubscript{2}O\textsubscript{5}.

1,2-Dinitrobenzene \quad \{528-29-0\} \quad M 168.1, m 116.5^\circ. \]  Crystd from EtOH.

1,3-Dinitrobenzene \quad \{99-65-0\} \quad M 168.1, m 90.5-91^\circ. \]  Crystd from alkaline EtOH soln (20g in 750mL 95\% EtOH at 40^\circ, plus 100mL of 2M NaOH) by cooling and adding 2.5L of water. The ppte, after filtering off, washing with water and sucking dry, was crystd from 120mL, then 80mL of absolute EtOH [Callow, Callow and Emmens Biochem J 32 1312 1938]. Has also been crystd from MeOH, CCl\textsubscript{4} and ethyl acetate. Can be sublimed in a vacuum. [Tanner \textit{J Org Chem} 52 2142 1987.]

1,4-Dinitrobenzene \quad \{100-25-4\} \quad M 168.1, m 173^\circ. \]  Crystd from EtOH or ethyl acetate. Dried under vacuum over P\textsubscript{2}O\textsubscript{5}. Can be sublimed in a vacuum.

2,4-Dinitrobenzenesulfenyl chloride \quad \{528-76-7\} \quad M 234.6, m 96^\circ. \]  Crystd from CCl\textsubscript{4}.

2,4-Dinitrobenzenesulfonyl chloride \quad \{1656-44-6\} \quad M 266.6, m 102^\circ. \]  Crystd from *benzene or *benzene/pet ether.

2,4-Dinitrobenzoic acid \quad \{610-30-3\} \quad M 212.1, m 183^\circ, \quad \text{pK}^{25} 1.42. \]  Crystd from aqueous 20\% EtOH (10mL/g), dried at 100^\circ.


3,4-Dinitrobenzoic acid [528-45-0] M 212.1, m 166°, pK25 2.81. Crystd from EtOH by addition of water.

3,5-Dinitrobenzoic acid [99-34-3] M 212.1, m 205°, pK25 2.73 (2.79). Crystd from distilled water or 50% EtOH (4mL/g). Dried in a vacuum desiccator or at 70° over BaO under vacuum for 6h.


3,5-Dinitrobenzyol chloride [99-33-2] M 230.6, m 69.5°. Crystd from CCl4 or pet ether (b 40-60°). It reacts readily with water, and should be kept in sealed tubes or under dry pet ether.

2,2'-Dinitrobiphenyl [2436-96-6] M 244.2, m 123-124°. Crystd from EtOH.

2,4'-Dinitrobiphenyl [606-81-5] M 244.2, m 92.7-93.7°. Crystd from EtOH.

4,4'-Dinitrobiphenyl [1528-74-1] M 244.2, m 240.9-241.8°. Crystd from benzene, EtOH (charcoal) or acetone. Dried under vacuum over P2O5.

2,6-Dinitro-p-cresol (2,6-dinitro-4-methylphenol) [609-93-3] M 198.1, m 78-79°, pKEst -3.7. Recrystd from EtOH and is steam volatile. TOXIC IRRITANT.


2,4-Dinitrodiphenylamine [961-68-2] M 259.2, m 157°, pK25 <0. Crystd from aqueous EtOH.


2,4-Dinitrofluorobenzene (Sanger's reagent) [70-34-8] M 186.1, m 25-27°, b 139°/2mm, 140-141°/5mm, d 1.483. Crystd from ether or EtOH. Vacuum distd through a Todd Column (see p. 174). If it is to be purified by distn in vacuo, the distn unit must be allowed to cool before air is allowed into the apparatus otherwise the residue carbonises spontaneously and an EXPLOSION may occur. The material is a skin irritant and may cause serious dermatitis.

1,8-Dinitronaphthalene [602-38-0] M 218.2, m 170-171°. Crystd from *benzene.

2,4-Dinitro-1-naphthol (Martius Yellow) [605-69-6] M 234.2, m 81-82°, pK25 -3.7. Crystd from *benzene or aqueous EtOH.

2,4-Dinitrophenetole [610-54-8] M 240.2, m 85-86°. Crystd from aqueous EtOH.


2,6-Dinitrophenol [573-56-8] M 184.1, m 63.0-63.7°, pK25 3.73. Crystd from *benzene/cyclohexane, aqueous EtOH, water or *benzene/pet ether (b 60-80°, 1:1).
3,4-Dinitrophenol [577-71-9] M 184.1, m 138°, pK$^{25}$ 5.42. Steam distd and crystd from water and air-dried. CAUTION - EXPLOSIVE when dry, store with 10% water.

3,5-Dinitrophenol [586-11-8] M 184.1, m 126°, pK$^{25}$ 6.68. Crystd from *benzene or CHCl₃/pet ether. Should be stored with 10% water because it is EXPLOSIVE when dry.


2,4-Dinitrophenylhydrazine (DNPH) [119-26-6] M 198.1, m 200°(dec), pK$_{EtOH}$ ~2.0. Crystd from butan-1-ol, dioxane, EtOH, *C₆H₆ or ethyl acetate. HCl has m 186°(dec).

2,2-Dinitropropane [595-49-3] M 162.1, m 53.5°. Crystd from EtOH or MeOH. Dried over CaCl₂ or under vacuum for 1h just above the melting point.

2,4-Dinitroresorcinol [519-44-8] M 200.1, m 149°, pK$^{25}$ 3.05. Crystd from aq EtOH. Explosive.


2,6-Dinitrothymol [303-21-9] M 240.2, m 53-54°. Crystd from aq EtOH.

2,3-Dinitrotoluene [602-01-7] M 182.1, m 63°. Distd in steam and crystd from water or *benzene/pet ether. Stored with 10% water. Could be EXPLOSIVE when dry.

2,4-Dinitrotoluene [121-14-2] M 182.1, m 70.5-71.0°. Crystd from acetone, isopropanol or MeOH. Dried under vacuum over H₂SO₄. Purified by zone melting. Could be EXPLOSIVE when dry.


2,6-Dinitrotoluene [606-20-2] M 182.1, m 64.3°. Crystd from acetone.

3,4-Dinitrotoluene [610-39-9] M 182.1, m 61°. Distil in steam and cryst from *benzene/pet ether. Store with 10% of water to avoid EXPLOSION.

3,5-Dinitro-o-toluic acid [28169-46-2] M 226.2, m 206°, pK$_{EtOH}$ ~3.0. Crystd from H₂O or aq EtOH.

2,4-Dinitro-m-xylene [603-02-1] M 196.2, m 83-84°. Crystd from EtOH.

Dinonyl phthalate (mainly 3,5,5-trimethylhexyl phthalate isomer) [28553-12-0; 14103-61-8] M 418.6, m 26-29°, b 170°/2mm, d 0.9640, n 1.4825. Washed with aqueous Na₂CO₃, then shaken with water. Ether was added to break the emulsion, and the soln was washed twice with water, and dried (CaCl₂). After evaporating the ether, the residual liquid was distd three times under reduced pressure. It was stored in a vacuum desiccator over P₂O₅.


1,3-Dioxane [505-22-6] M 88.1, b 104.5°/751mm, d 1.040, n 1.417. Dried with sodium and fractionally distd.
1,4-Dioxane \([123-91-1]\) \(M \ 88.1\), \(f \ 11.8^\circ\), \(b \ 101.3^\circ\), \(d^{25} \ 1.0292\), \(n^\circ \ 1.4236\), \(n^2^5 \ 1.42025\).
Prepared commercially either by dehydration of ethylene glycol with \(H_2SO_4\) and heating ethylene oxide or bis(\(\beta\)-chloroethyl)ether with \(NaOH\). Usual impurities are acetaldehyde, ethylene acetal, acetic acid, water and peroxides. Peroxides can be removed (and the aldehyde content decreased) by percolation through a column of activated alumina (80g per 100-200mL solvent), by refluxing with \(NaBH_4\) or anhydrous stannous chloride and distilling, or by acidification with conc HCl, shaking with ferrous sulfate and leaving in contact with it for 24h before filtering and purifying further.

Hess and Frahm [Chem Ber. 71 2627 1938] refluxed 2L of dioxane with 27mL conc HCl and 200mL water for 12h with slow passage of nitrogen to remove acetaldehyde. After cooling the soln KOH pellets were added slowly and with shaking until no more would dissolve and a second layer had separated. The dioxane was decanted, treated with fresh KOH pellets to remove any aq phase, then transferred to a clean flask where it was refluxed for 6-12h with sodium, then distd from it. Alternatively, Kraus and Vingee [J Am Chem Soc 56 311 1934] heated on a steam bath with solid KOH until fresh addition of KOH gave no more resin (due to acetaldehyde). After filtering through paper, the dioxane was refluxed over sodium until the surface of the metal was then distilled from sodium. The acetal (b 82.5\(^\circ\)) is removed during fractional distn. Traces of \(\ast\)benzene, if present, can be removed as the \(\ast\)benzene/MeOH azeotrope by distn in the presence of MeOH. Distn from LiAlH_4 removes aldehydes, peroxides and water. Dioxane can be dried using Linde type 4A molecular sieves. Other purification procedures include distn from excess \(C_2H_5MgBr\), refluxing with \(PbO_2\) to remove peroxides, fractional crystn by partial freezing and the addition of \(KI\) to dioxane acidified with aq HCl. Dioxane should be stored out of contact with air, preferably under \(N_2\).

A detailed purification procedure is as follows: Dioxane was stood over ferrous sulfate for at least 2 days, under nitrogen. Then water (100mL) and conc HCl (14mL) / litre of dioxane were added (giving a pale yellow colour). After refluxing for 8-12h with vigorous \(N_2\) bubbling, pellets of KOH were added to the warm soln to form two layers and to discharge the colour. The soln was cooled rapidly with more KOH pellets being added (magnetic stirring) until no more dissolved in the cooled soln. After 4-12h, if the lower phase was not black, the upper phase was decanted rapidly into a clean flask containing sodium, and refluxed over sodium (until freshly added sodium remained bright) for 1h. The middle fraction was collected (and checked for minimum absorbency below 250nm). The distillate was fractionally frozen three times by cooling in a refrigerator, with occasional shaking or stirring. This material was stored in a refrigerator. For use it was thawed, refluxed over sodium for 48h, and distilled into a container for use. All joints were clad with Teflon tape.

Coetzee and Chang [Pure Appl Chem 57 633 1985] dried the solvent by passing it slowly through a column (20g/L) of 3A molecular sieves activated by heating at 250\(^\circ\) for 24h. Impurities (including peroxides) were removed by passing the effluent slowly through a column packed with type NaX zeolite (pellets ground to 0.1mm size) activated by heating at 400\(^\circ\) for 24h or chromatographic grade basic \(Al_2O_3\) activated by heating at 250\(^\circ\) for 24h. After removal of peroxides the effluent was refluxed several hours over sodium wire, excluding moisture, distilled under nitrogen or argon and stored in the dark.

One of the best tests of purity of dioxane is the formation of the purple disodium benzophenone complex during reflux and its persistence on cooling. (Benzophenone is better than fluorenone for this purpose, and for the storing of the solvent.) [Carter, McClelland and Warhurst Trans Faraday Soc 56 343 1960]. TOXIC.

Rapid purification: Check for peroxides (see Chapter 1 and Chapter 2 for test under ethers). Pre-dry with \(CaCl_2\) or better over \(Na\) wire. Then reflux the pre-dried solvent over \(Na\) (1% w/v) and benzophenone (0.2% w/v) under an inert atmosphere until the blue colour of the benzophenone ketyl radical anion persists. Distil, and store over 4A molecular sieves in the dark.

1,3-Dioxolane \([646-06-0]\) \(M \ 74.1\), \(b \ 75.0-75.2^\circ\), \(d 1.0600\), \(n^{25} \ 1.3997\).
Dried with solid \(NaOH\), \(KOH\) or \(CaSO_4\), and distd from sodium or sodium amalgam. Barker et al. [J Chem Soc 802 1959] heated 34mL of dioxolane under reflux with 3g of \(PbO_2\) for 2h, then cooled and filtered. After adding xylene (40mL) and \(PbO_2\) (2g) to the filtrate, the mixture was fractionally distd. Addition of xylene (20mL) and sodium wire to the main fraction (b 70-71\(^\circ\)) led to vigorous reaction, following which the mixture was again fractionally distd. Xylene and sodium additions were made to the main fraction (b 73-74\(^\circ\)) before it was finally distd.

4,4'-Di-n-pentyloxyazoxybenzene \([64242-26-8]\) \(M \ 370.5\). Crystd from \(Me_2CO\), and dried by heating under vacuum.
Diphenic acid [482-05-3] M 242.2, m 228-229°, pK\textsubscript{25} 3.46. Crystd from water.

Diphenic anhydride [6050-13-1] M 466.3, m 217°. After removing free acid by extraction with cold aq Na\textsubscript{2}CO\textsubscript{3}, the residue has been crystd from acetic anhydride and dried at 100°. Acetic anhydride also converts the acid to the anhydride.

\textit{N,N'-Diphenylacetamidine} [621-09-0] M 210.3, m 131°. Crystd from EtOH, then sublimed under vacuum at ca 96° onto a “finger” cooled in solid CO\textsubscript{2}/MeOH, with continuous pumping to free it from occluded solvent.

Diphenylacetic acid [117-34-0] M 212.3, m 147.4-148.4°, pK\textsubscript{25} 3.94. Crystd from *benzene, H\textsubscript{2}O or aq 50% EtOH.

Diphenyl acetamide [1621-09-0] M 193.3, m 73-75°. Crystd from EtOH, then sublimed under vacuum at ca 96° onto a “finger” cooled in solid CO\textsubscript{2}/MeOH, with continuous pumping to free it from occluded solvent.

Diphenylacetonitrile [86-29-3] M 193.3, m 73-75°. Crystd from EtOH or pet ether (b 90-100°).

Diphenylacetylene (tolan) [501-65-5] M 178.2, m 62.5°, b 90-97°/0.3mm. Crystd from EtOH.

\textit{Diphenylamine} [122-39-4] M 169.2, m 62.0-62.5°, pK\textsubscript{25} 0.77 (aq H\textsubscript{2}SO\textsubscript{4}). Crystd from pet ether, MeOH, or EtOH/water. Dried under vacuum.

\textit{Diphenylamine-2-carboxylic acid} [91-40-7] M 213.2, m 184°, pK\textsubscript{25} 1.28 (aq H\textsubscript{2}SO\textsubscript{4}). pK\textsubscript{25} 3.86. See \textit{N-phenylanthranilic acid} on p. 327.

\textit{Diphenylamine-2,2'-dicarboxylic acid (2,2'-iminodibenzoic acid)} [579-92-0] M 257.2, m 298°(dec), pK\textsubscript{25} -3.7. Crystd from EtOH.


\textit{trans-trans-1,4-Diphenylbuta-1,3-diene} [538-81-8] M 206.3, m 153-153.5°. Its soln in pet ether (b 60-70°) was chromatographed on an alumina-Celite column (4:1) and the column was washed with the same solvent. The main zone was cut out, eluted with ethanol and transferred to pet ether, which was then dried and evaporated [Pinckard, Wille and Zechmesiter \textit{J Am Chem Soc} 70 1938 1948]. Recrystd from hexane.

\textit{sym-Diphenylcarbazide} [140-22-7] M 242.3, m 172°. A common impurity is phenylsemicarbazide which can be removed by chromatography [Willems et al. \textit{Anal Chim Acta} 51 544 1970]. Crystd from EtOH or glacial acetic acid.

\textit{1,5-Diphenylcarbazone} [538-62-5] M 240.3, m 124-127°. Crystd from EtOH (ca 5mL/g), and dried at 50°. A commercial sample, nominally \textit{sym}-diphenylcarbazone but of m 154-156°, was a mixture of diphenylcarbazone and diphenylcarbazone. The former was removed by dissolving 5g of the crude material in 75mL of warm EtOH, then adding 25g Na\textsubscript{2}CO\textsubscript{3} dissolved in 400mL of distd water. The alkaline soln was cooled and extracted six times with 50mL portions of diethyl ether (discarded). Diphenylcarbazone was then ppted by acidifying the alkaline soln with 3M HNO\textsubscript{3} or glacial acetic acid. It was filtered on a Büchner funnel, air dried, and stored in the dark [Gerlach and Frazier \textit{Anal Chem} 30 1142 1958]. Other impurities were phenylsemicarbazide and diphenylcarbodiazone. Impurities can be detected by chromatography [Willems et al. \textit{Anal Chim Acta} 51 544 1970].

\textit{Diphenyl carbonate} [102-09-0] M 214.2, m 80°. Purified by sublimation, and by preparative gas chromatography with 20% Apiezon on Embacel, and crystall from EtOH.

Diphenyl disulfide (phenyl disulfide) [882-33-7] M 218.3, m 60.5°. Crystd from MeOH. [Alberti et al. J Am Chem Soc 108 3024 1986] Crystd repeatedly from hot diethyl ether, then vac dried at 30° over P2O5, fused under nitrogen and re-dried, the whole procedure being repeated, with a final drying under vac for 24 h. Also recrystd from hexane/EtOH soln. [Burkey and Griller J Am Chem Soc 107 246 1985.]


1,1-Diphenylethylene [530-48-3] M 180.3, b 268-270°, d 1.024, n 1.6088. Distd under reduced pressure from KOH. Dried with CaH2 and redistd.

N,N'-Diphenylethylenediamine (Wanzlick's reagent) [150-61-8] M 212.3, m 67.5°, b 178-182°/2 mm pKₑₓₓ₁₋₋ = 0.5, pKₑₓₓ₂₋₋ = 3.8. Crystd from aqueous EtOH or MeOH.

N,N'-Diphenylformamidine [622-15-1] M 196.2, m 142°, 137°, 136-139°. Crystd from absolute EtOH, gives the hydrate with aqueous EtOH.

1,3-Diphenylguanidine [102-06-7] M 211.3, m 148°, pK₂⁻ = 10.12. Crystd from toluene, aqueous acetone or EtOH, and vacuum dried.

1,6-Diphenyl-1,3,5-hexatriene [1720-32-7] M 232.3, m 200-203°. Crystd from CHCl₃ or EtOH/CHCl₃ (1:1).

5,5-Diphenylhydantoin [57-41-0] M 252.3, m 293-295°. Crystd from EtOH.

1,1-Diphenylhydrazine (hydrazobenzene) [122-66-7] M 184.2, m 34°, 44°, 175°/10 mm, 222°/40 mm, pKₑₓₓ = 1.7. Crystd from hot EtOH containing a little ammonium sulfide or H2SO3 (to prevent atmospheric oxidation), preferably under nitrogen. Dried in a vacuum desiccator. Also crystd from pet ether (b 60-100°) to constant absorption spectrum. HCl, from EtOH has m 163-164°(dec). Picrate, from *C₆H₆, has m 123°(dec).

1,3-Diphenylisobenzofuran [5471 -63-6] M 270.3, m 129-130°. Recrystd from EtOH or EtOH/CHCl₃ (1:1) under red light (as in photographic dark rooms) or from *benzene in the dark.

Diphenylmethane [101-81-5] M 168.2, m 25.4°. Sublimed under vacuum, or distd at 72-75°/4 mm. Crystd from EtOH. Purified by fractional crystn of the melt.


Diphenylmethyl chloride (benzhydryl chloride) [90-99-3] M 202.7, m 17.0°, b 167°/17 mm, n 1.5960. Dried with Na2SO4 and fractionally distd under reduced pressure.

all-trans-1,8-Diphenyl-1,3,5,8-octatetraene [3029-40-1] M 258.4, m 235-237°. Crystd from EtOH.

2,5-Diphenyl-1,3,4-oxadiazole (PPD) [725-12-2] M 222.3, m 70° (hydrate), 139-140° (anhydr), b 231°/13 mm, 248°/16 mm. Crystd from EtOH and sublimed in vacuo.

2,5-Diphenyloxazole (PPO) [92-71-7] M 221.3, m 74°, b 360°/760 mm. Distd in steam and crystd from ligroin.
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*N,N'-Diphenyl-p-phenylenediamine* \([74-31-7]\) M 260.3, m 148-149°, b 219-224°/0.7mm, \(pK_{	ext{Et}_2} < 0\). Crystd from EtOH, chlorobenzene/pet ether or *benzene. Has also been crystd from aniline, then extracted three times with absolute EtOH.

1,1-Diphenyl-2-picrylhydrazine \([1707-75-1]\) M 195.3, m 174°(dec), 178-179.5°(dec). Crystd from CHCl₃, or *benzene/pet ether (1:1), then degassed at 100° and <10⁻⁵mm Hg for ca 50h to decompose the 1:1 molar complex formed with *benzene.

2,2-Diphenylpropionic acid \([5558-66-7]\) M 226.3, m 173-174°, \(pK_{	ext{Et}_2} \sim 3.8\). Crystd from EtOH.

3,3-Diphenylpropionic acid \([606-83-7]\) M 226.3, m 155°, \(pK_{	ext{Et}_2} \sim 4.5\). Crystd from EtOH.

Diphenyl sulfide \([139-66-2]\) M 186.3, b 145°/8mm, d 1.114, n 1.633. Washed with aqueous 5% NaOH, then water. Dried with CaCl₂, then with sodium. The sodium was filtered off and the diphenyl sulfide was distd under reduced pressure.

Diphenyl sulfone \([127-63-9]\) M 218.3, m 125°, b 378°(dec). Crystd from diethyl ether. Purified by zone melting.

Sym-Diphenylthiourea (thiocarbanilide) \([102-08-9]\) M 228.3, m 154°. Crystd from boiling EtOH by adding hot water and allowing to cool.

1,1-Diphenylurea \([603-54-3]\) M 212.3, m 238-239°. Crystd from MeOH.

Dipicolinic acid (pyridine-2,6-dicarboxylic acid) \([499-83-2]\) M 167.1, m 255°(dec), \(\lambda_{\text{max}} 270\text{nm}, \ pK_{1} 10.20, \ pK_{2} 4.68\). Crystd from water, and sublimed in a vacuum.

*N,N-Di-n-propylaniline* \([2217-07-4]\) M 177.3, b 127°/10mm, 238-241°/760mm, \(pK_{23} 5.68\). Refluxed for 3hr with acetic anhydride, then fractionally distd under reduced pressure.

Dipropylene glycol (octan-4,5-diol) \([110-98-5]\) M 134.2, b 109-110°/8mm, d 1.022, n 1.441. Fractionally distd below 15mm pressure, using packed column and taking precautions to avoid absorption of water.

Di-n-propyl ketone \([123-19-3]\) M 114.2, b 143.5°, d 0.8143, n 1.40732. Dried with CaSO₄, then distd from P₂O₅ under nitrogen.

Di-n-propyl sulfide \([111-47-7]\) M 118.2, b 141-142°, d 0.870, n 1.449. Washed with aqueous 5% NaOH, then water. Dried with CaCl₂ and distd from Na [Dunstan and Griffiths *J Chem Soc* 1344 1962].

Di-(4-pyridoyl)hydrazine \([4329-75-3]\) M 246.2, m 254-255°. Crystd from water.

2,2'-Dipyridylamine \([1202-34-2]\) M 171.2, m 84° and remelts at 95° after solidifying, b 176-178°/13mm, 307-308°/760mm, \(pK 6.69\) (in 20% EtOH). Crystd from *benzene or toluene [Blakley and De Armond *J Am Chem Soc* 109 4895 1987].

2,2'-Dipyridyl disulfide (2,2'dithiopyridine) \([2127-03-9]\) M 220.3, m 53°, 56-58°, 57-58°, \(pK_{1} 0.35, \ pK_{2} 2.45\). Recrystd from *C₆H₆/pet ether (6:7), ligroin or *C₆H₆. Picrate has m 119° (from EtOH). [Walter et al. *Justus Liebigs Ann Chem* 695 7785 1966; Marckwald et al. *Chem Ber* 33 1556 1900; Brocklehurst and Little *Biochem J* 133 6778 1973.]

1,2-Di-(4-pyridyl)-ethane \([4916-57-8]\) M 184.2, \(pK_{	ext{Et}_2} \sim 3.8, \ pK_{	ext{Et}_2} \sim 5.4\). Crystd from cyclohexane/*benzene (5:1).
trans-1,2-Di-(4-pyridyl)-ethylene [13362-78-2] M 182.2, m 153-154°, 155.5-156.5°, $pK_a^{1}$ 3.65, $pK_a^{2}$ 5.6. Crystd from water (1.6g/100mL at 100°). $Di$-$HCl$ has m 347°, from EtOH

1,3-Di-(4-pyridyl)-propane [17252-51-6] M 198.3, m 60.5-61.5°, $pK_{EtOH}$ -4.5, $pK_{EtOH}$ 5.5. Crystd from n-hexane/benzene (5:1).


2,5-Distyrylpyrazine [14990-02-4] M 284.3, m 219°. Recrystd from xylene; chromatographed on basic silica gel (60-80 mesh) using CH$_2$Cl$_2$ as eluent, then vac sublimed on to a cold surface at torr [Ebied Chem Soc, Faraday Trans 1 78 321 1982]. Operations should be carried out in the dark.

1,3-Dithiane [505-23-7] M 120.2, m 54°. Crystd from 1.5 times its weight of MeOH at 0°, and sublimed at 40-50°/0.1mm.

2,2'-Dithiobis(benzothiazole) [120-78-8] M 332.2, m 180°. Crystd from *benzene.


1,4-Dithierythritol (DTE, erythro-2,3-dihydroxy-1,4-dithiobutane) [6892-68-8] M 154.3, m 82-84°, $pK_1$ 9.0, $pK_2$ 9.9. Crystd from ether/hexane and stored in the dark at 0°.

Dithiooxamide (rubeanic acid) [79-40-3] M 154.3, m >300°. Crystd from EtOH and sublimed in a vacuum.

Dithiothreitol (DTT, Cleland's reagent) [27565-41-9] M 154.3, m 42-43°, $pK_1$ 8.3, $pK_2$ 9.5. Crystd from ether and sublimed at 37°/0.005mm. Should be stored at 0°.

Dithizone (diphenylthiocarbazone) [60-10-6] M 256.3, ratio of $\varepsilon_{620nm}/\varepsilon_{450nm}$ should be $\geq$1.65, $\varepsilon_{620}$ 3.4 x 10° (CHCl$_3$), $pK_2$ 4.6. The crude material is dissolved in CC$_4$ to give a concentrated soln. This is filtered through a sintered glass funnel and shaken with 0.8M aq ammonia to extract dithizonate ion. The aqueous layer is washed with several portions of CC$_4$ to remove undesirable materials. The aqueous layer is acidified with dil H$_2$SO$_4$ to precipitate pure dithizone. It is dried in a vacuum. When only small amounts of dithizone are required, purification by paper chromatography is convenient. [Cooper and Hibbits J Am Chem Soc 75 5084 1953.] Instead of CC$_4$, CHCl$_3$ can be used, and the final extract, after washing with water, can be evapd in air at 40-50° and dried in a desiccator. Complexes with Cd, Hg, Ni and Zn.


$N,N'$-Di-o-tolyguanidine [97-39-2] M 239.3, m 179° (175-176°), $pK_{EtOH}$ ~10.3. Crystd from aqueous EtOH.

Di-p-tolylphenylamine [20440-95-3] M 273.4, m 108.5°, $pK_{EtOH}$ ~5.0. Crystd from EtOH.


Djenkolic acid (S,S'-methylene-bis-L-cysteine) [498-59-9] M 254.3, m 300-350°(dec), $[\alpha]_{D}^{20}$ -65° (c 2, HCl) [See pK of S-methyl-L-cysteine]. Crystd from a large volume of water (sol 0.5g%).

$cis$-4,7,10,13,16,19-Docosahexaenoic acid [6217-54-5] M 328.5, m -44/10°, -44.1°, $n_D$ 1.5017, $pK_{EtOH}$ -4.6. Its solubility in CHCl$_3$ is 5%. It has been purified from fish oil by GLC using Ar as mobile phase and EGA as stationary phase with an ionisation detector [UV: Stoffel and Ahrens J Lipid Res 1
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1391959, and via the ester by evaporative "molecular" distillation using a 'continuous molecular still' at 10⁻⁴ mm with the highest temperature being 110⁰, and a total contact time with the hot surface being 60sec [Farmer and van den Heuvel J Chem Soc 427 1938]. The methyl ester has b 208-211⁰/2mm, d⁰ 0.9398, nD 1.5035. With Br₂ it forms a dodecabromide m ca 240° dec. Also the acid was converted to the methyl ester and purified through a three stage molecular still [as described by Sutton Chem Ind (London) 11383 1953] at 96⁰ with the rate adjusted so that one third of the material was removed each cycle of three distillations. The distillate (numbered 4) (13g) was dissolved in EtOH (100mL containing 8g of KOH) at -70⁰ and set aside for 4h at 30⁰ with occasional shaking under a vac. Water (100mL) is added and the soln is extracted with pentane, washed with HCl, dried (MgSO₄), filtered and evapd to give a clear oil (1.5g) m -44.5° to -44.1°. In the catalytic hydrogenation of the oil six mols of H₂ were absorbed and docosanoic acid (behenic acid) was produced with m 79.0-79.3° undepressed with an authentic sample [see docosanoic acid below] [Whitcutt Biochem J 67 60 1957].

**Docosane** [629-97-0] M 310.6, m 47⁰, b 224°/15mm. Crystd from EtOH or ether.


1-Docosanol (behenyl alcohol) [661-19-8] M 182.3, m 70.8⁰. Crystd from ether or chloroform/ether.

**n-Dodecane** [112-40-3] M 170.3, b 97.5-99.5⁰/5mm, 216⁰/760mm, d 0.748, n 1.42156. Passed through a column of Linde type 13X molecular sieves. Stored in contact with, and distd from, sodium. Passed through a column of activated silica gel. Has been crystd from diethyl ether at -60⁰. Unsaturated dry material which remained after passage through silica gel has been removed by catalytic hydrogenation (Pt20) at 451b/in² (3.06 atmospheres), followed by fractional distn under reduced pressure [Zook and Goldey J Am Chem Soc 75 3975 1953]. Also purified by partial crystn from the melt.

Dodecane-1,10-dioic acid (decane-1,10-dicarboxylic acid) [693-23-2] M 230.3, m 129⁰, b 245°/10mm, pKₑᵢ -4.8. Crystd from water, 75% or 95% EtOH (sol 10%), or glacial acetic acid.

1-Dodecanol (dodecyl alcohol) [112-53-8] M 186.3, m 24⁰, b 91°/1mm, 135°/10mm, 167°/40mm, 213°/200mm, 259°/atm, d²⁴ 0.8309 (liquid). Crystd from aqueous EtOH, and vacuum distd in a spinning-band column. [Ford and Marvel Org Synth 10 62 1930.]

1-Dodecanthiol [112-55-0] M 202.4, b 111-112°/3mm, 153-155°/24mm, d 0.844, n 1.458, pKₑᵢ -10.8. Dried with CaO for several days, then distd from CaO.


Dodecyl ether [4542-57-8] M 354.6, m 33⁰. Vacuum distd, then crystd from MeOH/*benzene.


Dodecyltrimethylammonium chloride \([112-00-5]\) M 263.9, m 246°(dec). Dissolved in MeOH, treated with active charcoal, filtered and dried in vacuo [Waldenburg J Phys Chem 88 1655 1984], or recrystd several times from 10% EtOH in acetone. Also repeatedly crysptd from EtOH/ether or MeOH. [Cella et al. J Am Chem Soc 74 2062 1952.]

Dulcitol \([606-66-2]\) M 182.2, m 188-189°, b 276-280°/1.1mm. Crystd from water by addition of EtOH.

Duroquinone (tetramethylbenzoquinone) \([527-17-3]\) M 164.2, m 110-111°. Also repeatedly crystd from EtOH, ether or MeOH. [Cella et al. J Am Chem Soc 74 2062 1952.]

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Duroquinone (tetramethylbenzoquinone) \([527-17-3]\) M 164.2, m 110-111°. Also repeatedly crystd from EtOH, ether or MeOH. [Cella et al. J Am Chem Soc 74 2062 1952.]

α-Ecdyson \([3604-87-3]\) M 464.7, m 239-242°, 242°, \(\alpha\)\(^{20}\) +72° (c 1, EtOH). Recrystd from tetrahydrofuran-pet ether, and from \(\text{H}_2\text{O}\) as a hydrate. It has been purified by chromatography on Al2 O3 and elution with EtOAc-MeOH. It has \(\lambda\) max at 242nm (\(c\) 12.400). Its acetate has m 214-216° from EtOAc-pet ether, and the 2,4-dinitrophenylhydrazone has m 170-175°(dec) from EtOAc. [Karlson and Hoffmeister Justus Liebigs Ann Chem 662 11963; Karlson Pure Appl Chem 14 75 1967.]

β-Ecdyson (β-echdysterone) \([5289-74-7]\) M 480.7, m 245-247°, \(\alpha\)\(^{20}\) +66° (c 1, MeOH). Crystd from water or tetrahydrofuran/pet ether.

Echinenone \([432-68-8]\) M 550.8, m 178-179°. A \(1\%\) (\(\lambda\) max \(2160\) (458nm) in pet ether. Purified by chromatography on partially deactivated alumina or magnesia, or by using a thin layer of silica gel G with 4:1 cyclohexane/diethyl ether as the developing solvent. Stored in the dark at -20°.

Eicosane \([112-95-8]\) M 282.6, m 36-37°, b 205°/15mm, d 36.7 0.7779, d\(^0\) 1.43453. Crystd from EtOH.

Elaidic (trans-oleic) acid \([112-79-8]\) M 282.5, m >360°, pK\(_{25}\) 4.9. Crystd from acetic acid, then EtOH.

Ellagic acid \((2H_2O)\) \([476-66-4]\) M 338.2, m >360°, pK\(_{\text{Est}(1)}\) -8, pK\(_{\text{Est}(2)}\) -11. Crystd from pyridine.

Elymoclavine \((8,9\text{-didehydro-6-methylergoline-8-methanol})\) \([548-43-6]\) M 254.3, m 249-253°(dec), \(\alpha\)\(^{20}\) -59° (c 1, EtOH). Crystd from MeOH.

Embonic acid (Pamoic acid, 4,4'-methylene bis[3-hydroxy-2-naphthalene carboxylic acid]) \([130-85-8]\) M 388.4, m 295°, >300°, pK\(_{\text{Est}(1)}\) -2.2, pK\(_{\text{Est}(2)}\) -13.2. Forms crystals from dilute pyridine which decomposition above 280° without melting. It is almost insoluble in \(\text{H}_2\text{O}\), EtOH, Et2O, \(\text{CH}_4\text{H}_6\), \(\text{CH}_3\text{CO}_2\text{H}\), sparingly soluble in \(\text{CHCl}_3\) but soluble in nitrobenzene, pyridine and alkalis [Barber and Gaimster J Appl Chem (London) 2 565 1952]. Used for making salts of organic bases.

Emetine hydrochloride hydrate \([316-42-7]\) M 553.6 + aq, m 235-240°, 235-250°, 240-250°, 248-250° (depending on \(\text{H}_2\text{O}\) content), \(\alpha\)\(^{20}\) -49.2° (free base, c 4, \(\text{CHCl}_3\), +18° (c 6, \(\text{H}_2\text{O}\), dry salt), pK\(_1\) 5.77, pK\(_2\) 6.64. It crystallises from MeOH-Et2O, MeOH or Et2O-EtOAc. The free base has m 104-105°, and the (-)-phenyl thiourea derivative has m 220-221° [from EtOAc-pet ether, \(\alpha\)\(^{25}\) -29.3° (\(\text{CHCl}_3\)). IR: 3413 (OH) and 261 1 (NH+) cm\(^{-1}\); UV \(\lambda\) max 230nm (\(c\) 16 200) and 282nm (\(c\) 6 890) [Brossi et al. Helv Chim Acta 42 1515 1959; Barash et al. J Chem Soc 3530 1959].

Emodine (1,3,8-trihydroxy-6-methyl-9,10-anthracenedione, archin) \([518-82-1]\) M 270.2, m 253-257°, 255-256°, 256-257°, 262°, 264° (phenolic pK\(_7\) 7-10). Forms orange needles from EtOH, Et2O, \(\text{C}_6\text{H}_6\), toluene or pyridine. It sublimes above 200° at 12mm. [Tutin and Clewer J Chem
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(−) Ephedrine hydrochloride [50-98-6] M 201.7, m 218°, [α]_{546}^{20} -48° (c 5, 2M HCl). Crystd from water.


R(−) Epinephrine (adrenalin) [51-43-4] M 183.2, m 215°(dec), [α]_{546}^{20} -61° (c 5, 0.5M HCl), K_{25} 8.75, K_{35}^{25} 9.89, K_{35}^{25} -13. Dissolved in dilute aqueous acid, then ppted by addn of dilute aqueous ammonia or alkali carbonates. (Epinephrine readily oxidises in neutral alkaline soln. This can be diminished if a little sulfite is added).

1,2-Epoxybutane [106-88-7] M 72.1, b 66.4-66.6°, d 0.837, n 1.3841. Dried with CaSO_{4}, and fractionally distd through a long (126cm) glass helices-packed column. The first fraction contains a water azeotrope.

(+) Equilenine [517-09-9] M 266.3, m 258-259°, [α]^{16}_{D} +87° (c 7.1, H_{2}O). Crystd from EtOH and dried in a vacuum.

Ergocornine [564-36-3] M 561.7, m 182-184°, [α]_{D}^{20} -176° (c 0.5, CHCl_{3}). Crystd with solvent of crystn from MeOH.

Ergocristine [511-08-0] M 573.7, m 165-170°, [α]_{D}^{20} -183° (c 0.5, CHCl_{3}). Crystd with 2 moles of solvent of crystn from *benzene.

Ergocryptine [511-09-1] M 575.7, m 212-214°, [α]_{D}^{20} -180° (c 0.5, CHCl_{3}). Crystd with solvent of crystn, from acetone, *benzene or methanol.

Ergosterol [57-87-4] M 396.7, m 165-166°, [α]_{546}^{20} -171° (in CHCl_{3}). Crystd from ethyl acetate, then from ethylene dichloride.

Ergotamine [113-15-5] M 581.6, m 212-214°(dec), [α]_{D}^{20} -160° (c 0.5, CHCl_{3}), K_{25} 6.40. Crystd from *benzene, then dried by prolonged heating in high vacuum. Very hygroscopic.


Eruccic acid (cis-13-docosenoic acid) [112-86-7] M 338.6, m 33.8°, b 358°/400mm, K_{E}_{st} ~4.9. Crystd from MeOH.

meso-Erythritol [149-32-6] M 122.1, m 122°. Crystd from distd water and dried at 60° in a vac oven.

Erythrityl tetranitrate [7297-25-8] M 302.1, m 61°. Crystd from EtOH.

β-Erythroidine [466-81-9] M 273.3, [α]_{D}^{20} + 89° (H_{2}O). Crystd from EtOH.

D-Erythronic acid (3R,34-dihydroxyfuran-2-one) [15667-21-7] M 118.1, m 98-100°, 103-104°, 104-105°, 105°, [α]_{D}^{20} -73.2° (c 0.5, H_{2}O), [α]_{546}^{20} -87.6° (c 4, H_{2}O). Recrystd from EtOAc (20 parts) or isoPrOH (3 parts). [Baker and MacDonald J Am Chem Soc 82 230 1960; Glattfeld and

**Esculetin** (cichorigenin, 6,7-dihydroxycoumarin) [305-01-1] M 178.2, m 272-275° (dec), 274° (dec), pK_{Ent1} -8.7, pK_{Ent2} -12.4. Forms prisms from AcOH or aq EtOH and provides leaflets on sublimation in a vacuum. [Sethna and Shah *Chem Rev*; Merz *Arch Pharm (Weinheim Ger)* **270** 486 1932.]

**Esolecin** (the 6-glucoside) has m 215O (dec), [ago -41O (c 5, pyridine).

**Eserine** (Physostigmine, Physostol, [(3aS-cis)-1,2,3,3a,8,8a-hexahydro-1,3a,8-trimethyl-pyrrolo[2,3-b]indoI-5-01 meth lcarbamate ester] [57-47-6] M 275.4, m 102-104°, 105-106°, [α]_{D}^{25} -67O (c 1.3, CHC13), [α]_{D}^{25} -120O (*C6H6), pK_{2}^{15} 1.96, pK_{1}^{15} 8.08. Recrystallises from Et20 or *C6H6 and forms an unstable low melting form m 86-87° [Harley-Mason and Jackson *J Chem Soc* 3651 1954; Wijnberg and Speckamp *Tetrahedron* **34** 2399 1978].

**1,3,5-Estratrien-3-ol-17-one** (Estrone Folliculin) [53-16-7] M 270.4, m 254° and 256°, [α]_{546}^{20} +198O (c 1, dioxane), pK_{2}^{15} 10.91. Crystd from EtOH.

**1,3,5-Estratrien-3,16a,17β-triol** (Estriol) [50-27-1] M 288.4, m 283O, [α]_{546}^{20} +66O (c 1, dioxane). Crystd from EtOH/ethyl acetate.

**Ethane** [74-84-0] M 30.1, f -172O, b -88O, d_{4}^{0} 1.0493 (air = 1). Ethylene can be removed by passing the gas through a sintered-glass disc into fuming H2SO4 then slowly through a column of charcoal satd with bromine. Bromine and HBr were removed by passage through firebrick coated with N,N-dimethyl-p-toluidine. The ethane was also passed over KOH pellets (to remove CO2) and dried with Mg(C104)2. Further purification was by several distns of liquified ethane, using a condensing temperature of -195°. Yang and Gant [J Phys Chem **65** 1861 1961] treated ethane by standing it for 24h at room temperature in a steel bomb containing activated charcoal treated with bromine. They then immersed the bomb in a Dry-ice/acetone bath and transferred the ethane to an activated charcoal trap cooled in liquid nitrogen. (The charcoal had previously been degassed by pumping for 24h at 450°.) By allowing the trap to warm slowly, the ethane was distd, retaining only the middle third. Removal of methane was achieved using Linde type 13X molecular sieves (previously degassed by pumping for 24h at 450°) in a trap which, after cooling in Dry-ice/acetone, was satd with ethane. After pumping for 10min, the ethane was recovered by warming the trap to room temperature. (The final gas contained less than 10⁻⁴ mole % of either ethylene or methane).

**Ethanesulfonyl chloride** [594-44-5] M 128.6, b 55°/9mm, 62°/12mm, 74°/19mm, 76-79°/22mm, 95-98°/50mm, 177°/760mm, d_{4}^{20} 1.357, n_{D}^{20} 1.4539. Purified by repeated distn to remove HCl formed from hydrolysis. Fuming, corrosive liquid, handle in a good fumehood. It is hydrolysed by aq N NaOH at room temperature and is best stored in aliquots in sealed ampules under N2. [Davies and Dick *J Chem Soc* 484 1932; Klamann and Drahovzal *Monatsh Chem* **83** 463 1952; Saunders et al. *Biochem J* **36** 372 1942.]

**Ethanethiol** (ethyl mercaptan) [75-08-1] M 62.1, b 32°/704mm, d_{5}^{20} 0.83147, pK_{2}^{25} 10.61. Dissolved in aqueous 20% NaOH, extracted with a small amount of *benzene and then steam distd until clear. After cooling, the alkaline soln was acidified slightly with 15% H2SO4 and the thiol was distd off, dried with CaSO4, CaCl2 or 4A molecular sieves, and fractionally distd under nitrogen [Ellis and Reid *J Am Chem Soc* **54** 1674 1932].

**Ethanol** [64-17-5] M 46.1, b 78.3°, d_{5}^{15} 0.79360, d_{5}^{5} 0.78506, n 1.36139, pK_{2}^{25} 15.93. Usual impurities of fermentation alcohol are fusel oils (mainly higher alcohols, especially pentanols), aldehydes, esters, ketones and water. With synthetic alcohol, likely impurities are water, aldehydes, aliphatic esters, acetone and diethyl ether. Traces of *benzene are present in ethanol that has been dehydrated by azeotropic distillation with *benzene. Anhydrous ethanol is very hygroscopic. Water (down to 0.05%) can be detected by formation of a voluminous ppte when aluminium ethoxide in *benzene is added to a test portion. Rectified
spirit (95% ethanol) is converted to *absolute* (99.5%) ethanol by refluxing with freshly ignited CaO (250g/L) for 6h, standing overnight and distilling with precautions to exclude moisture.

Numerous methods are available for further drying of *absolute* ethanol for making "Super dry ethanol". Lund and Bjerrum [Chem Ber 64 210 1931] used reaction with magnesium ethoxide, prepared by placing 5g of clean dry magnesium turnings and 0.5g of iodine (or a few drops of CCl₄), to activate the Mg, in a 2L flask, followed by 50-75 mL of *absolute* ethanol, and warming the mixture until a vigorous reaction occurs. When this subsides, heating is continued until all the magnesium is converted to magnesium ethoxide. Up to 1L of ethanol is added and, after an hour's reflux, it is distd off. The water content should be below 0.05%

Walden, Ulich and Laun [Z Phys Chem 114 275 1925] used amalgamated aluminium chips, prepared by degreasing aluminium chips (by washing with Et₂O and drying in a vac to remove grease from machining the Al), treating with alkali until hydrogen was vigorously evolved, washing with H₂O until the washings were weakly alkaline and then stirring with 1% HgCl₂ soln. After 2min, the chips were washed quickly with H₂O, then alcohol, then ether, and dried with filter paper. (The amalgam became warm.) These chips were added to the ethanol, which was then gently warmed for several hours until evolution of hydrogen ceased. The alcohol was distd and aspirated for some time with pure dry air. Smith [J Chem Soc 1288 1927] reacted 1L of *absolute* ethanol in a 2L flask with 7g of clean dry sodium, and added 25g of pure ethyl succinate 27g of pure ethyl phthalate was an alternative), and refluxed the mixture for 2h in a system protected from moisture, and then distd the ethanol. A modification used 40g of ethyl formate, instead, so that sodium formate separated out and, during reflux, the excess of ethyl formate decomposed to CO and ethanol.

Drying agents suitable for use with ethanol include Linde type 4A molecular sieves, calcium metal, and CaH₂. The calcium hydride (2g) was crushed to a powder and dissolved in 100mL *absolute* ethanol by gently boiling. About 70mL of the ethanol were distd off to remove any dissolved gases before the remainder was poured into 1L of *ca* 99.9% ethanol in a still, where it was boiled under reflux for 20h, while a slow stream of pure, dry hydrogen (better use nitrogen or Ar) was passed through. It was then distd [Rüber Z Elektrochem 29 334 1923]. If calcium was used for drying, about ten times the theoretical amount should be taken, and traces of ammonia (from some calcium nitride in the Ca metal) would be removed by passing dry air into the vapour during reflux.

Ethanol can be freed from traces of basic materials by distn from a little 2,4,6-trinitrobenzoic acid or sulfanilic acid. *Benzene can be removed by fractional distn after adding a little water (the *benzene/water/ethanol azeotrope distills at 64.9°); the alcohol is then redried using one of the methods described above. Alternatively, careful fractional distn can separate *benzene as the *benzene/ethanol azeotrope (b 68.2°). Aldehydes can be removed from ethanol by digesting with 8-10g of dissolved KOH and 5-10g of aluminium or zinc per L, followed by distn. Another method is to heat under reflux with KOH (20g/L) and AgNO₃ (10g/L) or to add 2.5-3g of lead acetate in 5mL of water to 1L of ethanol, followed (slowly and without stirring) by 5g of KOH in 25mL of ethanol: after 1hr the flask is shaken thoroughly, then set aside overnight before filtering and distilling. The residual water can be removed by standing the distillate over activated aluminium amalgam for 1 week, then filtering and distilling. Distn of ethanol from Raney nickel eliminates catalyst poisons.

Other purification procedures include pre-treatment with conc H₂SO₄ (3mL/L) to eliminate amines, and with KMnO₄ to oxidise aldehydes, followed by refluxing with KOH to resinify aldehydes, and distilling to remove traces of H₃PO₄ and other acidic impurities after passage through silica gel, and drying over CaSO₄. Water can be removed by azeotropic distn with dichloromethane (azeotrope boils at 38.1° and contains 1.8% water) or 2,2,4-trimethylpentane.

**Rapid purification:** Place degreased Mg turnings (grease from machining the turnings is removed by washing with dry EtOH then Et₂O, and drying in a vac) (5g) in a dry 2L round bottomed flask fitted with a reflux condenser (protect from air with a drying tube filled with CaCl₂ or KOH pellets) and flush with dry N₂. Then add iodine crystals (0.5g) and gently warm the flask until iodine vapour is formed and coats the turnings. Cool, then add EtOH (50mL) and carefully heat to reflux until the iodine disappears. Cool again and add more EtOH (to 1L) and reflux under N₂ for several hours. Distil and store over 3A molecular sieves (pre-heated at 300° -350° for several hours and cooled under dry N₂ or argon).

**S-Ethionine** [13073-35-3] M 163.2, m 282°(dec), [α]D²⁵ +23.7° (in 5M HCl), pK₂²⁵ 9.02 (for RS). Likely impurities are N-acetyl-(R and S)-ethionine, S-methionine, and R-ethionine. Crystd from water by adding 4 volumes of EtOH.
Ethoxycarbonyl isocyanate \[ \text{[19617-43-7]} \] M 115.1, b 51-55°/13mm, 56°/18mm, d\textsuperscript{2} 1.15. Fractionally distilled. \[ J \text{Heterocycl Chem} 5 837 1968. \]

Ethoxycarbonyl isothiocyanate \[ \text{[16182-04-0]} \] M 131.5, b 43°/14mm, 51-55°/13mm, 56°/18mm, d\textsuperscript{2} 1.12. Fractionally distill through a short column. It also distils at 83°/30mm with some decomposition liberating CO\textsubscript{2} and sulfurous gases, best distil below 20mm vacuum. \[ J \text{Chem Soc} 93 697 1908; 1340, 1948; J \text{Heterocycl Chem} 5 837 1968. \]

3-Ethoxy-N,N-diethylaniline \[ \text{[1846-92-2]} \] M 193.3, b 141-142°/15mm pK\textsubscript{est} -6.1. Refluxed for 3h with acetic anhydride, then fractionally distilled under reduced pressure.

2-Ethoxyethanol \[ \text{[110-80-5]} \] M 90.1, b 134.8°, d 0.931, n 1.40751. Dried with CaSO\textsubscript{4} or K\textsubscript{2}CO\textsubscript{3}, filtered and fractionally distill. Peroxides can be removed by refluxing with anhydrous SnCl\textsubscript{2} or by filtration under slight pressure through a column of activated alumina.

2-Ethoxy-1-ethoxycarbonyl-1,2-dihydroquinoline (EEDQ) \[ \text{[16357-59-8]} \] M 247.3, m 63.5-65°, 66-67°. Dissolve ~180g in CHCl\textsubscript{3}, evap to dryness under vac. Add dry Et\textsubscript{2}O (20mL) when a white solid separates on standing. Set aside for a few hours, collect solid, wash thoroughly with cold Et\textsubscript{2}O and dry in vac (-14Og, m 63.5-65°). A further crop of solid (~25g) is obtained from the filtrate on standing overnight. \[ Fieser and Fieser \text{Reagents for Organic Synthesis} 2 191 1969; Belleau et al. J \text{Am Chem Soc} 90 823 1968 and 90 1651 1968. \]

2-Ethoxyethyl ether \[ \text{[bis-(2-ethoxyethyl) ether]} \] \[ \text{[112-36-7]} \] M 162.2, b 76°/32mm, d 0.910, n 1.412. See diethyleneglycol diethyl ether on p. 203.

2-Ethoxycarbonyl ethyl methacrylate \[ \text{[23 70-63-0]} \] M 158.2, b 91-93°/35mm, d 0.965, n 1.429. Purified as described under methyl methacrylate.

1-Ethoxynaphthalene \[ \text{[5328-01-8]} \] M 172.2, b 136-138°/14mm, 282°/760mm, d 1.061, n 1.604. Fractionally distill (twice) under a vacuum, then dried with, and distill under a vacuum from, sodium.

2-Ethoxynaphthalene \[ \text{[93-18-5]} \] M 172.2, m 35.6-36.0°, b 142-143°/12mm. Crystd from pet ether. Dried under vacuum or distill in a vacuum.

Ethyl acetimidate \[ \text{[1000-84-6]} \] M 87.1, b 92-95°/atm, 89.7-90°/765mm, d 0.8671, n 1.4025, pK\textsubscript{est} -5.5. It is best to prepare it freshly from the hydrochloride (see below). Dissolve the hydrochloride (123.5g) by adding it slowly to an ice-cold mixt of H\textsubscript{2}O (500mL), K\textsubscript{2}CO\textsubscript{3} (276g) and Et\textsubscript{2}O (200mL) and stirring rapidly. The Et\textsubscript{2}O layer was separated, the aq layer was extd with Et\textsubscript{2}O (100mL), the combined Et\textsubscript{2}O layers were dried (MgSO\textsubscript{4}), evapd and the residual oil distill through a glass helices packed column (70x1.2cm). The yield was 19g (22%). \[ Glickman and Cope J \text{Am Chem Soc} 67 1020 1945; Chaplin and Hunter J Chem Soc 1118 1937; Methods Enzymol 25 585 1972. \]

Ethyl acetimidate hydrochloride \[ \text{[2208-07-3]} \] M 123.6, m 98-100°(dec), 110-115° (dec), 112-113°(dec), m 112-114°(dec), pK\textsubscript{est} -5.5. Recrystill by dissolving in the minimum volume of super dry EtOH and addition of dry Et\textsubscript{2}O or from dry Et\textsubscript{2}O. Dry in vacuum and store in a vacuum desiccator. Alternatively it could be crystd from EtOH (containing a couple of drops of ethanolic HCl) and adding dry Et\textsubscript{2}O. Filter and dry in a vac desiccator over H\textsubscript{2}SO\textsubscript{4} and NaOH. \[ Pinner \text{Chem Ber} 16 1654 1883. \] \[ Glickman and Cope J Am Chem Soc 67 1020 1945; Chaplin and Hunter J Chem Soc 1118 1937; McElvain and Schroeder J Am Chem Soc 71 40 1949; McElvain and Tate J Am Chem Soc 73 2233 1951; Methods Enzymol 25 585 1972. \]

Ethyl acetate \[ \text{[141-78-6]} \] M 88.1, b 77.1°, d 0.9003, n 1.37239, n\textsuperscript{25} 1.36979, pK\textsuperscript{25} -6.93 (aq H\textsubscript{2}SO\textsubscript{4}). The commonest impurities are water, EtOH and acetic acid. These can be removed by washing with aqueous 5% Na\textsubscript{2}CO\textsubscript{3}, then with saturated aqueous CaCl\textsubscript{2} or NaCl, and drying with K\textsubscript{2}CO\textsubscript{3}, CaSO\textsubscript{4} or MgSO\textsubscript{4}. More efficient drying is achieved if the solvent is further dried with P\textsubscript{2}O\textsubscript{5}, CaH\textsubscript{2} or molecular sieves before...
purification. CaO has also been used. Alternatively, ethanol can be converted to ethyl acetate by refluxing with acetic anhydride (ca. 1 mL per 10 mL of ester); the liquid is then fractionally distilled, dried with K₂CO₃ and redistilled.

**Rapid purification:** Distil, dry over K₂CO₃, distil again, and store over 4 Å molecular sieves.

**Ethyl acetooacetate** [141-97-9] M 130.1, b 71°/12 mm, 100°/80 mm, d 1.026, n 1.419, pK² 10.68. Shaken with small amounts of saturated aqueous NaHCO₃ (until no further effervescence), then with water. Dried with MgSO₄ or CaCl₂. Distilled under reduced pressure.

**Ethyl acrylate** [140-88-5] M 100.1, b 20°/40 mm, 99.5°/atm, d 0.922, n 1.406. Washed repeatedly with aqueous NaOH until free from inhibitors such as hydroquinone, then washed with saturated aqueous CaCl₂ and distilled under reduced pressure. Hydroquinone should be added if the ethyl acrylate is to be stored for extended periods. **LACHRYMATORY.**

**Ethylamine** [75-04-7] M 45.1, b 16.6°/760 mm, d 1.3663, pK₀ 10.79. Condensed in an all-glass apparatus cooled by circulating ice-water, and stored with KOH pellets below 0°.


**p-Ethylaniline** [589-16-2] M 121.2, b 88°/8 mm, d 0.975, n 1.554, pK² 5.00. Dissolved in *benzene, then acetylated. The acetyl derivative was recrystallised from *benzene/pet ether, and hydrolysed by refluxing 50 g with 500 mL of water and 115 mL of conc H₂SO₄ until the solution became clear. The amine sulfate was isolated, suspended in water and solid KOH was added to regenerate the free base, which was separated, dried and distilled from zinc dust under a vacuum [Berliner and Berliner J Am Chem Soc 76 6179 1954].

**Ethylbenzene** [100-41-6] M 106.2, b 136.2°, d 0.867, n 1.49594, n² 1.49330. Shaken with cold conc H₂SO₄ until a fresh portion of acid remained colourless, then washed with aqueous 10% NaOH or NaHCO₃, followed by distilled water until neutral. Dried with MgSO₄ or CaSO₄, then dried further with, and distilled from, sodium, sodium hydride, or CaH₂. Can also be dried by passing through silica gel. Sulfur-containing impurities have been removed by prolonged shaking with mercury. Also purified by fractional freezing.

**Ethyl benzoate** [93-89-0] M 150.2, b 98°/19 mm, 212.4°/760 mm, d 1.046, n¹ 1.5074, n² 1.5043, pK -7.37 (aq H₂SO₄). Washed with aq 5% Na₂CO₃, then satd CaCl₂, dried with CaSO₄ and distilled under reduced pressure.

**Ethyl bis-(2,4-dinitrophenyl)acetate** [5833-18-1] M 358.3, m 150-153°. Crystallized from toluene as pale yellow crystals.

**Ethyl bixin** [6895-43-8] M 436.6, m 138°. Crystallized from EtOH.

**Ethyl bromide** [74-96-4] M 109.0, b 0°/165 mm, 38°/745 mm, d 1.460, n 1.4241. The main impurities are usually EtOH and water, with both of which it forms azeotropes. Ethanol and unsaturated compounds can be removed by washing with conc H₂SO₄ until no further coloration is produced. The ethyl bromide is then washed with water, aq Na₂CO₃, and water again, then dried with CaCl₂, MgSO₄ or CaH₂, and distilled from P₂O₅. Olefinic impurities can also be removed by storing the ethyl bromide in daylight with elementary bromine, later removing the free bromine by extraction with dil aq Na₂S₂O₃, drying the ethyl bromide with CaCl₂ and fractionally distilling. Alternatively, unsaturated compounds can be removed by bubbling oxygen containing ca 5% ozone through the liquid for an hour, then washing with aqueous Na₂SO₃ to hydrolyse ozonides and remove hydrolysis products, followed by drying and distillation.
Ethyl bromoacetate [105-36-2] M 167.0, b 158.5°/758mm, d 1.50, n 1.450. Washed with saturated aqueous Na₂CO₃ (three times), 50% aq CaCl₂ (three times) and saturated aqueous NaCl (twice). Dried with MgSO₄, CaCl₂ or CaCO₃, and distd. LACHRYMATORY.

Ethyl 2-(bromomethyl)acrylate [17435-72-2] M 193.1, b 38°/0.8mm, d 1.398, n 1.479. If it contains some free acid, add H₂O, cool, and neutralise with NaHC₀₃ until evolution of CO₂ ceases. Extract the mixt with Et₂O (3x) and dry combined extracts (Na₂SO₄, 3h). Evap Et₂O and dist ester collecting fraction b 39-40°/0.9mm and check spectra. [Prep and NMR: Ramarajan et al. Org Synth Coll Vol VII 211 1990.]

Ethyl α-bromopropionate [535-11-5] M 181.0, b 69-70°/25mm, d 1.39, n 1.477. Washed with saturated aqueous Na₂CO₃ (three times), 50% aq CaCl₂ (three times) and saturated aqueous NaCl (twice). Dried with MgSO₄, CaCl₂ or CaCO₃, and distd. LACHRYMATORY.

Ethyl bromopyruvate [70-23-5] M 195.0, b 47°/0.5mm, 71-73°/5mm, 87-104°/14mm, d₁⁰ 1.561, n₁⁰ 1.464. Most likely impurity is free carboxylic acid (bromopyruvic or bromoacetic acids). Dissolve in dry Et₂O or dry CHCl₃, stir with CaCO₃ until effervescence ceases, filter, (may wash with a little H₂O rapidly), dry (MgSO₄) and distil at least twice. The 2,4-dinitrophenylone has m 144-145°. [Burros and Holland J Chem Soc 672 1947; Letsinger and Laco J Org Chem 21 764 1956; Kruse et al. J Am Chem Soc 76 5796 1954.]

2-Ethyl-1-butanol [97-95-0] M 102.2, b 146.3°, n₁⁵ 1.4243, n₂⁵ 1.4205. Dried with CaSO₄ for several weeks, filtered and fractionally distd.

2-Ethylbut-1-ene [760-21-4] M 84.1, b 66.6°, d 0.833, n 1.423. Washed with saturated aqueous NaOH, then water. Dried with CaCl₂, filtered and fractionally distd.

Ethyl n-butyrate [105-54-4] M 116.2, b 49°/50mm, 119-120°/760mm, d 0.880, n 1.393. Dried with anhydrous CuSO₄ and distd under dry nitrogen.

Ethyl carbonate [105-58-8] M 118.1, b 124-125°, d 0.975, n 1.38287. See diethyl carbonate on p. 203.

Ethyl chloride [75-00-3] M 64.5, b 12.4°, d 0.8978, n 1.3676. Passed through absorption towers containing, successively, conc H₂SO₄, NaOH pellets, P₂O₅ on glass wool, or soda-lime, CaCl₂, P₂O₅. Condensed into a flask containing CaH₂ and fractionally distd. Has also been purified by illumination in the presence of bromine at 0° using a 1000W lamp, followed by washing, drying and distn.

Ethyl chloroacetate [105-39-5] M 122.6, b 143-143.2°, d 1.150, n₂⁵ 1.4192. Shaken with saturated aqueous Na₂CO₃ (three times), aqueous 50% CaCl₂ (three times) and saturated aqueous NaCl (twice). Dried with Na₂SO₄ or MgSO₄ and distd. LACHRYMATORY.

Ethyl chloroformate [541-41-3] M 108.5, m -81°, b 94-95°, d 1.135, n 1.3974. Washed several times with water, redistd using an efficient fractionating column at atmospheric pressure and a CaCl₂ guard tube to keep free from moisture [Hamilton and Sly J Am Chem Soc 47 435 1925; Saunders, Slocombe and Hardy, J Am Chem Soc 73 3796 1951]. LACHRYMATORY AND TOXIC.
Ethyl chrysanthemate (ethyl 2,2-dimethyl-3(c and t)-[2-methylpropenyl]-cyclopropane carboxylate) [97-41-6] M 196.3, b 98-102°/11mm, 117-121°/20mm. Purified by vacuum distn. The free trans-acid has m 54° (from, EtOAc) and the free cis-acid has m 113-116° (from EtOAc). The 4-nitrophenyl ester has m 44-45° (from pet ether) [Campbell and Harper J Chem Soc 283 1945; IR: Allen et al. J Org Chem 22 1291 1957].

Ethyl cinnamate [103-36-6] M 176.2, f 6.7°, b 127°/6mm, 272.7°/768mm, d 1.040, n 1.55983. Washed with aqueous 10% Na2CO3, then water, dried (MgSO4), and distd. The purified ester was saponified with aqueous KOH, and, after acidifying the soln, cinnamic acid was isolated, washed and dried. The ester was reformed by refluxing for 15h the cinnamic acid (25g) with abs EtOH (23g), conc H2SO4 (4g) and dry *benzene (100mL), after which it was isolated, washed, dried and distd under reduced pressure [Jeffery and Vogel J Chem Soc 658 1958].

Ethyl trans-crotonate [623-70-1] M 114.2, b 137°, d 0.917, n 1.425. Washed with aqueous 5% Na2CO3, washed with saturated CaCl2, dried with CaCl2 and distd.

Ethyl cyanoacetate [105-56-6] M 113.1, b 206.0°, d 1.061, n 1.41751. Shaken several times with aqueous 10% Na2CO3, washed well with water, dried with Na2SO4 and fractionally distd.


Ethylcyclohexane [1678-91-7] M 112.2, b 131.8°, d 0.789, n 1.43304, n25 1.43073. Purified by azeotropic distn with 2-ethoxyethanol, then the alcohol was washed out with water and, after drying, the ethylcyclohexane was redistd.

Ethyl cyclohexanecarboxylate [3289-28-9] M 156.2, b 76-77°/10mm, 92-93°/34mm, d 0.960, n 1.420. Washed with M sodium hydroxide solution, then water, dried with Na2SO4 and distd.

Ethyl diazoacetate [623-73-4] M 114.1, m -22°, b 42°/5mm, 45°/12mm, 85-86°/88mm, 140-141°/720mm, 140-143°/atm, d17.6 1.0852, nD 17.6 1.4588. A very volatile yellow oil with a strong pungent odour. EXPLOSIVE [distillation even under reduced pressure is dangerous and may result in an explosion — TAKE ALL THE NECESSARY PRECAUTIONS IF DISTILLATION IS TO BE CARRIED OUT]. It explodes in contact with conc H2SO4 - trace acid causes rapid decomp. It is slightly sol in H2O, but is miscible with EtOH, *C6H6, pet ether and Et2O. To purify dissolve in Et2O [using CH2Cl2 instead of Et2O protects the ester from acid], wash with 10%aq Na2CO3, dry (MgSO4), filter and repeat as many times as possible until the Et2O layer loses its yellow colour, remove the solvent below 20° (vac). Note that prolonged heating may lead to rapid decomp and low yields. It can also be purified by steam distn under reduced pressure but with considerable loss in yield. Place the residual oil in a brown bottle and keep below 10°, and use as soon as possible without distilling. [Womack and Nelson Org Synth Coll Vol III 392 1955; UV: Miller and White J Am Chem Soc 79 5974 1957; Fieser 1 367 1967.]

Ethyl dibromoacetate [617-33-4] M 245.9, b 81-82°/14.5mm, n22 1.4973. Washed briefly with conc aqueous NaHCO3, then with aqueous CaCl2. Dried with CaCl2 and distd under reduced pressure.

Ethyl α,β-dibromo-β-phenylpropionate [5464-70-0, erythro 30983-70-1] M 336.0, m 75°. Crystd from pet ether (b 60-80°).

Ethyl dichloroacetate [535-15-9] M 157.0, b 131.0-131.5°/401mm, d 1.28, n 1.438. Shaken with aqueous 3% NaHCO3 to remove free acid, washed with distd water, dried for 3 days with CaSO4 and distd under reduced pressure.
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Ethyl 3,3-diethoxypropionate \[10601-80-6\] M 190.2, b 58.5°/1.5mm, 65°/2mm, 95-96°/12mm, d^2_0 0.78, n_D^2 1.4101. Dissolve in dry Et_2O, and dry with solid NaHCO_3, filter and distil carefully fractionate [Dyer and Johnson J Am Chem Soc 56 223 1934].

Ethyl 1,3-dithiane-2-carboxylate \[20462-00-4\] M 192.3, b 75-77°/0.2mm, 96°/0.4mm, d^2_0 1.220, n_D^2 1.5379. Dissolve in CHCl_3, wash with aqueous K_2CO_3, 2 x with H_2O, dry over MgSO_4, filter, evaporate and distil [Eliel and Hartman J Org Chem 37 505 1972; Seebach Synthesis 1 17 1969].

Ethyl 1,3-dithiolane-2-carboxylate \[20461-99-8\] M 178.3, b 85°/0.1mm, d^2_0 1.250, n_D^2 1.538. Dissolve in CHCl_3, wash with aqueous K_2CO_3, 2 x with H_2O, dry over MgSO_4, filter, evaporate and distil [Hermann et al Tetrahedron Lett 2599 1973; Corey and Erickson J Org Chem 36 3553 1971].

Ethylene (ethene) \[74-85-1\] M 28.0, m -169.4°, b -102°/700mm. Purified by passage through a series of towers containing molecular sieves or anhydrous CaSO_4 or a cuprous ammonia soln, then conc H_2SO_4, followed by KOH pellets. Alternatively, ethylene has been condensed in liquid nitrogen, with melting, freezing and pumping to remove air before passage through an activated charcoal trap, followed by a further condensation in liquid air. A sputtered sodium trap has also been used, to remove oxygen.

Ethylene \[N,N'\text{-bis[(o-hydroxyphenyl)glycine]}\] \[1170-02-1\] M 360.4, m 249°(dec), pK_awt 1.8, pK_awt 4.8, pK_awt 9.0. Purified by extensive Soxhlet extraction with acetone. [Bonadies and Carrano J Am Chem Soc 108 4088 1986].

Ethylene carbonate (1,3-dioxolan-2-one) \[96-49-1\] M 88.1, m 37°, n 1.38. Dried over P_2O_5 then fractionally distd at 10mm pressure. Crystd from dry diethyl ether.

Ethylenediamine (1,2-diaminoethane) \[107-15-3\] M 60.1, f 11.0°, b 117.0°, d 0.897, n 1.45677, n_30^2 1.4513, pK_1' 6.86, pK_2' 9.92. Forms a constant-boiling (b 118.5°) mixture with water (15%) [hygroscopic and miscible with water]. Recommended purification procedure [Asthana and Mukherjee in J.F. Coetzee (ed), Purification of Solvents, Pergamon Press, Oxford, 1982 cf p 53]: to 1L of ethylenediamine was added 70g of type 5A Linde molecular sieves and shaken for 12h. The liquid was decanted and shaken for a further 12h with a mixture of CaO (50g) and KOH (15g). The supernatant was fractionally distd (at 20:1 reflux ratio) in contact with freshly activated molecular sieves. The fraction distilling at 117.2°/760mm was collected. Finally it was fractionally distilled from sodium metal. All distns and storage of ethylenediamine should be carried out under nitrogen to prevent reaction with CO_2 and water. Material containing 30% water was dried with solid NaOH (600g/L), heated on a water bath for 10h. Above 60°, separation into two phases took place. The hot ethylenediamine layer was decanted off, refluxed with 40g of sodium for 2h and distd [Putnam and Kobe Trans Electrochem Soc 74 609 1938]. Ethylenediamine is usually distd under nitrogen. Type 5A Linde molecular sieves (70g/L), then a mixture of 50g of CaO and 15g of KOH (15g). The supernatant was fractionally distd (at 20:1 reflux ratio) in contact with freshly activated molecular sieves. The fraction distilling at 117.2°/760mm was collected. Finally it was fractionally distilled from sodium metal. All distns and storage of ethylenediamine should be carried out under nitrogen to prevent reaction with CO_2 and water. Material containing 30% water was dried with solid NaOH (600g/L), heated on a water bath for 10h. Above 60°, separation into two phases took place. The hot ethylenediamine layer was decanted off, refluxed with 40g of sodium for 2h and distd [Putnam and Kobe Trans Electrochem Soc 74 609 1938]. Ethylenediamine is usually distd under nitrogen. Type 5A Linde molecular sieves (70g/L), then a mixture of 50g of CaO and 15g of KOH/L, with further dehydration of the supernatant with molecular sieves has also been used for drying this diamine, followed by distn from molecular sieves and, finally, from sodium metal. A spectroscopically improved material was obtained by shaking with freshly baked alumina (20g/L) before distn.

N,N'-Ethylenediaminediacetic acid (EDDA) \[5657-17-0\] M 176.2, m 222-224°(dec), pK_1 6.48, pK_2 9.57 (for NH groups). Crystd from water.

Ethylenediamine dihydrochloride \[333-18-6\] M 133.0, pK_1 6.86, pK_2 9.92. Crystd from water.

Ethylenediaminetetraacetic acid (EDTA) \[60-00-4\] M 292.3, m 253°(dec), pK_1 0.26, pK_2 0.96, pK_3 2.60, pK_4 2.67, pK_5 6.16, pK_6 10.26. Dissolved in aqueous KOH or ammonium hydroxide, and pted with dil HCl or HNO_3, twice. Boiled twice with distd water to remove mineral acid, then recrystd from water or dimethylformamide. Dried at 110°. Also recrystd from boiling 1N HCl, wash crystals with distd H_2O and dried in vacuo. [Ma and Ray Biochemistry 19 751 1980].

Ethylene dimethacrylate \[97-90-5\] M 198.2, b 98-100°/5mm, d 1.053, n 1.456. Distd through a short Vigreux column at about 1mm pressure, in the presence of 3% (w/w) of phenyl-b-naphthylamine.
Ethylene dimyristate [627-84-9] M 482.8, m 61.7°. Crystd from *benzene-MeOH or diethyl ether-MeOH, and dried in a vacuum desiccator.

Ethylene dipalmitate [624-03-3] M 538.9, m 69.1°. Crystd from *benzene-MeOH or diethyl ether-MeOH and dried in a vacuum desiccator.

Ethylene distearate [627-83-8] M 595.0, m 75.3°. Crystd from *benzene-MeOH or diethyl ether-MeOH and dried in a vacuum desiccator.

Ethylene glycol [107-21-1] M 62.1, b 68°/4mm, 197.9°/760mm, d 1.0986, n° 1.43312, n° 1.43056, pK° 10.6. Very hygroscopic, and also likely to contain higher diols. Dried with CaO, CaSO₄, MgSO₄ or NaOH and distd under vacuum. Further dried by reaction with sodium under nitrogen, refluxed for several hours and distd. The distillate was then passed through a column of Linde type 4A molecular sieves and finally distd under nitrogen, from more molecular sieves. Fractionally distd.


Ethylene glycol diacetate [111-55-7] M 146.2, b 190.1°, 79-81°/11mm, d° 1.4188, n 1.4150. Dried with CaCl₂, filtd (excluding moisture) fractionally distd under reduced pressure.

Ethylene glycol dibutyl ether [112-48-1] M 174.3, b 78-80°/0.2mm, d 1.105, n 1.42. Shaken with aq 5% Na₂CO₃, dried with MgSO₄ and stored with chromatographic alumina to prevent peroxide formation.

Ethylene glycol diethyl ether (1,2-diethoxyethane) [629-14-1] M 118.2, b 121.5°, d 0.842, n 1.392. After refluxing for 12h, a mixture of the ether (2L), conc HCl (27mL) and water (200mL), with slow passage of nitrogen, the soh was cooled, and KOH pellets were added slowly and with shaking until no more dissolved. The organic layer was decanted, treated with some KOH pellets and again decanted. It was refluxed with, and distd from sodium immediately before use. Alternatively, after removal of peroxides by treatment with activated alumina, the ether has been refluxed in the presence of the blue ketyl formed by sodium-potassium alloy with benzophenone, then distd.


Ethylene oxide [75-21-8] M 44.0, b 13.5°/746mm, d° 0.882, n° 1.3597. Dried with CaSO₄, then distd from crushed NaOH. Has also been purified by its passage, as a gas, through towers containing solid NaOH.

Ethylene thiourea (2-imidazolidinethione) [96-45-7] M 102.2, m 203-204°. Crystd from EtOH or amyl alcohol.

Ethylene urea (2-imidazolidone) [120-93-4] M 86.1, m 131°. Crystd from MeOH (charcoal).

Ethynylamine (aziridine) [151-56-4] M 43.1, b 55.5°/760mm, d 0.8321, pK° 8.00. See aziridine on p. 117.

2-Ethylethylenimine [2549-67-9] M 71.1, b 88.5-89°, pK° 8.31. Freshly distd from sodium before use. TOXIC.

Ethyl formate [109-94-4] M 74.1, b 54.2°, d 0.921, d° 0.909, n 1.35994, n° 1.3565. Free acid or alcohol is removed by standing with anhydrous K₂CO₃, with occasional shaking, then decanting and
distilling from P2O5. Alternatively, the ester can be stood with CaH2 for several days, then distd from fresh CaH2. Cannot be dried with CaCl2 because it reacts rapidly with the ester to form a crystalline compound.

**Ethyl gallate** [831-61-8] M 198.2, m 150-151°, 163-165°. Recryst from 1,2-dichloroethane. UV: λmax (neutral species) 275nm (ε 10 000); (anion) 235nm (ε 10 300), 279nm (ε 11 400) and 324nm (ε 8 500) [Campbell and Coppinger J Am Chem Soc 73 2708 1951].

**2-Ethyl-1-hexanol** [104-76-7] M 130.2, b 184.3°, d 0.833, n 1.431. Dried with sodium, then fractionally distd.

**2-Ethylhexyl vinyl ether** [37769-62-3, 103-44-6] M 156.3, b 177-178°/atm. Usually contains amines as polymerization inhibitors. These are removed by fractional distn.


**Ethyl iodide** (iodoethane) [75-03-6] M 156.0, b 72.4°, d 1.933, n15 1.5862, n25 1.5104. Drying with P2O5 is unsatisfactory, and with CaCl2 is incomplete. It is probably best to dry with sodium wire and distil [Hammond et al. J Am Chem Soc 82 704 1960]. Exposure of ethyl iodide to light leads to rapid decomposition, with the liberation of iodine. Free iodine can be removed by shaking with several portions of dil aq Na2S2O3 (until the colour is discharged), followed by washing with water, drying (with CaCl2, then sodium), and distn. The distd ethyl iodide is stored, over mercury, in a dark bottle away from direct sunlight. Other purification procedures include passage through a 60cm column of silica gel, followed by distn; and treatment with elemental bromine, extraction of free halogen with Na2S2O3 soln, followed by washing with water, drying and distn. Free iodine and HI have also been removed by direct distn through a LeBel-Henninger column containing copper turnings. Purification by shaking with alkaline solns, and storage over silver, are reported to be unsatisfactory.

**Ethyl isobutyrate** [97-62-1] M 116.2, b 110°, d 0.867, n 1.388. Washed with aqueous 5% Na2CO3, then with saturated aqueous CaCl2. Dried with CaSO4 and distd.


**3-Ethylisothionicotinamide** [10605-12-6] M 166.2, m 164-166°(dec). Cryst from EtOH.

**Ethyl isovalerate** [108-64-5] M 130.2, b 134.7°, d 0.8664, n 1.39621, n25 1.3975. Washed with aqueous 5% Na2CO3, then saturated aqueous CaCl2. Dried with CaSO4 and distd.


**Ethyl methacrylate** [97-63-2] M 114.2, b 599/100mm, d 0.915, n 1.515. Washed successively with 5% aqueous NaN02, 5% NaHSO3, 5% NaOH, then water. Dried with MgSO4, added 0.2% (w/w) of phenyl-β-naphthylamine, and distd through a short Vigreux column [Schulz J Am Chem Soc 80 1854 1958].

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Ethyl methyl ether [540-67-0] M 60.1, b 10.8°, d° 0.725. Dried with CaSO₄, passed through an alumina column (to remove peroxides), then fractionally distd.


3-Ethyl-4-methylpyridine [529-21-5] M 121.2, b 76°/12mm, 194.5°/750mm, d 0.947, n₁.510, pKₑₓt ~6.3. Dried with solid NaOH, and fractionally distd.

5-Ethyl-2-methylpyridine [104-90-5] M 121.2, b 178.5°/765mm, d 0.919, n 1.497, pK₂° 6.51. Purified by preparative GLC on a column of 20% squalene on Chromosorb P at 70°.

N-Ethylmorpholine [100-74-3] M 115.2, b 138-139°/763mm, d 0.912, n 1.445, pK₅ 7.67. Distd twice, then converted by HCl gas into the hydrochloride (extremely deliquescent) which was crystd from anhydrous EtOH-acetone (1:2) [Herries, Mathias and Rabin Biochem J 85 127 1962].

Ethyl nitroacetate [626-35-7] M 133.1, b 42-43°/0.2mm, 71-72°/3mm, 93-96°/9mm, 194-195°/atm, d₂⁰ 1.1953, n₁.4260, pK₂⁵ 5.82. Purified by repeated distn. IR 1748 (C=O), 1570 and 1337 (NO₂), and 800 cm⁻¹ [Hazeldine J Chem Soc 2525 1953]. The hydrazine salt crystallises from 95% EtOH or MeOH as yellow crystals m 104-105° [Ungnade and Kissinger J Org Chem 22 1661 1957, Emmons and Freeman J Am Chem Soc 77 4391 1955].

Ethyl p-nitrobenzoate [99-77-4] M 195.2, m 56°. Dissolved in diethyl ether and washed with aqueous alkali, then the ether was evaporated and the solid recrystd from EtOH.

Ethyl orthoformate [122-51-0] M 148.2, b 144°/760mm, d 0.892, n 1.391. Shaken with aqueous 2% NaOH, dried with solid KOH and distd from sodium through a 20cm Vigreux column.


p-Ethylphenol [123-07-9] M 122.2, m 47-48°, b 218.0°/762mm, n₂⁰ 1.5239, pK₂° 10.21. Non-acidic impurities were removed by passing steam through a boiling soln containing 1 mole of the phenol and 1.75 moles of NaOH (asaq 10% soln). The residue was cooled and acidified with 30% (v/v) H₂SO₄, and the free phenol was extracted into diethyl ether. The extract was washed with water, dried with CaSO₄ and the ether was evaporated. The phenol was distd at 100mm pressure through a Stedman gauze-packed column (see p. 441). It was further purified by fractional crystn by partial freezing, and by zone refining, under nitrogen [Biddiscombe et al. J Chem Soc 5764 1963]. Alternative purification is via the benzoate, as for phenol.

Ethyl phenylacetate [101-97-3] M 164.2, b 99-99.3°/14mm, d 1.030, n 1.499. Shaken with saturated aqueous Na₂CO₃ (three times), aqueous 50% CaCl₂ (twice) and saturated aqueous NaCl (twice). Dried with CaCl₂ and distd under reduced pressure.

3-Ethyl-5-phenylhydantoin (Ethotoin) [86-35-1] M 204.2, m 94°. Crystd from water.


3-Ethyl-3-phenyl-2,6-piperidinedione (Glutethimide) [77-21-4] M 217.3, m 84°. Crystd from diethyl ether or ethyl acetate/pet ether.

Ethyl propionate [105-37-3] M 102.1, b 99.1°, d 0.891, n₁⁵ 1.38643, n 1.38394. Treated with anhydrous CuSO₄ and distd under nitrogen.
2-Ethylpyridine [100-71-0] M 107.2, b 148.6°, d 0.942, pK₂ 5.89. Dried with BaO, and fractionally distd. Purified by conversion to the picrate, recryst and regeneration of the free base followed by distn.

4-Ethylpyridine [536-75-4] M 107.2, b 168.2-168.3°, d 0.942, pK₂ 6.02. Dried with BaO, and fractionally distd. Also converted to the picrate, recrystd and the free base regenerated and distd.


Ethyl pyruvate [617-35-6] M 116.1, m -50°, b 44-45°/10mm, 56°/20mm, 69-71°/42mm, 80°/23mm, 155-156°, d₂⁰ 1.047, nD₁⁰ 1.4052. Shake the ester with 10mL portions of satd aq CaCl₂ soln (removes ethyl acetate) and the organic layer is removed by centrifugation, decantation and filtration, and is distilled under reduced pressure. Purification of small quantities is carried out via the bisulfite adduct: the ester (2.2mL) is shaken with saturated NaHSO₃ (3.6mL), chill in a freezing mixture when crystals separate rapidly (particularly if seeded). After 5min EtOH (10mL) is added and the crystals are filtered off, washed with EtOH and Et₂O and dried. Yield ca 3g of bisulfite adduct.

Ethyl Red [2-(4-diethylaminophenylazo)benzoic acid] [76058-33-8] M 197.4, m 150-152°, pK₁ 2.5, pK₂ 9.5. Crystd from EtOH/diethyl ether or toluene. Indicator: pH 4.4 (red) and 6.2 (yellow)

Ethyl stearate [111-61-5] M 312.5, m 33°, b 213-215°/15mm. The solid portion was separated from the partially solid starting material, then crystd twice from EtOH, dried by azeotropic distn with benzene, and fractionally distd in a spinning-band column at low pressure [Welsh Trans Faraday Soc 55 52 1959].

Ethyl thiocyanate (ethyl rhodanide) [542-90-5] M 87.1, b 144-145°, d 1.011, n 1.462. Fractionally distd at atmospheric pressure. (CARE LACHRYMATOR.)


N-Ethyl thiourea [625-53-6] M 104.2, m 110°. Crystd from EtOH, MeOH or ether.

Ethyl trichloroacetate [515-84-4] M 191.4, b 100-100.5°/30mm, d 1.383. Shaken with saturated aqueous Na₂CO₃ (three times), aqueous 50% CaCl₂ (three times), saturated aqueous NaCl (twice), then distd with CaCl₂ and distd under reduced pressure.


Ethyl trifluoromethanesulfonate [425-75-2] M 178.1, b 115°/atm, 118-120°/atm, d₂⁰ 1.378, nD₁⁰ 1.336. The ester reacts slowly with H₂O and aqueous alkali. If its IR has no OH bands (~3000 cm⁻¹) then purify by redistillation. If OH bands are present then dilute with dry Et₂O and shake (carefully) with aqueous NaHCO₃ until effervescence ceases, then wash with H₂O and dry (MgSO₄), filter, evaporate and distil the residue under slight vacuum then at atmospheric pressure in a N₂ atmosphere. IT IS A POWERFUL ALKYLATING AGENT, AND THE FUMES ARE VERY TOXIC - CARRY ALL OPERATIONS IN AN EFFICIENT FUME CUPBOARD. [Gramstad and Hazeldine J Chem Soc 173 1956; Howells and McCown Chem Rev 77 69 1977.]
S-Ethyl trifluorothioacetate \[\text{M} 158.1, \text{b} \text{88-90°/atm, 90.5°/760mm, d}^2\text{1.255, n}^\circ\text{1.372. If IR is free of OH bands then fractionate, but if OH bands are present then dilute with dry Et}_2\text{O, wash with 5% KOH and H}_2\text{O, dry over MgSO}_4\text{ and fractionate through an efficient column [Hauptschein et al. J Am Chem Soc 74 4005 1952]. Powerful obnoxious odour.}}

Ethyl vinyl ether \[\text{M} 72.1, \text{b} \text{35.5°, d} 0.755. Contains polymerization inhibitors (usually amines, e.g. triethanolamine) which can be removed by fractional distillation. Redistilled from sodium. LACHRYMATORY.}

1-Ethynyl-1-cyclohexanol \[\text{M} 124.2, \text{m} 30-33°, 32-33°, \text{b} 74°/12mm, 76-78°/17mm, 171-172°/694mm, 180°/atm, d^2_{D} 0.9734, n^\circ_{D} 1.4801. Dissolve in Et}_2\text{O, wash with H}_2\text{O, dilute NaHCO}_3\text{, H}_2\text{O again, dry (Na}_2\text{SO}_4\text{), filter, evaporate and distil the residue. IR (CCl}_4\text{): 3448 (OH), 2941 (CH), 1449-1123 and 956 cm}^{-1}; \text{NMR (CCl}_4\text{) }\Delta_J: \text{3.2 (OH), 2.5 (=CH), 1.70 (m 10H, CH}_2\text{) [Hasbrouck and Kiessling J Org Chem 38 2103 1972].}

Ethynyl p-tolylsulfone \[\text{M} 180.2, \text{m} 73-74°. Recrystallized from pet ether and dried in vac.

Etiocholane (5β-androstosterone) \[\text{M} 260.5, \text{m} 78-80°. Crystallized from acetone.

Etiocholanic acid \[\text{M} 304.5, \text{m} 228-229°, pK}_{Est} -4.7. Crystallized from glacial acetic acid and sublimed at 160°/0.002mm. The methyl ester has m 99-101°. [Weiland et al. Z Physiol Chem 161 80 1926.]

Etioporphyrin I \[\text{M} 478.7, \text{m} 360-363°. Crystallized from pyridine or CHCl}_3\text{-pet ether.}

Eucaliptol (1,8-cineol, 1,8-epoxy-p-menthane, 1,3,3-trimethyl-2-oxabicyclo[2.2.2]-octane) \[\text{M} 154.2, \text{m} 1.3°, 1.5°, \text{b} 39-39.3°/4mm, 176-176.4°/760mm, d^2_{D} 0.9232, n^\circ_{D} 1.4575. Purified by dilution with an equal volume of pet ether, then saturated with dry HBr. The ppte was filtered off, washed with small vols of pet ether, then cineole was regenerated by stirring the crystals with H}_2\text{O. It can also be purified via its o-cresol or resorcinol addition compounds. Stored over Na until required. Purified by fractional distillation. Insoluble in H}_2\text{O but soluble in organic solvents. [IR: Kome et al. Nippon Kagaku Zasshi [J Chem Soc Japan (Pure Chem Sect)] 80 66 1959; Chem Abstr 60 3 1961.}

Eugenol (4-allyl-2-methoxyphenol) \[\text{M} 164.2, \text{b} 253°/760mm, 255°/760mm, d^2_{D} 1.066, n^\circ_{D} 1.540, pK}_{25} 10.19. Fractional distillation gives a pale yellow liquid which darkens and thickens on air. Should store under N}_2 at -20°. [Waterman and Friedster Rec Trav Chim Pays-Bas 48 1272 1929.]

Eugenol methyl ether (4-allyl-1,2-dimethoxybenzene) \[\text{M} 178.2, \text{m} -4°, \text{b} 127-129°/11mm, 146°/30mm, 154.7°/760mm, d^2_{D} 1.0354, n^\circ_{D} 1.5341. Recrystallized from hexane at low temp and redistilled (preferably in vacuo). [Hillmer and Schorning Z Phys Chem [A] 167 407 1934; Briner and Fliszár Helv Chim Acta 42 2063 1959.]

(+)-α-Fenchol \[\text{M} 154.3, \text{m} 40-43°, 47-47.5°, \text{b} 201-202°, [\text{α}]^2_D +12.5° (c 10, EtOH). It is prepared by reduction of (+)-fenchone and is purified by recrystallization from *C}_6\text{H}_6\text{-pet ether, or distillation. The 2-carboxybenzoyl (monophthalate) derivative has m 146.5-147.5° [α]^2_D -20.4° (EtOH), and the 2-phenylurethane has m 81°. [Beckmann and Metzger Chem Ber 89 2738 1956.]

(+)-Fenchone (1S,1,3,3-trimethyl-norbornan-2-one) \[\text{M} 152.2, \text{m} 5-7°, 6.1°, \text{b} 63-65°/13mm, 66°/15mm, 122°/10mm, d^2_{D} 0.9434, n^\circ_{D} 1.4636, [\text{α}]^2_D +66.9° (neat, or in c 1.5, EtOH), [\text{α}]^2_{D+} +60.4° (neat). The oily liquid is purified by distillation in a vacuum, and is very soluble in EtOH and Et}_2\text{O. [Boyle et al. J Chem Soc, Chem Commun 395 1971, Hückel Justus Liebigs Ann Chem 549 186 1941; (+)-isomer: Braun and Jacob Chem Ber 66 1461 1933.] It forms two oximes; cis-oxime: m
167° (cryst from pet ether) \([\alpha]_{D}^{20} +46.5^\circ\) (c 2, EtOH). O-benzoyloxime m 81° \([\alpha]_{D}^{20} +49^\circ\) (EtOH) and oxime-\(\text{HCl}\) m 136° (dec). The trans-oxime has m 123° (cryst from pet ether) \([\alpha]_{D}^{20} +148^\circ\) (c 2, EtOH) and the O-benzoyloxime has m 125° \([\alpha]_{D}^{20} +128.5^\circ\) (c 2, EtOH) [Hückel Justus Liebigs Ann Chem 549 186 1941; Hückel and Sachs Justus Liebigs Ann Chem 498 166 1932].

(-)-Fenchone (1R,1,3,3-trimethyl-norbornan-2-one) \([7787-20-4]\) M 152.2, m 5.2°, b 67.2°/10mm, 191-195°/atm, d\(_{4}^2\) \(0.9484, n_{D}^2\) 1.4630, \([\alpha]_{D}^{20} -66.8^\circ\) (neat). Purification as for the (+)-enantiomer above and should have the same physical properties except for the optical rotations. UV: \(h_{\text{max}}\) 285nm (E 12.29). [Braun and Jacob Chem Ber 66 1461 1933; UV: Ohloff et al. Chem Ber 90 106 1957.]

Flavone (2-phenyl-4H-1-benzopyran-4-one) \([525-82-6]\) M 222.3, m 100°. Crystd from pet ether.


2-Fluorenamine \([153-78-6]\) M 181.2. See 2-aminofluorene on p. 106.

9-Fluorenamine \([525-03-1]\) M 181.2, m 64-65°, \(pK_{\text{Eu}} \sim3.5\). Crystd from hexane.

Fluorene \([86-73-7]\) M 166.2, m 114.7-115.1°, b 160°/15mm. Purified by chromatography of CCl\(_4\) or pet ether (b 40-60°) soln on alumina, with *benzene as eluent. Crystd from 95% EtOH, 90% acetic acid and again from EtOH. Crystn using glacial acetic acid retained an impurity which was removed by partial mercuration and pptn with LiBr [Brown, Dubeck and Goldman J Am Chem Soc 84 1229 1962]. Has also been crystd from hexane, or *benzene/EtOH, distd under vacuum and purified by zone refining. [Gorman et al. J Am Chem Soc 107 4404 1985.]


Fluorene-2,7-diamine \([525-64-4]\) M 196.3, m 165-166°. Crystd from hot H\(_2\)O or aq EtOH, dried in a vac and stored in the dark.

9-Fluorenylmethyl chloroformate (FMOC-\(\text{CI}\)) \([28920-43-6]\) M 258.7, m 61-63°, 61.4-63°. The IR should contain no OH bands (at ~3000 cm\(^{-1}\)) due to the hydrolysis product 9-fluorenylmethanol. Purify by recrystn from dry Et\(_2\)O. IR (CHCl\(_3\)) has band at 1770 cm\(^{-1}\) (CO) and the NMR (CDCl\(_3\)) has \(\delta\) at 4-4.6 (m 2H, \(\text{CHCH}_{2}\)) and 7.1-7.8 (m, 8 aromatic H). The azide (FMOC-\(\text{N}_3\)) has m 89-90° (from hexane) and IR (CHCl\(_3\)) at 2135 (N\(_3\)) and 1730 (C=O) cm\(^{-1}\); and the carbamate (FMOC-\(\text{NHNH}_2\)) has m 171° dec (from nitromethane), IR (KBr) 3310, 3202 (NH) and 1686 (CONH) cm\(^{-1}\). [Caprino and Han J Org Chem 37, 3404 1972 and J Am Chem Soc 92 1657 1989; Fiirst et al. J Chromatogr 499 537 1990.]

9-Fluorenylmethyl succinimidyl carbonate \([82911-69-1]\) M 337.3, m 147-151° (dec), 151° (dec). Recrystd from CHCl\(_3\)-Et\(_2\)O, or from pet ether (b 40-60°). [Pauet Can J Chem 60 976 1982; Lapatsaris et al. Synthesis 671 1983.]

Fluorescein [9-(\(\alpha\)-carboxyphenyl-6-hydroxy-3H-xanthene-3-one] \([2321-07-5]\) M 320.0, \(\varepsilon_{495\text{nm}}\) 7.84 x 10\(^4\) (in 10\(^{-3}\)M NaOH), \(pK_a\) 2.2, \(pK_b\) 4.4, \(pK_c\) 6.7. Dissolved in dilute aqueous NaOH, filtered and pptd by adding dilute (1:1) HCl. The process was repeated twice more and the fluorescein was dried at 100°. Alternatively, it has been crystd from acetone by allowing the soln to evaporate at 37° in an open beaker. Also recrystd from EtOH and dried in a vacuum oven.

Fluoresceinamine (mixture of 5- and 6-aminofluorescein) \([27599-63-9]\) M 347.3, m 314-316° (dec, 5-amino) and m >200° (dec). Dissolve in EtOH, treat with charcoal, filter, evaporate and dry
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residue in vacuum at 100° overnight. Also recrystallise from 6% HCl, then dissolve in 0.5% aqueous NaOH and ppte by acidifying with acetic acid. The separate amines are made from the respective nitro compounds which are best separated via their acetate salts. They have similar RF of 0.26 on Silica Gel Merck F254 in 5 mL MeOH + 150 mL Et20 satd with H2O. IR (Me2SO) has a band at 1690 cm⁻¹ (CO₂⁻) and sometimes a weak band at 1750 cm⁻¹ due to lactone. UV (EtOH) of 6-isomer λmax 222 (ε 60 000) and 5-isomer λmax 222 (ε 60 000) and 285 (ε 20.600). [IR: McKinney and Churchill J Chem Soc (C) 654 1970; McKinney et al. J Org Chem 27 3986 1962; UV: Verbiscar J Org Chem 29 490 1964.]

Fluorescein isothiocyanate isomer I (5-isocyanato isomer) [3326-32-7; 27072-45-3 mixture of 5- and 6-isomers] M 389.4, m >160° (slow dec). It is made from the pure 5-amino isomer. Purified by dissolving in boiling Me2CO, filtering and adding pet ether (b 60-70°) until it becomes turbid. If an oil separates then decant and add more pet ether to the supernatant and cool. Orange-yellow crystals separate, collect and dry in vacuo. Should give one spot on TLC (silica gel) in EtOAc, pyridine, AcOH (50:1:1) and in 
Me2NCH0, CHC13, 28% N4OH (10:5:4). IR (Me2SO): 2110 (NCS) and 1760 (C=O). The NMR spectra in Me2CO-d₆ of the 5- and 6-isomers are distinctly different for the protons in the *benzene ring; the W in phosphate buffer pH 8.0 shows a max at ~490nm. [Sinsheimer et al. Anal Biochem 57 227 1974; McKinney et al. Anal Biochem 7 74 1964.]


Fluorobenzene [462-06-6] M 96.1, b 84.8°, d 1.025, n 1.46573, n30 1.4610. Dried for several days with P₂O₅, then fractionally distd.

o-Fluorobenzoic acid [445-29-4] M 140.1, m 127°, pK₂ 3.27. Crystd from 50% aqueous EtOH, then zone melted or vacuum sublimed at 130-140°.

m-Fluorobenzoic acid [445-38-9] M 140.1, m 124°, pK₂ 3.86. Crystd from 50% aqueous EtOH, then vacuum sublimed at 130-140°.

p-Fluorobenzoic acid [456-22-4] M 140.1, m 182°, pK₂ 4.15. Crystd from 50% aqueous EtOH, then zone melted or vacuum sublimed at 130-140°.

3-Fluoro-4-hydroxyphenylacetic acid [458-09-3] M 170.1, m 33°, pKₑᵢᵗ(1)~4.4, pKₑᵢᵗ(2)~9.4. Crystd from water.

1-Fluoro-4-nitrobenzene [350-46-9] M 141.1, m 27° (stable form), 21.5° (unstable form), b 205.3°/735mm, 95-97.5°/22mm, 86.6°/14mm. Crystd from EtOH.


o-Fluorophenol [367-12-4] M 112.1, m 16°, b 53°/14mm, d 1.257, n 1.514, pK₂ 8.70. Passed at least twice through a gas chromatographic column for small quantities, or fractionally distd under reduced pressure.


4-Fluorophenyl isocyanate [1195-45-5] M 137.1, b 55°/8mm, m 1.514. Purify by repeated fractionation through an efficient column. If IR indicated that there is too much urea (in the presence of moisture the symmetrical urea is formed) then dissolve in dry EtOH-free CHCl₃, filter, evaporate and distil. It is a pungent LACHRYMATORY liquid. [see Hardy J Chem Soc 2011 1934; and Hickinbottom Reactions of Organic Compounds Longmans p. 493 1957.]
4-Fluorophenyl isothiocyanate [1544-68-9] M 153.2, m 24-26°, 26-27°, b 66°/2 mm, 215°/atm, 228°/760 mm, nD^20 1.6116. Likely impurity is the symmetrical thiourea. Dissolve the isothiocyanate in dry CHCl₃, filter and distil the residue in a vacuum. It can also be steam distilled, the oily layer separated, dried over CaCl₂ and distilled in vacuo. Bis-(4-fluorophenyl)thiourea has m 145° (from aq EtOH). [Browne and Dyson J Chem Soc 3285 1931; Buu Hoi et al. J Chem Soc 1573 1955; Olander Org Synth Coll Vol I 448 1941].


p-Fluorotoluene [95-52-3] M 110.1, b 114.4°, d 1.005, n 1.475. Dried with P₂O₅ or CaSO₄ and fractionally distd through a silvered vacuum-jacketed glass column with 1/8th-in glass helices. A high reflux ratio is necessary because of the closeness of the boiling points of the o-, m- and p- isomers [Potter and Saylor J Am Chem Soc 37 90 1951].


Formaldehyde [50-00-0] M 30.0, m 92°, b -79.6°/20 mm, d²⁰ 0.815, pK²⁵ 13.27 (hydrate). Commonly contains added MeOH. Addition of KOH soln (1 mole KOH: 100 moles HCHO) to 40% formaldehyde soh, or evaporation to dryness, gives paraformaldehyde polymer which, after washing with water, is dried in a vacuum desiccator over P₂O₅ or H₂SO₄. Formaldehyde is regenerated by heating the paraformaldehyde to 120° under vacuum, or by decomposing it with barium peroxide. The monomer, a gas, is passed through a glass-wool filter cooled to -4° in CaCl₂/ice mixture to remove particles of polymer, then dried by passage over P₂O₅ and either condensed in a bulb immersed in liquid nitrogen or absorbed in ice-cold conductivity water.

Formaldehyde dimethyl acetal (dimethoxymethane, methylal, formal) [1109-87-5] M 76.1, m -108°, b 41-42°/736 mm, 41-43°/atm, 42-46°/atm, d²⁰ 0.8608, nD²⁰ 1.35335. It is a volatile flammable liquid which is soluble in three parts of H₂O, and is readily hydrolysed by acids. Purify by shaking with an equal vol of 20% aq NaOH, stand for 20 min, dry over fused CaCl₂, filter and fractionally distil through an efficient column, store over molecular sieves. [Buchler et al. Org Synth Coll Vol III 469 1955; Ind Eng Chem 18 1092 1926; Rambaud and Besserre Bull Soc Chim Fr 45 1955; IR: λmax 238 nm (log ε 2.73) [Fehnel and Carmack J Am Chem Soc 71 96 1949; Fehér and Vogelbruch Chem Ber 91 996 1958; Böhme and Marz Chem Ber 74 1672 1941]. Oxidation with aq KMnO₄ yields bis-(methylsulfonyl)methane which has m 142-143° [Fiecchi et al. Tetrahedron Lett 1681 1967].

Formaldehyde dimethyl mercaptal (bis-[methylthio)methane] [1618-26-4] M 108.2, b 44-47°/13 mm, 45.5°/18 mm, 148-149°/atm, d²⁰ 1.0594, nD²⁰ 1.5322. Work in an efficient fume cupboard as the substance may contain traces (or more) of methylmercaptan which has a very bad odour. Dissolve in Et₂O, shake with aqueous alkaline then dry over anhydrous K₂CO₃, filter and distil over K₂CO₃ under a stream of N₂. If the odour is very strong then allow all gas efluents to bubble through 5% aqueous NaOH soln which is then treated with dilute KMN₄O₄ in order to oxidise MeSH to odourless products. UV: λmax 238 nm (log ε 2.73) [Fehnel and Carmack J Am Chem Soc 71 90 1949; Fühér and Vogelbruch Chem Ber 91 996 1958; Böhme and Marz Chem Ber 74 1672 1941]. Oxidation with aq KMnO₄ yields bis-(methylsulfonyl)methane which has m 142-143° [Fiecchi et al. Tetrahedron Lett 1681 1967].

Formamide [75-12-7] M 45.0, l 2.6°, b 103°/99 mm, 210.5°/760 mm(dec), d 1.13, n 1.44754, nD²⁰ 1.44682. Formamide is easily hydrolysed by acids and bases. It also reacts with peroxides, acid halides, acid anhydrides, esters and (on heating) alcohols; while strong dehydrating agents convert it to a nitrile. It is very hygroscopic. Commercial material often contains acids and ammonium formate. Vorhoek [J Am Chem Soc 58 2577 1956] added some bromothymol blue to formamide and then neutralised it with NaOH before heating to 80-90° under reduced pressure to distil off ammonia and water. The amide was again neutralised and the process was repeated until the liquid remained neutral on heating. Sodium formate was added, and the formamide was reduced under reduced pressure at 80-90°. The distillate was again neutralised and redistilled. It wasthen fractionally crystd in the absence of CO₂ and water by partial freezing.
Formamide (specific conductance 2 x 10^{-7} \text{ ohm}^{-1} \text{ cm}^{-1}) of low water content was dried by passage through a column of 3A molecular sieves, then deionized by treatment with a mixed-bed ion-exchange resin loaded with H^+ and HCONH^- ions (using sodium formamide in formamide)[Notley and Spiro J Chem Soc (B) 362 1966].

Formamidine acetate [3473-63-0] M 104.1, m 159-161^o (dec), 164^o (dec), pK_{Em} \sim 12. Unlike the hydrochloride, the acetate salt is not hygroscopic. It is recrystd from a small volume of acetic acid, by addition of EtOH and the crysts are washed with EtOH then Et_2O and dried in a vac. [Taylor, Ehrhart and Karanisi Org Synth 46 39 1966.]

Formamidine sulfinic acid (thiourea-S-dioxide) [1758-73-2] M 108.1, m 124-126^o (dec). Dissolved in five parts of aq 1:1% NaHSO_3 at 60-63^o (charcoal), then crystd slowly, with agitation, at 10^o. Filtered. Dried immediately at 60^o [Koniecki and Linch Anal Chem 30 1134 1958].

Formanilide [103-70-8] M 121.1, m 50^o, b 166^o/14mm, 216^o/120mm, d 1.14. Crystd from ligroin/xylene.

Formic acid [64-18-6] M 46.0 (anhydr), f 8.3^o, b 25^o/40mm, 100.7^o/760mm, d 1.22, n 1.37140, n_{25} 1.36938, pK_{Z5} 3.74. Anhydrous formic acid can be obtained by direct fractional distillation under reduced pressure, the receiver being cooled in ice-water. The use of P_2O_5 or CaCl_2 as dehydrating agents is unsatisfactory. Reagent grade 88% formic acid can be satisfactorily dried by refluxing with phthalic anhydride for 6h and then distilling. Alternatively, if it is left in contact with freshly prepared anhydrous CuSO_4 for several days about one half of the water is removed from 88% formic acid: distn removes the remainder. Boric anhydride (prepared by melting boric acid in an oven at a high temperature, cooling in a desiccator, and powdering) is a suitable dehydrating agent for 98% formic acid; after prolonged stirring with the anhydride the formic acid is distd under vacuum. Formic acid can be further purified by fractional crystn using partial freezing.

Forskolin (5-[acetyloxy]-3-ethyldodecahydro-6,10b-trihydroxy-3,4a,7,7,10a-penta-methyl-[3R-(3α,4αβ,5β,6β,6αα,10αβ,10bα]-1H-naphtho[2,1-b]pyran-1-one) [66575-29-9] M 410.5, m 229-232^o, 228-233^o. Recrystd from *C_6H_6-pet ether. It is antihypertensive, positive ionotropic, platelet aggregation inhibitory and adenylate cyclase activating properties [Chem Abstr 89 1978 244150, de Souza et al. Med Res Rev 3 201 1983].

D(-)-Fructose [57-48-7] M 180.2, m 103-106^o, [α]_{25^o}^{D} +190^o (after 1h, c 10, H_2O), pK_{25}^{2+} 12.03. Dissolved in an equal weight of water (charcoal, previously washed with water to remove any soluble material), filtered and evaporated under reduced pressure at 45-50^o to give a syrup containing 90% of fructose. After cooling to 40^o, the syrup was seeded and kept at this temperature for 20-30h with occasional stimng. The crystals were removed by centrifugation, washed with a small quantity of water and dried to constant weight under a vacuum over conc H_2SO_4. For higher purity, this material was recrystd from 50% aqueous ethanol [Tsuzuki, Yamazaki and Kagami J Am Chem Soc 72 1071 1950].

D(+)-Fucose [3615-37-0] M 164.2, m 144^o, [α]_{25^o}^{D} +89^o (after 24h, c 10 in H_2O). Crystd from EtOH.

Fullerene C_{60} (Buckminsterfullerene C_{60}, Footballene, Buckyball 60) [99685-96-8] M 720.66 and Fullerene C_{70} [115383-22-7] M 840.77. Purified from the soluble toluene extract (400mg) of the soot (Fullerite) formed from resistive heating of graphite by adsorption on neutral alumina (100g; Brockmann I; 60 x 8cm). Elution with toluene-hexane (5:95 v/v) gives ca 250mg of quite pure C_{60}. It has characteristic spectral properties (see below). Further elution with toluene-hexane (20:80 v/v; i.e. increased polarity of solvent) provides 50mg of "pure" C_{70} [J Am Chem Soc 113 1050 1991]. Chromatography on alumina can be improved by using conditions which favour adsorption rather than crystn. Thus the residue from toluene extraction (1g) in CS_2 (ca 300mL) is adsorbed on alumina (375g, standard grade, neutral ca 150 mesh, Brockmann I) and loaded as a slurry in toluene-hexanes (5:95 v/v) to a 50 x 8cm column of alumina (1.5kg) in the same solvent. To avoid crystn of the fullerenes, 10% of toluene in hexanes is added quickly followed by 5% of toluene in hexanes after the fullerenes had left the loading fraction (2-3h). With a flow rate of 15mL/min the purple C_{60} fraction is eluted during a 3-4h period. Evapn of the eluates gives 550-
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630mg of product which, after recryst from CS$_2$-cyclohexane yields 520-600mg of C$_{60}$ which contains adsorbed solvent. On drying at 275$^\circ$C/10$^{-3}$mm for 48h a 2% weight loss is observed although the C$_{60}$ still contains traces of solvent. Further elution of the column with 20% of toluene in hexanes provides 130mg of C$_{70}$ containing 10-14% of C$_{60}$ (by $^{13}$C NMR). This was rechromatographed as above using a half scale column and adsorbing the 130mg in CS$_2$ (20mL) on alumina (24g) and gave 105mg of recrystd C$_{70}$ (containing 2% of C$_{60}$). The purity of C$_{60}$ can be improved further by washing the crystalline product with Et$_2$O and Me$_2$CO followed by recryst from *C$_6$H$_6$ and vacuum drying at high temperatures. [J Chem Soc, Chem Commun 956 1992.]

Carbon soot from resistive heating of a carbon rod in a partial helium atmosphere (0.3bar) under specified conditions is extracted with boiling *C$_6$H$_6$ or toluene, filtered and the red-brown soln evapd to give crystalline material in 14% yield which is mainly a mixture of fullerenes C$_{60}$ and C$_{70}$. Chromatographic filtration of the 'crude' mixture with *C$_6$H$_6$ allows no separation of components, but some separation was observed on silica gel TLC with n-hexane or n-pentane, but not cyclohexane. Analytical HPLC with hexanes (5mm Ecomosphere silica) gave satisfactory separation of C$_{60}$ and C$_{70}$ (retention times of 6.64 and 6.93min respectively) at a flow rate of 0.5mL/min and using a detector at 256nm. HPLC indicated the presence of minor (<1.5% of total mass) unidentified C$_n$ with species (retention times of 5.86 and 8.31min. Column chromatography on flash silica gel with hexanes gives a few fractions of C$_{60}$ with >95% purity but later fractions contain mixtures of C$_{60}$ and C$_{70}$. These can be in 99.85 and >99% purity respectively by column chromatography on neutral alumina. [J Phys Chem 94 8630 [1990].]

Separation of C$_{60}$ and C$_{70}$ can be achieved by HPLC on a dinitroaminopropyl (DNAP) silica (5um pore size, 300A pore diameter) column with a gradient from n-hexane to 50% CH$_2$Cl$_2$ using a diode array detector at wavelengths 330nm (for C$_{60}$) and 384nm (for C$_{70}$). [Am Chem Soc 113, 2940, 1991.]

Soxhlet extraction of the 'soot' is a good preliminary procedure, or if material of only ca 98% purity is required. Soxhlet extraction with toluene is run (20min per cycle) until colourless solvent filled the upper part of the Soxhlet equipment (10h). One third of the toluene remained in the pot. After cooling, the solution was filtered through a glass frit. This solid (purple in toluene) was ca 98% C$_{60}$. This powder was again extracted in a Soxhlet using identical conditions as before and the C$_{60}$ was recrystd from toluene to give 99.5% pure C$_{60}$. C$_{70}$ has greater affinity than C$_{60}$ on neutral alumina. [J Chem Soc, Chem Commun 1402 1992.]

Purification of C$_{60}$ from a C$_{60}$/C$_{70}$ mixture was achieved by dissolving in an aqueous soln of γ (but not β) cyclodextrin (0.02M) upon refluxing. The rate of dissolution (as can be followed by UV spectra) is quite slow and constant up to 10$^{-5}$M of C$_{60}$. The highest concn of C$_{60}$ in H$_2$O obtained was 8 x 10$^{-5}$M and a 2 γ-cyclodextrin:1 C$_{60}$ clathrate is obtained. C$_{60}$ is extracted from this aqueous soln by toluene and C$_{60}$ of >99 purity is obtained by evaporation. With excess of γ-cyclodextrin more C$_{60}$ dissolves and the complex precipitates. The ppte is insol in cold H$_2$O but sol in boiling H$_2$O to give a yellow soln. [J Chem Soc, Chem Commun 604 1922.]

C$_{60}$ and C$_{70}$ can also be readily purified by inclusion complexes with p-tert-butylcalix[6] and [8]arenes. Fresh carbon-arc soot (7.5g) is stirred with toluene (250mL) for 1h and filtered. To the filtrate is added p-tert-butylcalix[8]arene, refluxed for 10min and filtered. The filtrate is seeded and set aside overnight at 20$^\circ$. The C$_{60}$ complex separated as yellow-brown plates and recrystd twice from toluene (1g from 80mL), 90% yield. Addition of CHCl$_3$ (5mL) to the complex (0.85g) gave C$_{60}$ (0.28g, 92% from recryst complex).

p-tert-Butylcalix[6]arene-(C$_{60}$)$_2$ complex is prepared by adding to a refluxing soln of C$_{60}$ (5mg) in toluene (5mL), p-tert-butylcalix[6]arene (4.4mg). The hot soln was filtered rapidly and cooled overnight to give prisms (5.5mg, 77% yield). Pure C$_{60}$ is obtained by decomposing the complex with CHCl$_3$ as above.

The p-tert-butylcalix[6]arene-(C$_{70}$)$_2$ complex is obtained by adding p-tert-butylcalix[6]arene (5.8mg) to a refluxing soln of C$_{70}$ (5mg) in toluene (2mL), filtering hot and slowly cooling, to give red-brown needles (2.5mg, 31% yield) of the complex. Pure C$_{70}$ is then obtained by decomposing the complex with CHCl$_3$.

Decomposition of these complexes can also be achieved by boiling a toluene soln over KOH pellets for ca 10min. The calixarenes form Na salts which do not complex with the fullerenes. These appear to be the most satisfactory means at present for preparing large quantities of relatively pure fullerene C$_{60}$ and C$_{70}$ and is considerably cheaper than previous methods. [Nature 368 229 1994.]

Repeated chromatography on neutral alumina yields minor quantities of solid samples of C$_{70}$, C$_{84}$, C$_{90}$ and C$_{94}$ believed to be higher fullerenes. A stable oxide C$_{70}$O has been identified. Chromatographic procedures for the separation of these compounds are reported. [Science 252 548 1991.]
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Physical properties of Fullerene C_{60}: It does not melt below 360°, and starts to sublime at 300° in vacuo. It is a mustard coloured solid that appears brown or black with increasing film thickness. It is soluble in common organic solvents, particularly aromatic hydrocarbons which give a beautiful magenta colour. Toluene solutions are purple in colour. Soln in *C_{6}H_{6} (5mg/mL), but dissolves slowly. Crysts of C_{60} are both needles and plates. UV-Vis in hexanes: \( \lambda_{\text{max}} \text{nm} \log{e} \) 211(5.17), 227sh(4.91), 256(5.24), 328(4.71), 357sh(4.08), 368sh(3.91), 376sh(3.75), 390(3.52), 395sh(3.30), 403(3.48), 407(3.78), 492sh(2.72)< 540(2.85), 568(2.78), 590(2.86), 598(2.87) and 620(2.60).

IR (KBr): \( v \) 1429m, 1182m, 724m, 576m and 527s cm\(^{-1} \). 13C NMR: one signal at 142.68ppm.

Physical properties of Fullerene C_{70}: It does not melt below 360°, and starts to sublime at 350° in vacuo. A reddish-brown solid, greenish black in thicker films. Solns are port-wine red in colour. Mixtures of C_{60} and C_{70} are red due to C_{70} being more intensely coloured. It is less soluble than C_{60} in *C_{6}H_{6} but also dissolves slowly. C_{70} gives orange coloured soln in toluene. Drying at 200-250° is not sufficient to remove All solvent. Samples need to be sublimed to be free from solvent. UV-Vis in hexanes: \( \lambda_{\text{max}} \text{nm} \log{e} \) 214(5.05), 235(5.06), 249sh(4.95), 268sh(4.78), 313(4.23), 330(4.38), 359(4.29), 468(4.16), 542(3.78), 590sh(3.38), 609(3.32), 623sh(3.09), 635sh(3.13) and 646sh(2.80).

IR (KBr): \( v \) 1430m, 1428m, 1420m, 1413m, 1133mv, 1087w, 795s, 674ms, 642ms, 577s, 566m, 535ms and 458m cm\(^{-1} \). 13C NMR [run in the presence of Cr(pentan-2,4-dione)\(_3\) which induces a ca 0.12ppm in the spectrum]: Five signals at 150.07, 147.52, 146.82, 144.77 and 130.28 ppm, unaffected by proton decoupling.


Fumagillin [2,4,6,8-decatetraene-1,10-dioic acid mono[4-(1,2-epoxy-1,5-dimethyl-4-hexenyl)-5-methoxy-1-oxaspiro[2.5]ester] \( \{231010-15-8\} \) M 458.5, \( m \) 194-195°, \( [\alpha]_{D}^{20} -26.2^\circ \) (in 95% EtOH), \( pK_{\text{est}} -4.5 \). Forty grams of a commercial sample containing 42% fumagillin, 45% sucrose, 10% antifoam agent and 3% of other impurities were digested with 150mL of CHC{l}3. The insoluble sucrose was filtered off and washed with CHCl{3}. The combined CHCl{3} extracts were evaporated almost to dryness at room temperature under reduced pressure. The residue was triturated with 20mL of MeOH and the fumagillin was filtered off by suction. It was crystd twice from 500mL of hot MeOH by standing overnight in a refrigerator (yellow needles). (The long chain fatty ester used as antifoam agent was still present, but was then removed by repeated digestion, on a steam bath, with 100mL of diethyl ether.) For further purification, the fumagillin (log) was dissolved in 150mL of 0.2M ammonia, and the insoluble residue was filtered off. The ammonia soln (cooled in running cold water) was then brought to pH 4 by careful addn of M HCl with constant shaking in the presence of 150mL of CHCl{3}. (Fumagillin is acid-labile and must be removed rapidly from the aq acid soln.) The CHCl{3} extract was washed several times with distd water, dried (Na_{2}SO_{4}) and evaporated under reduced pressure. The solid residue was washed with 20mL of MeOH. The fumagillin was filtered by suction, then crystd from 200mL of hot MeOH. [Tarbell et al. \textit{J Am Chem Soc} \textit{77} 5610 1955.]

Alternatively, 10g of fumagillin in 100mL CHCl{3} was passed through a silica gel (5g) column to remove tarry material, and the CHCl{3} was evaporated to leave an oil which gave fumagillin on crystn from amyl acetate. It recrystallises from MeOH (charcoal). The fumagillin was stored in dark bottles in the absence of oxygen and at low temperatures. [Schenk, Hargie and Isarasena \textit{J Am Chem Soc} \textit{77} 5610 1955.]

Fumaraldehyde bis-(dimethyl acetal) \( \text{(trans-1,1,4,4-tetramethoxybut-2-ene)} \) \( \{6068-62-8\} \) M 176.2, \( b \) 100-103°/15mm, 101-103°/25mm, \( d_4^{10} 1.011, n_D^{10} 1.425 \). Dry over fused CaCl{2} and dist in vacuo. The maleic (cis) isomer has \( b \) 112°/1 lmm, and \( d_23 0.932 \) and \( d_51 1.4243 \). [Zeik and Heusner \textit{Chem Ber} \textit{90} 1869 1957; Clauson-Kaas et al. \textit{Acta Chem Scand} \textit{9} 111 1955; Clauson-Kaas \textit{Acta Chem Scand} \textit{6} 569 1952.]

Fumaric \( \text{(trans-but-2-ene-1,4-dioic)} \) acid \( \{110-17-8\} \) M 116.1, \( m \) 289.5-291.5° (sealed tube), \( pK_{\text{a}1}^{10} 3.10, pK_{\text{a}2}^{10} 4.60 \) (4.38). Crystd from hot M HCl or water. Dried at 100°.
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**Furan** [110-00-9] M 68.1, b 31.3°, d 1.42, n 1.4214. Shaken with aqueous 5% KOH, dried with CaSO₄ or Na₂SO₄, then distd under nitrogen, from KOH or sodium, immediately before use. A trace of hydroquinone could be added as an inhibitor of oxidation.


Furan-2-carboxylic (2-furoic) acid [88-14-2] M 112.1, m 133-134°, b 141-144°/20mm, 230-232°/760mm, pK¹ 7.3 (O-protonation), pK₂ 3.32. Crystd from hot water (charcoal), dried at 120° for 2h, then recrystd from CHCl₃, and again dried at 120° for 2h. For use as a standard in volumetric analysis, good quality commercial acid should be crystd from CHCl₃ and dried as above or sublimed at 130-140° at 50-60mm or less.


Furan-3-carboxylic (3-furoic) acid [488-93-7] M 112.1, m 122-123°, pK 4.03. Crystd from water.

Furan-3,4-dicarboxylic acid [3387-26-6] M 156.1, m 217-218° pK¹ 1.44, pK₂ 7.84. Crystd from water.

**Furfural** (2-furfuraldehyde) [98-01-11] M 96.1, b 54-56°/11mm, 59-60°/15mm, 67.8°/20mm, 90°/65mm, 161°/760mm, d² 1.159, n² 1.52608, pK -6.5 (O-protonation). Unstable to air, light and acids. Impurities include formic acid, β-formylacrylic acid and furan-2-carboxylic acid. Distd over an oil bath from 7% (w/w) Na₂CO₃ (added to neutralise acids, especially pyromucic acid). Redistd from 2% (w/w) Na₂CO₃, and then, finally fractionally distd under vacuum. It is stored in the dark. [Evans and Aylesworth *Ind Eng Chem (Anal ed)* 18 24 1926.]

Impurities resulting from storage can be removed by passage through chromatographic grade alumina. Furfural can be separated from impurities other than carbonyl compounds by the bisulfite addition compound. The aldehyde is steam volatile.

It has been purified by distn (using a Claisen head) under reduced pressure. This is essential as is the use of an oil bath with temperatures of no more than 130° are highly recommended. When furfural is distd at atm press (in a stream of N₂), or under reduced pressure with a free flame (caution because the aldehyde is flammable) an almost colourless oil is obtained. After a few days and sometimes a few hours the oil gradually darkens and finally becomes black. This change is accelerated by light but occurs more slowly when kept in a brown bottle. However, when the aldehyde is distd under vacuum and the bath temperature kept below 130° during the distn, the oil develops only a slight colour when exposed to direct sunlight during several days. The distn of very impure material should NOT be attempted at atm pressure otherwise the product darkens rapidly. After one distn under vacuum a distn at atmospheric pressure can be carried out without too much decomposition and darkening. The liquid irritates mucous membranes. Store in dark containers under N₂. [Adams and Voorhees *Org Synth Coll Vol I* 280 1941.]

**Furfuryl alcohol** (2-furylmethanol) [98-00-0] M 98.1, b 68-69°/20mm, 170.0°/750mm, d 1.132, n 1.4873, n° 1.4801, pK 2.61. Distd under reduced pressure to remove tarry material, shaken with aqueous NaHCO₃, dried with Na₂SO₄ and fractionally distd under reduced pressure from Na₂CO₃. Further dried by shaking with Linde 5Å molecular sieves.

**Furfurylamine** (2-aminomethylfuran) [617-89-0] M 97.1, b 142.5-143°/735mm, d 1.059, n 1.489, pK 8.89. Distd under nitrogen from KOH through a column packed with glass helices.

**Furil** [492-94-4] M 190.2, m 165-166°. Crystd from MeOH or *benzene* (charcoal).

Galactaric Acid (mucic acid)  [526-99-6] M 210.1, m 212-213°(dec) pK_{1}^{25} 3.09 (3.29), pK_{2}^{25} 3.63 (4.41). Dissolved in the minimum volume of dil aq NaOH, and ppted by adding dil HCl. The temperature should be kept below 25°.

D-Galactonic acid  [576-36-3] M 196.2, m 148°, pK_{est} -3.5. Crystd from EtOH. Cyclises to D-galactonono-1,4-lactone, m 134-136°, [α]_{546}^{20} -78° (in H_{2}O). Crystd from EtOH.

D(+)-Galactosamine hydrochloride  [1772-03-8] M 215.6, m 181-185°, [α]_{D}^{25} +96.4° (after 24h, c 3.2 in H_{2}O), pK_{est} 7.7 (free base). Dissolved in a small volume of H_{2}O. Then added three volumes of EtOH, followed by acetone until faintly turbid and stood overnight in a refrigerator. [Roseman and Ludoweig J Am Chem Soc 76 301 1954.]

α-D-Galactose  [59-23-4] M 180.2, m 167-168°, [α]_{D}^{20} +80.4° (after 24h, c 4 in H_{2}O), pK_{25} 12.48. Crystd twice from aqueous 80% EtOH at -10°, then dried under vacuum over P_{2}O_{5}.

Gallic acid (H_{2}O) (3,4,5-trihydroxybenzoic acid)  [5995-86-8] (H_{2}O), 149-91-7 (anhydr) M 188.1, m 253°(dec), pK_{1}^{25} 4.27, pK_{2}^{25} 8.68. Crystd from water.

Galvinoxyl [2,6-di-tert-butyl-α-(3,5-di-tert-butyl-4-oxo-2,5-cyclohexadiene-1-ylidene)-p-toloyloxy]  [2370-18-5] M 421.65, m 153.2-153.6°, 158-159°. A stable free radical scavanger of short-lived free radicals with odd electrons on C or O. Best prepared freshly by oxidation of 3,3',5,5'-tetra-tert-butyl-4,4'-dihydroxydiphenyl-methane [m 154°, 157.1-157.6°; obtained by gently heating for 10-15min 2,6-di-tert-butylphenol, formaldehyde and NaOH in EtOH and recryst from EtOH (20g/lOOmL) as colorless plates, Karasch and Joshi J Org Chem 22 1435 1957; Bartlett et al. J Am Chem Soc 82 1756 1960 and 84 2596 1962. Oxidation is carried out under Nz with PbO_{2} in Et_{2}O or isooctane [Galvin A. Coppinger J Am Chem Soc 79 501 1957; Bartlett et al. above] or with alkaline potassium ferricyanide [Karasch and Joshi, above], whereby Galvinoxyl separates as deep blue crystals, and is recrystd twice under N_{2} from C_{6}H_{6} soln by suction evaporation at 30°. The VIS spectrum has λ_{max} 407nm (E 30,000), 431nm (E 154,000) and weak absorption at 772.5nm, and IR: ν 1577 and 2967cm^{-1}, and is estimated by iodometric titration. It is sensitive to O_{2} in presence of OH- ions and to traces of strong acid in hydroxylic or hydrocarbon solvents. At 62.5° in a 0.62mM soln in C_{6}H_{6} the radical decays with a first order k = 4 x 10^{-8} sec^{-1} (half life 1.7 x 10^{17} sec, ~200 days) as observed by the change in OD at 550nm [see also Green and Adam J Org Chem 28 3550 1963].

Genistein (4',5,7-trihydroxyisoflavone)  [446-72-0] M 270.2, m 297-298°, [α]_{D}^{20} -28° (c 0.6, 20mM NaOH), (phenolic pKs 8-10). Crystd from 60% aqueous EtOH or water.

Genistin (genistein-7-D-glucoside)  [529-59-9] M 432.4, m 256°. Crystd from 80% EtOH/water.

α-Gentiobiose (amygdalose, 6-O-α-D-glucopyranosyl-D-glucopyranose)  [5995-99-5] (bi-pyranose) M 342.3, m 86°, [α]_{D}^{25} 11° (after 24h, c 4, H_{2}O). Crystd from MeOH (retains solvent of crystn).

β-Gentiobiose (see above)  [5996-00-9 (bi-pyranose); 554-91-6 (one open ring)] M 342.3, m 190-195°, [α]_{D}^{20} +8° (after 6h, c 3, H_{2}O). Crystd from MeOH or EtOH.

Geraniol  [106-24-1] M 154.3, b 230°, d 0.879, n 1.4766. Purified by ascending chromatography or by thin layer chromatography on plates of kieselguhr G with acetone/water/liquid paraffin (130:70:1) as solvent system. Hexane/ethyl acetate (1:4) is also suitable. Also purified by GLC on a silicone-treated column of Carbowax 20M (10%) on Chromosorb W (60-80 mesh). [Porter Pure Appl Chem 20 499 1969.] Stored in full, tightly sealed containers in the cool, protected from light.

Gibberilic acid (GA_{3})  [77-06-5] M 346.4, m 233-235°(dec), [α]_{D}^{25} +92° (c 1, MeOH), pK 4.0. Crystd from ethyl acetate.
Girard Reagent T (2-hydrazino-N,N,N-trimethyl-2-oxo-ethanaminium chloride) \[123-46-6\]
M 167.6, m 192°. Should be crystd from absolute EtOH (slight decomposition) when it has a slight odour, and stored in tightly stoppered containers because it is hygroscopic.

Glucamine \[488-43-7\] M 181.2, m 127°, \([\alpha]_D^{20} -8°\) (c 10, H\(_2\)O), pK\(_{NH}\) -9.0. Crystd from MeOH.

D-Glucosamine \[3118-85-2\] M 197.2, m 144°, \([\alpha]_D^{12} +31°\) (c 2, H\(_2\)O). Crystd from EtOH.

D-Glucon-\(\delta\)-lactone \[90-80-2\] M 178.1, m 152-153°, \([\alpha]_D^{20} +76°\) (c 4, H\(_2\)O). Crystd from ethylene glycol monomethyl ether and dried for 1h at 110°.

D-Glucosamine hydrochloride \[66-84-2\] M 215.6, m >300°, \([\alpha]_D^{25} +71.8°\) (after 20h, c 4, H\(_2\)O). Crystd from 3M HCl, water, and finally water/EtOH/acetone as for galactosamine hydrochloride.

\(\alpha\)-D-Glucose \[492-62-6\] M 180.2, m 146°, \([\alpha]_D^{20} +52.5°\) (after 24h, c 4, H\(_2\)O), pK\(_D\) 12.46.

\(\beta\)-D-Glucose \[50-99-7\] M 180.2, m 148-150°. Crystd from hot glacial acetic acid.

\(\alpha\)-D-Glucose pentaacetate \[604-68-2\] M 390.4, m 110-111°, 112°, \([\alpha]_D^{20} +119°\) (c 5, CHCl\(_3\)). Crystd from MeOH or EtOH.

\(\beta\)-D-Glucose pentaacetate \[604-69-3\] M 390.4, m 131-132°, \([\alpha]_D^{20} +5°\) (c 5, CHCl\(_3\)). Crystd from MeOH or EtOH.

D-Glucose phenylhydrazone \[534-97-4\] M 358.4, m 208°. Crystd from aqueous EtOH.

D-Glucuronic acid \[6556-12-3\] M 194.1, m 165°, \([\alpha]_D^{20} +36°\) (c 3, H\(_2\)O), pK\(_D^2\) 3.18. Crystd from EtOH or ethyl acetate.

D-Glucuronolactone \[32449-92-6\] M 176.1, m 175-177°, \([\alpha]_D^{20} +22°\) (after 24h, c 10, H\(_2\)O). Crystd from water.

L-Glutamic acid \[56-86-0\] M 147.1, m 224-225°(dec), \([\alpha]_D^{25} +31.4°\) (c 5, 5M HCl), pK\(_1^L\) 2.06, pK\(_2^L\) 4.35, pK\(_D^L\) 9.85. Crystd from H\(_2\)O acidified to pH 3.2 by adding 4 volumes of EtOH, and dried at 110°. Likely impurities are aspartic acid and cysteine.

L-Glutamic acid-\(\gamma\)-benzyl ester \[1676-73-9\] M 237.3, m 179-181°, \([\alpha]_D^{20} 19.3°\) (c 1, HOAc), pK\(_{1^L}\) 2.17, pK\(_{2^L}\) 9.00. Recrystd from H\(_2\)O and stored at 0°. [Estrin Biochem Prep 13 25 1971.]

L-Glutamine \[56-85-9\] M 146.2, m 184-185°, \([\alpha]_D^{25} +31.8°\) (M HCl), pK\(_{1^L}\) 2.17, pK\(_{2^L}\) 9.13. Likely impurities are glutamic acid, ammonium pyroglutamate, tyrosine, asparagine, isoglutamine, arginine. Crystd from water.

Glutaraldehyde \[111-30-8\] M 100.1, b 71°/10mm, as 50% aq soln. Likely impurities are oxidation products - acids, semialdehydes and polymers. It can be purified by repeated washing with activated charcoal (Norit) followed by vacuum filtration, using 15-20g charcoal/100mL of glutaraldehyde soln. Vacuum distn at 60-65°/15mm, discarding the first 5-10%, was followed by dilution with an equal volume of freshly distilled water at 70-75°, using magnetic stirring under nitrogen. The soln is stored at low temp (3-4°).
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in a tightly stoppered container, and protected from light. Standardised by titration with hydroxylamine.

[Anderson J Histochem Cytochem 15 652 1967.]

Glutaric acid \([110-94-1]\) M 132.1, m 97.5-98.0, pK_1^{25} 4.35, pK_2^{25} 5.40. Crystd from *benzene, CHCl_3, distilled water or *benzene containing 10% (w/w) of diethyl ether. Dried under vacuum.

\[\text{dl-} \text{Glyceraldehyde} \quad [56-82-6] \quad \text{M} 90.1, \text{m} 145.0. \text{Crystd from EtOH/diethyl ether.}\]

Glycerol \([56-81-5]\) M 92.1, m 18.2°, b 182°/20mm, 290°/760mm, d 1.261, n_25 1.47352, pK 14.4. Glycerol was dissolved in an equal volume of n-butanol (or n-propanol, amyl alcohol or liquid ammonia) in a water-tight container, cooled and seeded while slowly revolving in an ice-water slurry. The crystals were collected by centrifugation, then washed with cold acetone or isopropyl ether. [Hass and Patterson Ind Eng Chem (Anal Ed) 33 615 1941.]

**Coloured impurities can be removed from substantially dry glycerol by extraction with 2,2,4-trimethylpentane. Alternatively, glycerol can be decolorised and dried by treatment with activated charcoal and alumina, followed by filtering. Glycerol can be distd at 15mm in a stream of dry nitrogen, and stored in a desiccator over P_2O_5.**

Crude glycerol can be purified by digestion with conc H_2SO_4 and saponification with a lime paste, then re-acidified with H_2SO_4, filtered, treated with an anion exchange resin and fractionally distd under vacuum.

Glycidol (oxirane-2-methanol) \([RS-(-)\) \(556-52-5; \) \(R-(-)\) \(570-44-2; \) \(S-(-)\) \(604-56-7]\) M 74.1, b 61-62°/15mm, d 1.117, n_25 1.433 (±), b 49-50°/7mm, 66-67°/19mm, [α]_D^{20} -15° (neat) (S-isomer, § also available on polymer support), b 56-56°/115mm, d 1.117, n 1.429, [α]_D^{20} +15° (neat). Purified by fractional distn. The 4-nitrobenzoates have m 56° (±), m 60-62°, [α]_D^{20} -37.9° (c 3.8 CHCl_3) for R-(-)-isomer [106268-95-5]; m 60-62°, [α]_D^{20} +38° (c 1 CHCl_3) for S-(+) -isomer m 60-62°, [α]_D^{20} -38° (c 1 CHCl_3) [115459-65-9], and are recrystd from Et_2O or Et_2O/pet ether (b 40-60°) [S-isomer. Burgos et al. J Org Chem 52 4973 1987; Sowden and Fischer J Am Chem Soc 64 1291 1942.]

**Glycinamide hydrochloride \([1668-10-6]\) M 110.5, m 186-189° (207-208°), pK_1^{15} -6.10, pK_2^{15} -1.78, pK_3^{15} 7.95. Crystd from EtOH.**

**Glycine see aminoacetic acid.**

Glycine ethyl ester hydrochloride \([623-33-6]\) M 136.9, m 145-146°, pK_2^{25} 7.69. Crystd from absolute EtOH.

**Glycine hydrochloride \([600-04-7]\) M 111.5, m 176-178°. Crystd from absolute EtOH.**

Glycine methyl ester hydrochloride \([5680-79-5]\) M 125.6, m 174°(dec), pK_2^{25} 7.66. Crystd from MeOH.


Glycocholic acid (N-cholylglycine) \([475-31-0]\) M 465.6, m 154-155°, 165-168°, [α]_S^{14} 20 +37° (c 1, EtOH), pK 4.4. Crystd from hot water as sesquihydrate. Dried at 100°.

Glycolic (α-hydroxyacetic) acid \([79-14-1]\) M 76.1, m 81°, pK_2^{25} 3.62. Crystd from diethyl ether.

\(N\)-Glycylanilide \([555-48-6]\) M 150.2, m 62°, pK_{EtOH} 8.0. Crystd from water, sol in Et_2O.

Glycyglycine \([556-50-3]\) M 132.1, m 260-262°(dec), pK_2^{20} 8.40, pK_3^{30} 8.04. Crystd from aqueous 50% EtOH or water at 50-60° by addition of EtOH. Dried at 110°.
Glycylglycine hydrochloride [13059-60-4] M 168.6, m 215-220°, 235-236°, 260-262°, pK\textsubscript{1} 3.12, pK\textsubscript{2} 8.17. Crystd from 95% EtOH.

Glycy-L-proline [704-15-4] M 172.2, m 185°, pK\textsubscript{1} 2.81, pK\textsubscript{2} 8.65. Crystd from water at 50-60° by addition of EtOH.

dl-Glycylserine [687-38-7] M 162.2, m 207°(dec), pK\textsubscript{1} 2.92, pK\textsubscript{2} 8.10. Crystd from H\textsubscript{2}O (charcoal) by addition of EtOH.

Glycyrrhizic acid ammonium salt (3H\textsubscript{2}O) [53956-04-0] M 823.0, m 210°(dec), [α\textsubscript{D}\textsubscript{546} +60° (c 1, 50% aq EtOH), pK\textsubscript{est} -4.0. Crystd from glacial acetic acid, then dissolved in ethanolic ammonia and evaporated.

Glyoxal bis(2-hydroxyanil) [149-16-2] M 240.3, m 210-213°, ε\textsubscript{294nm} 9880. Crystd from MeOH or EtOH.

Glyoxylic acid [298-12-4] M 74.0, m 98°(anhydr), 50-52°(monohydrate), pK\textsubscript{2} 2.98. Crystd from water as the monohydrate.

Gramine (3-dimethylaminoethylindole) [87-52-5] M 174.3, m 134°, pK\textsubscript{2} 16.00 (NH acidic). Crystd from diethyl ether, ethanol or acetone.

Griseofulvin [126-07-8] M 352.8, m 220°, [α\textsubscript{D}\textsubscript{12} +365° (c 1, acetone). Crystd from *benzene.

Guaiaic acid [4,4'-(2,3-dimethyl-1-butene-(1,4-diyl)-bis-(2-methoxyphenol)] [500-40-3] M 328.4, m 99-100.5°, pK\textsubscript{est} -10.0. Crystd from EtOH.

Guaiaicol (2-methoxyphenol) [90-05-1] M 124.1, m 32°, b 106°/24mm, 205°/746mm, pK\textsubscript{2} 9.90. Crystd from *benzene/pet ether or distd.

Guaiaicol carbonate [553-17-3] M 274.3, m 88.1°. Crystd from EtOH.

Guanidine [118-00-3] M 59.1, m ~50°, pK\textsubscript{2} 13.6. Crystd from water/EtOH under nitrogen. Very deliquescent and absorbs CO\textsubscript{2} from the air readily.

Guanidine carbonate [593-85-1] M 180.2, m 197°. Crystd from MeOH.

Guanidine hydrochloride [50-01-1] M 95.5, m 191-183°. Crystd from hot methanol by chilling to about -10°, with vigorous stirring. The fine crystals were filtered through fritted glass, washed with cold (-10°) methanol, dried at 50° under vacuum for 5h. (The product is more pure than that obtained by crystn at room temperature from methanol by adding large amounts of diethyl ether.) [Kolthoff et al. J Am Chem Soc 79 S102 1957].

Guanosin (H\textsubscript{2}O) [118-00-3] M 283.2, m 240-250°(dec), [α\textsubscript{D}\textsubscript{546} -86° (c 1, 0.1M NaOH), pK\textsubscript{1} 1.9, pK\textsubscript{2} 9.24, pK\textsubscript{3} 12.33. Crystd from water. Dried at 110°.


Harmine [442-51-3] M 212.3, m 261°(dec), pK\textsubscript{20} 7.61. Crystd from MeOH.

Hecogenine acetate \([915-35-5]\) \(M \) 472.7, \(m \) 265-268\(^\circ\), \([\alpha]_{D}^{23} -4.5\) \(^\circ\) (c 1, CHCl\(_3\)). Crystd from MeOH.

Heptadecanoic acid (margaric) \([506-12-7]\) \(M \) 270.5, \(m \) 60-61\(^\circ\), \(b \) 227\(^\circ\)/100mm, \(pK_{\text{est}} -4.9\). Crystd from MeOH or pet ether.

1-Heptadecanol \([1454-85-9]\) \(M \) 256.5, \(m \) 54\(^\circ\). Crystd from acetone.

Heptafluoro-2-iodopropane \([677-69-0]\) \(M \) 295.9, \(b \) 41\(^\circ\). Purified by gas chromatography on a triacetin (glyceryl triacetate) column, followed by bulb-to-bulb distn at low temperature. Stored over Cu powder to stabilise it.

\(n\)-Heptaldehyde \([111-71-7]\) \(M \) 114.2, \(b \) 40.5\(^\circ\)/12mm, 152.8\(^\circ\)/760mm, \(m \) 0.819, \(n^{25} 1.4130\). Dried with CaSO\(_4\) or Na\(_2\)SO\(_4\) and fractionally distd under reduced pressure. More extensive purification by pptn as the bisulfite compound (formed by adding the aldehyde to saturated aqueous NaHSO\(_3\)) which was filtered off and recrystd from hot H\(_2\)O. The crystals, after being filtered and washed well with H\(_2\)O, were hydrolysed by adding 700mL of aqueous Na\(_2\)CO\(_3\) (12.5% w/w of anhydrous Na\(_2\)CO\(_3\)) per 100g of aldehyde. The aldehyde was then steam distd, separated, dried with CuSO\(_4\) and distd under reduced pressure in a slow stream of nitrogen. [McNesby and Davis \(J\) Am Chem Soc 76 2148 1954].

\(n\)-Heptaldehyde \(n\)-Heptaldoxime \([629-31-2]\) \(M \) 129.2, \(m \) 53-55\(^\circ\). Crystd from 60\% aqueous EtOH.

\(n\)-Heptane \([142-18-5]\) \(M \) 100.2, \(b \) 98.4\(^\circ\), \(d \) 0.684, \(n \) 1.38765, \(n^{25} 1.38512\). Passage through a silica gel column greatly reduces the ultraviolet absorption of \(n\)-heptane. (The silica gel is previously heated to 350\(^\circ\) before use.) For more extensive purification, heptane is shaken with successive small portions of conc H\(_2\)SO\(_4\) until the lower (acid) layer remains colourless. The heptane is then washed successively with water, aq 10\% Na\(_2\)CO\(_3\), water (twice), and dried with CaSO\(_4\), MgSO\(_4\) or CaCl\(_2\). It is distd from sodium. \(n\)-Heptane can be distd azeotropically with methanol, then the methanol can be washed out with water and, after drying, the heptane is redistd. Other purification procedures include passage through activated basic alumina, drying with CaH\(_2\), storage with sodium, and stirring with 0.5N KMnO\(_4\) in 6N H\(_2\)SO\(_4\) for 12h after treatment with conc H\(_2\)SO\(_4\). Carbonyl-containing impurities have been removed by percolation through a column of impregnated Celite made by dissolving 0.5g of 2,4-dinitrophenylhydrazine in 6mL of 85\% H\(_3\)PO\(_4\) by grinding together, then adding 4mL of distilled water and 10g Celite. [Schwartz and Parks Anal Chem 33 1396 1961].

\(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)-Heptane \(n\)
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B30 611 1976 gave m 69-70°. Hydrolysis using an equivalent of base in methanol gave the desired glucoside. This is a non-ionic detergent for reconstituting membrane proteins and has a critical micelle concentration of 30 mM. [Shimamoto et al. J Biochem (Tokyo) 97 1807 1985; Saito and Tsuchiya Chem Pharm Bull Jpn 33 503 1985].

Hesperetin (3',5,7-trihydroxy-4'-methoxyflavanone) \( [520-33-2] \) M 302.3, \( m \) 227-228°, \( pK_{est} \) \(-8.5-10.5 \) (phenolic). Crystd from EtOAc or ethanol. The natural (-) form has \([\alpha]_{D}^{20} \) -38° (c 2, EtOH). Note that C2 is chiral.

Hesperidin (hesperetin 7-rhamnoside) \( [520-26-3] \) M 610.6, \( m \) 258-262°, \([\alpha]_{546}^{20} \) -82° (c 2, pyridine). Dissolved in dilute aqueous alkali and ppted by adjusting the pH to 6-7.

Hexachlorobenzene \( [118-74-1] \) M 284.8, \( m \) 230.2-231.0°. Crystd repeatedly from *benzene. Dried under vacuum over P$_2$O$_5$.


1,2,3,4,5,6-Hexachlorocyclohexane \([\alpha]_{-319-84-6} \); \( \gamma \) \(-58-89-9 \) M 290.8, \( m \) 158° (\( \alpha \)-), 312° (\( \beta \),) 112.5° (\( \gamma \)-isomer). Crystd from EtOH. Purified by zone melting. Possible CANCER AGENT, TOXIC.

Hexachlorocyclopentadiene \( [77-47-4] \) M 272.8, \( b \) 80°/1mm, \( d \) 1.702, \( n^2_5 \) 1.5628. Dried under vacuum in nitrogen.

Hexachloroethane \( [67-72-1] \) M 236.7, m 187°. Steam distd, then crystd from 95% EtOH. Dried in the dark under vacuum.

Hexacosane \( [630-01-3] \) M 366.7, m 56.4°, \( b \) 169°/0.05mm, 205°/1mm, 262°/15mm. Distd under vacuum and crystd from diethyl ether.

Hexacosanoic acid (cerotinic acid) \( [506-46-7] \) M 396.7, \( m \) 86-87°, 88-89°, \( pK_{est} \) \(-4.9 \). Crystd from EtOH, aq EtOH and pet ether+Me$_2$CO.

1,14-Hexadecanedioic acid (thaspic acid). \( [505-54-4] \) M 286.4, \( m \) 126°, \( pK_{est(1)} \) -4.5, \( pK_{est(2)} \) -5.5. Crystd from EtOH, ethyl acetate or *C$_6$H$_6$.

n-Hexadecene (Cetane) \( [544-75-3] \) M 226.5, \( m \) 18.2°, \( b \) 105°/0.1mm, \( d \) 0.773, \( n \) 1.4345, \( n^2_5 \) 1.4325. Passed through a column of silica gel and distd under vacuum in a column packed with Pyrex helices. Stored over silica gel. Crystd from acetone, or fractionally crystd by partial freezing.

Hexadecanoic acid (palmitic acid) \( [57-10-3] \) M 256.4, \( m \) 62-63°, \( b \) 215°/15mm, \( pK_{25} \) 6.46 (50% aq EtOH), 5.0 (H$_2$O). Purified by slow (overnight) recrystn from hexane. Some samples were also crystd from acetone, EtOH or EtOAc. Crystals were stood in air to lose solvent, or were pumped dry of solvent on a vacuum line. [Iwahashi et al. J Chem Soc, Faraday Trans 1 81 973 1985; pK: White J Am Chem Soc 72 1950].

Hexadecyl 3-hydroxynaphthalene-2-carboxylate \( [531-84-0] \) M 412.6, \( m \) 73-74°. Recrystd from hot EtOH and sublimed in a vacuum. [Oshima and Hayashi J Soc Chem Ind Jpn 44 821 1941].

1,5-Hexadiene \( [592-42-7] \) M 82.2, \( b \) 59.6°, \( d \) 0.694, \( n \) 1.4039. Distd from NaBH$_4$.

Hexaethylbenzene \( [604-88-6] \) M 246.3, \( m \) 128.7-129.5°. Crystd from *benzene or *benzene/EtOH.

Hexafluoroacetone \( [684-16-2] \), \( 34202-69-2 \) (3H$_2$O) M 166.1, \( m \) -129°, (trihydrate m 18-21°), \( b \) -28°. Dehydrated by passage of the vapour over P$_2$O$_5$. Ethylene was removed by passing the dried vapour
through a tube containing Pyrex glass wool moistened with conc H₂SO₄. Further purification was by low temperature distn using Warde-Le Roy stills. Stored in the dark at -78°. [Holmes and Kutschke *Trans Faraday Soc* 58 333 1962]

**Hexafluoroacetylaceton** (1,1,1,5,5,5-hexafluoro-2,4-pentanedione) [1522-22-1] M 208.1, b 68°/736mm, 70-70.2°/760mm, 68-71°/atm, d₂⁰ 1.490, n_D₂⁰ 1.333. It forms a dihydrate which has no UV spectrum compared with hmax (CHCl₃) 273nm (Eₗ 7,800) for the anhydrous ketone. The dihydrate dec at -90°. The hydrate (10g) plus anhyd CaSO₄ (Drierite, 30g) are heated and distd; the distillate is treated with more CaSO₄ and redist. When the distillate is treated with aqueous NaOH and heated, the dihydrate crystallises on cooling. The Cu complex has m 135° (after sublimation). [Gilman et al. *J Am Chem Soc* 78 2790 1956; Belford et al. *J Inorg Nucl Chem* 2 11 1956]

**Hexafluoroacetylaceton** [392-56-3] M 186.1, m 5.1°, b 79-80°, d 1.61, n 1.378. Main impurities are incompletely fluorinated benzenes. Purified by standing in contact with oleum for 4h at room temperature, repeating until the oleum does not become coloured. Washed several times with water, then dried with P₂O₅. Final purification was by repeated fractional cryst.

**Hexafluoroacetylaceton** [76-16-4] M 138.0, b -79°. Purified for pyrolysis studies by passage through a copper vessel containing CoF₃ at ca 270°, and held for 3h in a bottle with a heated (1300°) platinum wire. It was then fractionally distd. [Steunenberg and Cady *J Am Chem Soc* 74 4165 1952]

1,1,1,3,3,3-Hexafluoropropan-2-ol [920-66-1] M 168.1, b 57-58°/760mm, d 1.4563, n₂₀ 1.2750. Distd from 3A molecular sieves, retaining the middle fraction.

**Hexafluoroacetylaceton** [111-49-9] M 99.2, b 70-72°/30mm, 135-138°/atm, d 0.879, n 1.466, pK⁰ 11.10 (pK₈ 9.71, pK₇ 9.71). Purified by dissolving in Et₂O and adding ethanolic HCl until all the base separates as the white hydrochloride, filter, wash with Et₂O and dry (m 236°). The salt is dissolved in the minimum vol of H₂O and basified to pH ~ 14 with 10N KOH. The soln is extracted with Et₂O, the extract is dried over KOH, evapd and distd. The base is a FLAMMABLE and TOXIC liquid, and best kept as the salt. The nitrate has m 120-123°, Picrate has m 145-147°, and the Tosylate has m 76.5° (ligroin). [Müller and Sauerwald *Monatsh Chem* 48 727 1927; Hjelt and Agback *Acta Chem Scand* 18 194 1964]

**Hexafluoroacetylaceton** [R-(-)- 53585-93-6; S-(+)- 61475-31-8] M 158.2, m 127-129°, 128-129°, 129.7°, [α]₂⁰⁺ (c 1, AcOH) and [α]₂⁰− (c 1, AcOH) and [α]₂⁰⁻ (c 7.6, EtOH). For hexagonal clusters by recrystallisation from CCl₄ or Et₂O. [Wood and Comley *J Chem Soc* 2638 1924; Lettré et al. *Chem Ber* 69 1594 1936]. The racemate has m 137.2-137.6° (134-135°) [Smith et al. *J Am Chem Soc* 71 3772 1949]

**Hexafluoroacetylaceton** [87-85-4] M 162.3, m 165-165.5°. Sublimed, then crystd from abs EtOH, *benzene, EtOH/benzene or EtOH/cyclohexane. Also purified by zone melting. Dried under vac over P₂O₅.

**Hexafluoroacetylaceton** [7641-77-2] M 162.3, m 7°, b 60°/20mm, d 0.803, n 1.4480. Purified by passage through alumina [Traylor and Mikształ *J Am Chem Soc* 109 2770 1987]

**Hexafluoroacetylaceton** [124-09-4] M 116.2, m 42°, b 46-47°/1mm, 84.9°/9 mm, 100°/20mm, 204-205°/760mm, pK₁⁺ 10.24, pK₂⁺ 11.02. Crystd in a stream of nitrogen. Sublimed in a vacuum.

**Hexafluoroacetylaceton** [6055-52-3] M 189.2, m 248°. Crystd from water or EtOH.

**Hexamethylene glycol** (1,6-hexanediol) [629-11-8] M 118.2, m 41.6°, 43-45°, b 134°/10mm, 250°, n 1.458. Fractionally crystd from its melt or from water. Distils in vacuo.
Hexamethylenetetramine (Urotrope, hexamine, HMTA) [100-97-0] M 140.1, m 280° (subln), 290-292° (sealed tube, CARE), d 1.331, pK₂ 4.85 (6.30). It is soluble in H₂O (67%), CHCl₃ (10%), EtOH (8%) and Et₂O (0.3%), and a 0.2M soln has a pH of 8.4. Dissolve in hot abs EtOH (reflux. Norite), filter using a heated funnel, cool at room temp first then in ice. Wash crts with cold Et₂O, dry in air or under a vacuum. A further crop can be obtained by adding Et₂O to the filtrate. It sublimes above 260° without melting. The picrate has m 179° (dec). [pK 4.85: Reilley and Schmid Anal Chem 30 947 1958; pK 6.30: Pummerer and Hofmann Chem Ber 56 1255 1923.]

n-Hexane [110-54-3] M 86.2, b 68.7°, d 0.660, n 1.37486, n₂ 1.37226. Purification as for n-heptane. Modifications include the use of chlorosulfonic acid or 35% fuming H₂SO₄ instead of conc H₂SO₄ in washing the alkane, and final drying and distn from sodium hydride. Unsatd compounds can be removed by shaking the hexane with nitrating acid (58% H₂SO₄, 25% conc HNO₃, 17% water, or 50% HNO₃, 50% H₂SO₄), then washing the hydrocarbon layer with conc H₂SO₄, followed by H₂O, drying, and distg over sodium or n-butyl lithium. Also purified by distn under nitrogen from sodium benzophenone ketyl solubilised with tetraglyme. Also purified by passage through a silica gel column followed by distn [Kajii et al. J Phys Chem 91 2791 1987]. FLAMMABLE liquid and possible nerve toxin.

Rapid purification: Distil, discarding the first forerun and stored over 4A molecular sieves.


1-Hexene [592-41-6] M 84.2, b 63°, d 0.674, n 1.388. Purified by stirring over Na/K alloy for at least 6h, then fractionally distd from sodium under nitrogen.


trans-3-Hexene [13269-52-8] M 84.2, b 67-69°, d 0.678, n 1.393. Purifn as for 1-hexene above.

meso-Hexestrol [84-16-2] M 270.4, m 185-188°. Crystd from *benzene or aqueous EtOH.

n-Hexyl alcohol (1-hexanol) [111-27-3] M 102.2, b 157.5°, d 0.818, n₁ 1.4198, n₂ 1.4158. Commercial material usually contains other alcohols which are difficult to remove. A suitable method is to esterify with hydroxybenzoic acid, recrystallise the ester and saponify. [Olivier Rec Trav Chim, Pays-Bas 55 1027 1936.] Drying agents include K₂CO₃ and CaSO₄, followed by filtration and distn. (Some decomposition to the olefin occurred when Al amalgam was used as drying agent at room temperature, even though the amalgam was removed prior to distn.) If the alcohol is required anhydrous, the redistd material can be refluxed with the appropriate alky] phthalate or succinate, as described under Ethanol.

n-Hexylamine [111-26-2] M 101.2, b 131°, d 0.765, n 1.419, pK₂ 10.64. Dried with, and fractionally distd from KOH or CaH₂.

n-Hexyl bromide [111-25-1] M 165.1, b 87-88°/90mm, 155°/743mm, d 1.176, n 1.448. Shaken with H₂SO₄, washed with water, dried with K₂CO₃ and fractionally distd.


1-Hexyne [693-02-7] M 82.2, b 12.5°/75mm, 71°/760mm, d 0.7156, n 1.398. Distr from NaN₃ to remove peroxides. Stood with sodium for 24h, then fractionally distd under reduced pressure. Also dried by repeated vac transfer into freshly activated 4A molecular sieves, followed by vacuum transfer into Na/K alloy and stirring for 1h before fractionally distilling.
2-Hexyne  [764-35-2]  M 82.2, b 83.8°/760 mm, d 0.73146, n 1.41382. Purification as for 1-hexyne above.

3-Hexyne  [928-49-4]  M 82.2, b 81°/760 mm, d 0.7231, n 1.4115. Purification as for 1-hexyne above.

Histamine  [51-45-6]  M 111.2, m 86° (sealed tube), b 167°/0.8 mm, 209°/18 mm, pK$_1$ 6.02, pK$_2$ 9.70. Crystd from benzene or chloroform.

Histamine dihydrochloride  [56-92-8]  M 184.1, m 249-252° (244-245°). Crystd from aq EtOH.

S-Histidine  [71-00-1]  M 155.2, m 287° (dec), [α]$_D^{25}$ -39.7° (c 1, H$_2$O), +13.0° (6 M HCl), pK$_1$ 1.96, pK$_2$ 6.12, pK$_3$ 9.17. Likely impurity is arginine. Adsorbed from aqueous soln on to Dowex 50-H$^+$ ion-exchange resin, washed with 1.5 M HCl (to remove other amino acids), then eluted with 4 M HCl as the dihydrochloride. Histidine is also purified as the dihydrochloride which is finally dissolved in water, the pH adjusted to 7.0, and the free zwitterionic base crystallises out on addition of EtOH. Sol in H$_2$O is 4.2% at 25°.

S-Histidine dihydrochloride  [1007-42-7]  M 242.1, m 245°, [α]$_D^{25}$ +47.5° (c 2, H$_2$O). Crystd from water or aqueous EtOH, and washed with acetone, then diethyl ether. Converted to the histidine di-(3,4-dichlorobenzenesulfonate) salt by dissolving 3,4-dichlorobenzenesulfonic acid (1.5 g/10 mL) in the aqueous histidine soln with warming, and then the soln is cooled in ice. The resulting crystals (m 280° dec) can be recrystd from 5% aqueous 3,4-dichlorobenzenesulfonic acid, then dried over CaCl$_2$ under vacuum, and washed with diethyl ether to remove excess reagent. The dihydrochloride can be regenerated by passing the soln through a Dowex-1 (Cl$^-$ form) ion-exchange column. The solid is obtained by evapn of the soln on a steam bath or better in a vacuum. [Greenstein and Winitz, The Amino Acids Vol 3 p. 1976 1961.]

S-Histidine monohydrochloride  (H$_2$O)  [5934-29-2 (H$_2$O); 7048-02-4]  M 209.6, m 80° monohydrate, 254° (dec), [α]$_D^{25}$ +13.0° (6 M HCl). Crystd from aqueous EtOH.


Homocysteine  [462-10-2]  M 268.4, m 260-265° (dec), pK$_1$ 1.59, pK$_2$ 2.54, pK$_3$ 8.52, pK$_4$ 9.44. Crystd from water.

Homophthalic acid  [89-51-0]  M 180.2, m 182-183°, 189-190°. (depends on heating rate) pK$_{Etl(1)}$ -3.5, pK$_{Etl(2)}$ -4.3. Crystd from boiling water (25 mL/g). Dried at 100°.

Homopiperazine  (1,4-diazepane)  [505-66-8]  M 100.2, m 38-40°, 43°, b 60°/10 mm, 92°/50 mm, 169°/atm, pK$_1$ 6.70, pK$_2$ 10.41. Parified by fractionation through a column of 10 theoretical plates with a reflux ratio of 3:1. It boiled at 169° and the cool distillate crystallises in plates at 43°. [Poppelsdorf and Myerly J Org Chem 26 131 1961.] Its pKa values are 6.89 and 10.65 at 40°, and 6.28 and 9.86 at 40° [Pagano et al. J Phys Chem 65 1062 1961]. The 1,4-bis(4-bromobenzoyl) derivative has m 194-198° (from EtOH); the hydrochloride has m 270-290° (from EtOH) and the picrate has m 265° (dec) [Lloyd et al. J Chem Soc (C) 780 1966].

L-Homoserine (2-amino-4-hydroxybutyric acid)  [672-15-1]  M 119.1, m 203°, [α]$_D^{26}$ +18.3° (in 2 M HCl), pK$_{Ehl(1)}$ -2.1, pK$_{Ehl(2)}$ -9.3. Likely impurities are N-chloroacetetyl-L-homoserine, N-chloroacetetyl-D-homoserine, L-homoserine, homoserine lactone, homoserine anhydride (formed in strong solns of homoserine if slightly acidic). Cyclises to the lactone in strongly acidic soln. Crystd from water by adding 9 volumes of EtOH.

Homoveratronitrile  (3,4-dimethoxybenzyl nitrite)  [93-17-4]  M 177.2, m 62-64°, 68°, b 184°/20 mm, 195-196°/2 mm, 208°/atm. Its solubility is 10% in MeOH. and has been recrystd from
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EtOH or MeOH. Purified by distillation followed by recrystn. [Niederl and Ziering J Am Chem Soc 64 885 1952; Julian and Sturgis J Am Chem Soc 57 1126 1935.]


Hyamine 1622 [[diisobutylphenoxethoxyethyl]dimethylbenzlammonium chloride, benzethionium chloride] [121-54-0] M 448.1, m 164-166° (sinters at 120°, monohydrate). Crystd from boiling acetone after filtering, or from CHCl3-pet ether. The ppte was filtered off, washed with diethyl ether and dried for 24h in a vacuum desiccator.

Hydantoin (2,4-dihydroxyimidazole) [461-72-3] M 100.1, m 216°, 220°, pK25 9.15. Crystd from MeOH. The dihydrochloride has m 104-105° from aq HCl and the di-hydrochloride has m 214-215°.


1-Hydrazinophthalazine hydrochloride (hydralazine hydrochloride) [304-20-1] M 196.6, m 172-173°, pK20 6.57. Crystd from MeOH.


meso-Hydrobenzoin [579-43-1] M 214.3, m 139°. Crystd from EtOH or water.

Hydroquinone (1,4-dihydroxybenzene, quinol) [123-31-9] M 110.1, m 175.4, 176.6°, pK20 9.91, p K2 11.56. Crystd from acetone,*benzene, EtOH, EtOH/*benzene, water or acetonitrile (25g in 30mL), preferably under nitrogen. Dried under vacuum. [Wolfenden et al. J Am Chem Soc 109 463 1987.]

4'-Hydroxyacetanilidene [103-90-2] See 4-acetamidophenol on p. 83.


eythro-3-Hydroxy-RS-aspartic acid  [6532-76-9]  M 149.1, pK$^1$ 1.91, pK$^2$ 3.51, pK$^3$ 9.11. Likely impurities are 3-chloromalic acid, ammonium chloride, threo-3-hydroxyaspartic acid. Crystd from water.


p-Hydroxybenzaldehyde  [123-08-0]  M 122.1, m 115-116°, pK$^2$ 7.61. Crystd from water (containing some H$_2$SO$_4$). Dried over P$_2$O$_5$ under vacuum.


4-Hydroxybenzophenone  [1137-42-4]  M 198.2, m 133.4-133.8°, pK$^2$ 7.95. See p-benzoylphenol on p. 126.


§ A polystyrene supported version is available.


3-Hydroxy-2-butanone (acetoin)  [513-86-0]  M 88.1, b 144-145°, [m 100-105° dimer]. Washed with EtOH until colourless, then with diethyl ether or acetone to remove biacetyl. Air dried by suction and further dried in a vacuum desiccator.

(±)-α-Hydroxy-γ-butyrolactone  [19444-84-9]  M 102.1, b 84°/0.2mm, 133°/10mm, d$^4$ 1.310, n$^D$ 1.4656. It has been purified by repeated fractionation, forms a colourless liquid. It has to be distd at high vacuum otherwise it will dehydrate. The aceiotoxy derivative has b 94°/0.2mm. [NMR: Daremon and Rambaud Bull Soc Chim Fr 294 1971; Schmitz et al. Chem Ber 108 1010 1975.]
4-Hydroxycinnamic acid  \((p\text{-coumaric acid})\) \([501-98-4] \) M 164.2, m 210-213°, 214-215°, 215° \(pK_{\text{a1}}^1 4.64, \ pK_{\text{a2}}^1 9.45.\) Crystd from \(\text{H}_2\text{O}\) (charcoal). Needles from conc aqueous solutions as the anhydrous acid, but from hot dilute solutions the monohydrate acid separates on slow cooling. The acid (33g) has been recrystd from 2.5L of \(\text{H}_2\text{O}\) (1.5g charcoal) yielding 28.4g of recrystd acid, m 207°. It is insol in \(\text{C}_6\text{H}_6\) or pet ether. The UV in 95% \(\text{EtOH}\) has \(A_{\text{max}} 223\) and 286nm (\(\epsilon 14,450\) and 19000 \(M^{-1}\text{cm}^{-1}\)). [UV Wheeler and Covarrubias \(J\) \(\text{Org Chem} \ 28 2015 1963;\) Corti \(\text{Helv Chim Acta} \ 32 681 1949.\]

4-Hydroxycoumarin \([1076-38-6]\) M 162.1, m 206°, \(pK_{\text{a1}} \sim 9.0.\) Crystd from water and dried in a vacuum desiccator over Sicapent.

3-(4-Hydroxy-3,5-dimethoxyphenyl) acrylic acid \([530-59-6]\) M 234.1, m 204-205°(dec), \(pK_{\text{a1}} 4.6, \ pK_{\text{a2}} 9.3.\) Crystd from water.

4-Hydroxydiphenylamine \([122-37-2]\) M 185.2, m 72-73°, \(pK_{\text{a1}} \sim 10.0.\) Crystd from chlorobenzene/pet ether.

12-Hydroxydodecanoic acid \([505-95-3]\) M 216.3, m 86-88°, \(pK_{\text{a1}} \sim 4.8.\) Crystd from toluene [Sadowik et al. \(J\) \(\text{Am Chem Soc} \ 108 7789 1986].

2-Hydroxy-4-(n-dodecyloxy) benzophenone \([2985-59-3]\) M 382.5, m 50-52°, \(pK_{\text{a1}} \sim 7.1.\) Recryst from \(n\)-hexane and then 10% (v/v) \(\text{EtOH}\) in acetonitrile [Valenty et al. \(J\) \(\text{Am Chem Soc} \ 106 6155 1984].

\(N\)-[2-Hydroxyethyl] ethylenediamine \([2-(2\text{-aminoethylamino})\text{ethanol}]\) \([111-41-1]\) M 104.1, b 91.2°/5mm, 238-240°/752mm, n 1.485, d 1.030, \(pK_{\text{a1}} 3.75, \ pK_{\text{a2}} 9.15.\) Distilled twice through a Vigreux column. Redistilled from solid \(\text{NaOH}\), then from \(\text{CaH}_2\). Alternatively, it can be converted to the dihydrochloride and recrystallised from water. It is then dried, mixed with excess of solid \(\text{NaOH}\) and the free base distilled from the mixture. It is finally redistilled from \(\text{CaH}_2\). [Drinkard, Bauer and Bailar \(J\) \(\text{Am Chem Soc} \ 82 2992 1960].

\(N\)-[2-Hydroxyethyl] ethylenediaminetriacetic acid (HEDTA) \([150-39-0]\) M 278.3, m 212-214°(dec), \(pK_{\text{a1}} 2.51, \ pK_{\text{a2}} 5.31, \ pK_{\text{a3}} 9.86.\) Crystd from warm \(\text{H}_2\text{O}\), after filtering, by addition of 95% \(\text{EtOH}\) and allowing to cool. The crystals, collected on a sintered-glass funnel, were washed three times with cold absolute \(\text{EtOH}\), then from \(\text{CaH}_2\). Alternatively, it can be converted to the dihydrochloride and recrystallised from water. It is then dried, mixed with excess of solid \(\text{NaOH}\) and the free base distilled from the mixture. It is finally redistilled from \(\text{CaH}_2\). [Spedding, Powell and Wheelwright \(J\) \(\text{Am Chem Soc} \ 78 34 1956].

\(N\)-Hydroxyethyliminodiacetic acid (HIMDA) \([93-62-9]\) M 177.2, m 181°(dec), \(pK_{\text{a1}} 2.16, \ pK_{\text{a2}} 8.72, \ pK_{\text{a3}} 13.7 \) (OH). Crystd from water.

2-Hydroxyethyltrimethylethenediamine (MONO-TRIS) \([7343-51-3]\) M 165.2, m 91°, \(pK_{\text{a1}} \sim 9.8.\) Crystd twice from \(\text{EtOH}\). Dried under vacuum at 25°.

2-Hydroxyethyl methacrylate \([868-77-9]\) M 130.1, b 67°/3.5mm, d 1.071, n 1.452. Dissolved in water and extracted with \(n\)-heptane to remove ethylene glycol dimethacrylate (checked by gas-liquid chromatography and by NMR) and distilled twice under reduced pressure [Strop, Mikes and Kalal \(J\) \(\text{Phys Chem} \ 80 694 1976].

\(N\)-2-Hydroxyethylpiperazine-\(N\)’-2-ethanesulfonic acid (HEPES) \([7365-45-9]\) M 238.3, \(pK_{\text{a1}} 7.55.\) Crystd from hot \(\text{EtOH}\) and water.

3-Hydroxyflavone \([577-85-5]\) M 238.2, m 169-170°, 171-172°. Recrystd from \(\text{MeOH}, \text{EtOH}\) or hexane. Also purified by repeated sublimation under high vacuum, and dried by high vacuum pumping for at least one hour [Bruker and Kelly \(J\) \(\text{Phys Chem} \ 91 2856 1987].


4-Hydroxyindane [1641-41-1] M 134.2, m 49-50°, b 120°/12mm, pKₐ²5 10.32. Crystd from pet ether. Acetyl deriv has m 30-32° (from EtOH), b 127°/14mm. [Dallacker et al. Chem Ber 105 2568 1972.]


4-Hydroxy-3-methoxyacetophenone [498-02-2] M 166.2, m 115°, pKₑᵢₕ ~7.9. Crystd from water, or EtOH/pet ether.


1-Hydroxymethyladamantane [770-71-8] M 166.3, m 115°. Dissolve in Et₂O, wash with aqueous 0.1N NaOH and H₂O, dry over CaCl₂, evaporate and recryst residue from aqueous MeOH. [Chem Ber 92 1629 1959.]

17α-Hydroxy-17α-methyl-3-androsterone (Mestanolone) [521-11-9] M 304.5°, m 192-193°. Crystd from ethyl acetate.


3-Hydroxy-4-methylbenzaldehyde [57295-30-4] M 136.1, m 116-117°, b 179°/15mm, pKₑᵢₕ ~10.2. Crystd from water.

dl-2-Hydroxy-2-methylbutyric acid [3739-30-8] M 118.1, m 72-73°, pKᵢ²5 3.73. Crystd from benzene, and sublimed at 90°.


R-γ-Hydroxymethyl-γ-butyrolactone [52813-63-5] M 116.1, b 101-102°/0.048mm, dᵣ²₀ 1.2238, nᵣ²₀ 1.471, [α]D²₀ 38°, [α]D²₀ 33° (c 3, EtOH), [α]D²₀ 53.5° (c 3, EtOH). Purified by column chromatography in Silica gel 60 (Merck 70-230 mesh) and eluting with 7% EtOH-73% CHCl₃. IR (film): 3400 (OH), 1765 (C=O) and 1180 (COC) cm⁻¹. [Eguchi and Kakuta Bull Chem Soc Jpn 47 1704 1974; IR and NMR: Ravid et al. Tetrahedron 34 1449 1978.]

7-Hydroxy-4-methylcoumarin (4-methylumbelliferone) [90-33-5] M 176.2, m 185-186°, pKₑᵢₕ ~10.0. Crystd from absolute EtOH. (See also entry on p. 548 in Chapter 6.)

2-Hydroxymethyl-12-crown-4 [75507-26-5] M 206.2, dᵣ²₀ 1.186, nᵣ²₀ 1.480. Purified by chromatography on Al₂O₃ with EtOAc as eluent to give a hygroscopic colourless oil with IR 3418 (OH) and 1103 (COC) cm⁻¹, NMR δ 3.70 (s). [Pugia et al. J Org Chem 52 2617 1987.]

S(-)-5-Hydroxymethyl-2(5H)-furanone [78508-96-0] M 114.1, 39-42°, 40-44°, b 130°/0.3mm, [α]D²₀ -180°, [α]D²₀ -148° (c 1.4, H₂O). It has been purified by chromatography on
Silica gel using hexane-EtOAc (1:1) to give a colourless oil which was distd using a Kügelrohr apparatus and the distillate crystallises on cooling. It has RF 0.51 on Whatman No 1 paper using pentan-1-ol and 85% formic acid (1:1) and developing with ammoniacal AgNO₃. [Boll Acta Chem Scand 22 3245 1968; NMR: Oppolzer et al. Helv Chim Acta 68 2100 1985.]

5-(Hydroxymethyl)furfural [67-47-0] M 126.1, m 33.5°, b 114-116°/1mm. Crystd from diethyl ether/pet ether.

3-Hydroxy-3-methylglutaric acid (Meglulot) [503-49-1] M 162.1, m 99-102°, 108-109°, 100°, pKₑᵩ₁ ~4.0, pKₑᵩ₂ ~5.0. Recrystd from diethyl ether/hexane and dried under vac at 60° for 1h.

dl-3-Hydroxy-N-methylmorphinan [297-90-5] M 257.4, m 251-253°. Crystd from anisole + aqueous EtOH.


4-Hydroxy-4-methyl-2-pentanone [123-42-2] M 116.2, b 166°, d 0.932, n₁ 1.4235, n₂ 1.4213. Loses water when heated. Can be dried with CaSO₄, then fractionally distd under reduced pressure.


2-Hydroxy-2-methylpropionic acid (α-hydroxyisobutyric acid, 2-methylactic acid)) [594-61-6] M 104.1, m 79°, b 114°/12mm, 212°/760mm, pK₂ 3.78. Distd in steam, crystd from diethyl ether or benzene, sublimed at 50° and dried under vacuum.

8-Hydroxy-2-methylquinoline [826-81-3] M 159.2, m 74-75°, b 266-267°, pK₁ 5.61, pK₂ 10.16. Crystd from EtOH or aqueous EtOH.

2-Hydroxy-1-naphthaldehyde [708-06-5] M 172.2, m 82°, b 192°/27mm, pKₑᵩ ~7.8. Crystd from EtOH (1.5mL/g), ethyl acetate or water.


3-Hydroxy-2-naphto-4'-chloro-o-toluidide [92-76-2] M 311.8, m 243.5-244.5°. Crystd from xylene [Schnopper, Broussard and La Forgia Anal Chem 31 1542 1959].


2-Hydroxy-1,4-naphthaquinone  [83-72-7]  M 174.2, m 192°(dec), pK$^1_{15}$ -5.6 (C=O protonation), pK$^2_{25}$ 4.00 (phenolic OH). Crystd from *benzene.

5-Hydroxy-1,4-naphthaquinone (Juglone)  [481-39-0]  M 174.2, m 155°, 164-165°, pK 8.7. Crystd from *benzene/pet ether or pet ether.

6-Hydroxy-2-naphthyl disulfide  [6088-51-3]  M 350.5, m 221-222°, 226-227°, pK$^{est}$ -9.0. Crystallises as leaflets from AcOH and is slightly soluble in EtOH, and AcOH, but is soluble in *C$_2$H$_6$ and in alkalis to give a yellow soln. [Zincke and Dereser Chem Ber 51 352 1918.] The acetoxy derivative has m 198-200° (from AcOH or dioxane-MeOH) and the diacetyl derivative has m 167-168° (from AcOH). A small amount of impure disulfide can be purified by dissolving in a small volume of Me$_2$CO and adding a large volume of toluene, filter rapidly and concentrate to one third of its volume. The hot toluene soln is filtered rapidly from any tarry residue, and crystals separate on cooling. After recrystn from hot acetic acid gives crystals m 220-223° [Barrett and Seligman Science 116 323 1952].

2-Hydroxy-5-nitrobenzyl bromide  [772-33-8]  M 232.0, m 147°, pK$_{Eth}$ -8.0. Crystd from *benzene or *benzene/ligroin.

4-Hydroxy-2-n-octylquinoline N-oxide  [316-66-5]  M 287.4, m 148-149°, pK$_{Eth}$ -6.0. Crystd from EtOH.

N-Hydroxy-5-norbornene-2,3-dicarboxylic acid imide  [21715-90-2]  M 179.2, m 165-166°, 166-169°, pK$_{Eth}$~6. Dissolve in CHCl$_3$, filter, evaporate and recrystallise from EtOAc. IR (nujol): 1695, 1710 and 3100 (OH) cm$^{-1}$. O-Acetyl derivative has m 113-114° (from EtOH) with IR bands at 1730, 1770 and 1815 cm$^{-1}$ only, and the O-benzoyl derivative has m 143-144° (from propan-2-ol or *C$_2$H$_6$). [Bauer and Miarka J Org Chem 24 1293 1959; Fujino et al. Chem Pharm Bull Jpn 22 1857 1974].

DL-erythro-3-Hydroxynorvaline (2-amino-3-hydroxypentanoic acid)  [34042-00-7]  M 133.2, m 257-259° (dec), 263° (dec), pK$^{10}$ 2.32, pK$^{20}$ 9.12. Purified by recrystn from aqueous EtOH. The Cu salt has m 255-256° (dec), the benzoyl derivative has m 181°, and the N-phenylcarbamoyl derivative has m 164°. [Buston et al. J Biol Chem 204 665 1953].

2-Hydroxyoctanoic acid (2-hydroxycaprylic acid)  [617-73-2]  M 160.2, m 69.5°, b 160-165°/10mm, pK$_{Eth}$~3.7. Crystd from EtOH/pet ether or ether/ligroin.


2-Hydroxyphenylacetic acid  [614-75-5]  M 152.2, m 148-149°, b 240-243°/760 mm, pK$_{Eth(1)}$~4.3, pK$_{Eth(2)}$~10.1. Crystd from ether or chloroform (m from latter is always lower).


4-Hydroxyphenylacetic acid  [156-38-7]  M 152.2, m 150-151°, 152°, pK$^1_{1}$ 4.28, pK$^2_{2}$ 10.1. Crystd from water or Et$_2$O/pet ether.


3-Hydroxy-2-phenylcinchominic acid  [485-89-2]  M 265.3, m 206-207° (dec). Crystd from EtOH.

N-(4-Hydroxyphenyl)-3-phenylsalicylamide [550-57-2] M 305.3, m 183-184°, pK<sub>Est</sub>~9.5. Crystd from aqueous MeOH.

L-2-Hydroxy-3-phenylpropionic acid (3-phenyl lactic acid) [20312-36-1] M 166.2, m 125-126°, [α]<sub>D</sub>~ -18.7° (EtOH), pK see below. Crystd from water, MeOH, EtOH or *benzene.

dl-2-Hydroxy-3-phenylpropionic acid [828-01-3] M 180.2, m 220°(dec), pK~7.0. Crystd from ether or H<sub>2</sub>O.


3-p-Hydroxyphenylpropionic acid (phloretic acid) [Sol]-97-31 M 166.2, m 129-130°, 131-133°, pK<sub>1</sub>~3.7, pK<sub>2</sub>~10.1. Crystd from ether or H<sub>2</sub>O.

p-Hydroxyphenylpyruvic acid [156-39-8] M 180.2, m 220°(dec), pK<sub>Est</sub>~2.3. Crystd three times from 0.1M HCl/EtOH (4:1, v/v) immediately before use [Rose and Powell Biochem J 87 541 1963] or from Et<sub>2</sub>O. The 3,4-Dinitrophenylhydrazone has m 178°.

3-β-Hydroxy-5-pregnen-20-one (pregnenolone) [145-13-1] M 316.5, m 189-190°, [α]<sub>D</sub>~ +30° (EtOH), [α]<sub>S</sub>~ +141° (c 2, dioxane), λ<sub>max</sub> 240nm. Crystd from acetone or EtOH. Acetate: m 239-240° and caproate: m 119-121° crystallised from CHCl<sub>3</sub>/MeOH.

17α-Hydroxyprogesterone [604-09-1] M 330.5, m 222-223°, [α]<sub>D</sub>~ +141° (c 2, dioxane), λ<sub>max</sub> 240nm. Crystd from acetone or EtOH. Acetate: m 239-240° and caproate: m 119-121° crystallised from CHCl<sub>3</sub>/MeOH.


2-(α-Hydroxypropyl)piperidine (2-piperidinepropanol) [24448-89-3] M 143.2, m 121°, b 226°, pK<sub>Est</sub>~10.2. Crystd from ether.

7-(2-Hydroxypropyl)theophylline (Proxyllyline) [603-00-9] M 238.2, m 135-136°. Crystd from EtOH.


2-Hydroxypyridine (2-pyridone) [142-08-5] M 95.1, m 105-107°, b 181-185°/24mm, ε<sub>293nm</sub> 5900 (H<sub>2</sub>O) pK<sub>1</sub>~1.25, pK<sub>2</sub>~11.99. Distd under vacuum to remove coloured impurity, then crystd from
*benzene, CCl₄, EtOH or CHCl₃/diethyl ether. It can be sublimed under high vacuum. [DePue et al. J Am Chem Soc 107 2131 1985.1]

3-Hydroxypyridine  [109-00-2]  M 95.1, m 129⁰, pKᵢ¹ 5.10, pKᵢ² 8.6. Crystd from water or EtOH.

4-Hydroxypyridine (4-pyridone)  [626-64-2]  M 95.1, m 65⁰(hydrate), 148.5⁰ (anhydr), b >350⁰/760mm, pKᵢ¹ 3.20, pKᵢ² 11.12. Crystd from H₂O. Loses H₂O on drying in vacuo over H₂SO₄. Stored over KOH because it is hygroscopic.

2(6)-Hydroxypyridine-5(3)-carboxylic acid (6-hydroxonicotinic acid)  [5006-66-6]  M 139.1, m 304⁰(dec), pKᵢ² 3.82. Crystd from water.

4-Hydroxypyridine-2,6-dicarboxylic acid (chelidamic acid)  [138-60-3]  M 183.1, m 254⁰(dec), pKᵢ¹ 1.9, pKᵢ² 3.18, pKᵢ³ 10.85. Crystd from water.


4-Hydroxypyrimidine  [4562-27-0]  M 96.1, m 164-165⁰, pKᵢ² 1.66, pKᵢ³ 8.63. Crystd from *benzene or ethyl acetate.

2-Hydroxypyrimidine hydrochloride  [38353-09-2]  M 132.5, m 205⁰(dec). Crystd from EtOH.

2-Hydroxyquinoline (carbostyril)  [59-31-4]  M 145.2, m 199-200⁰, pKᵢ² 0.31, pKᵢ³ 11.76. Crystd from MeOH.


8-Hydroxyquinoline-5-sulfonic acid (H₂O)  [84-88-8]  M 243.3, m >310⁰, pKᵢ² 4.09, pKᵢ³ 8.66. Crystd from water or dil HCl (ca 2% by weight).


trans-4-Hydroxystilbene  [6554-98-9]  M 196.3, m 189⁰. Crystd from *benzene or acetic acid.


4-Hydroxy-2,2,6,6-tetramethylpiperidine  [2403-88-5]  M 157.3, m 130-131⁰, pK 10.05. Crystd from water as hydrate, and crystd from ether as the anhydrous base.

Hydroxy(tosyloxy)iodobenzene [phenyl(hydroxy)tosyloxyiodine, hydroxy(4-methyl-benzenesulfonato-O)phenyliodine, Koser's reagent]  [27126-76-7] M 392.2, m 134-136⁰, 135-138⁰, 134-136⁰, 136-138.5⁰. Possible impurities are tosic acid (removed by washing with Me₂CO) and acetic acid (removed by washing with Et₂O). It is purified by dissolving in the minimum vol of MeOH, adding
EtO to cloud point and setting aside for the prisms to separate [Koser and Wettach J Org Chem 42 1476 1977; NMR: Koser et al. J Org Chem 41 3609 1976]. It has also been crystd from CH2Cl2 (needles, m 140-142°) [Neiland and Karele J Org Chem, USSR (Engl Transl) 6 889 1970].

4(6)-Hydroxy-2,5,6(2,4,5)-triaminopyrimidine sulfate [35011-47-3] M 257.22, m >340°, pK1 2.0, pK2 5.1, pK3 10.1. This salt has very low solubility in H2O. It is best purified by conversion into the dihydrochloride salt which is then reconverted to the insoluble sulfate salt. The sulfate salt (2.57g, 10mmoles) is suspended in H2O (20mL) containing BaCl2 (10mmoles) and stirred in a boiling water bath for 15min. After cooling the insoluble BaSO4 is filtered off and washed with boiling H2O (10mL). The combined filtrate and washings are made acidic with HCl and evaporated to dryness. The residual hydrochloride salt is recrystd from H2O by adding conc HCl whereby the dihydrochloride salt separates as clusters which darken at 260° and dec >300° [Baugh and Shaw J Org Chem 29 3610 1964; King and Spengley J Chem Soc 2144 1952]. The hydrochloride is then dissolved in H2O and while hot an equivalent of H2SO4 is added when the sulfate separates as a white microcrystalline solid which is filtered off washed liberally with H2O and dried in vacuum over P2O5. [Albert and Wood J Appl Chem London 3 521 1953; UV: Cavalieri et al. J Am Chem Soc 70 3875 1948; see also Pfleiderer Chem Ber 90 2272 1957; Traube Chem Ber 33 1371 1900].


Ibogaine [83-74-9] M 300.3, m 152-153°, [a]D20 -54° (EtOH), pK 8.1 (80% aq MeOCH2CH2OH). Crystd from aqueous EtOH and sublimates at 150°/0.01mm.

1,3-Indandione [606-23-5] M 146.2, m 129-132°, pK\textsubscript{i} 7.2 (1% aq EtOH). Recrystd from EtOH [Bernasconi and Paschalis J Am Chem Soc 108 2969 1986].

Indane [496-11-7] M 118.1, b 177°, d 0.960, n 1.538. Shaken with conc H\textsubscript{2}SO\textsubscript{4}, then water, dried and fractionally distd.

Indanthrene [81-77-6] M 442.4, m 470-500°. Crystd repeatedly from 1,2,4-trichlorobenzene.

Indazole [271-44-3] M 118.1, m 147°, pK\textsubscript{f} 1.32, p K\textsubscript{i} 13.80 (acidic NH). Crystd from water. 

Indene [95-13-6] M 116.2, f -1.5°, b 114.5°/100mm, d 0.994, n 1.5763. Shaken with 6M HCl for 24h (to remove basic nitrogenous material), then refluxed with 40% NaOH for 2h (to remove benzonitrile). Fractionally distd, then fractionally crystd by partial freezing. The higher-melting portion was converted to its sodium salt by adding a quarter of its weight of sodamide under nitrogen and stirring for 3h at 120°. Unreacted organic material was distd off at 120°/1mm. The sodium salts were hydrolysed with water, and the organic fraction was separated by steam distn, followed by fractional distn. Before use, the distillate was passed, under nitrogen, through a column of activated silica gel. [Russell J Am Chem Soc 78 1041 1956.]

Indigo [482-89-3] M 262.3, sublimes at -300°, m 390°(dec), and halogen-substituted indigo dyes. Reduced in alkaline soln with sodium hydrosulfite, and filtered. The filtrate was then oxidised by air, and the resulting ppt was filtered off, dried at 65-70°, ground to a fine powder, and extracted with CH\textsubscript{2}Cl\textsubscript{2} in a Soxhlet extractor. Evapn of the CH\textsubscript{2}Cl\textsubscript{2} gave the purified dye. [Brode, Pearson and Wyman J Am Chem Soc 76 1034 1954; spectral characteristics are listed.]

Indole [120-72-9] M 117.2, m 52°, b 124°/5mm, 253-254°/760mm, pK\textsubscript{i} 2.47 (Ho scale), p K\textsubscript{i} 16.97 (acidic NH). Crystd from *benzene, hexane, water or EtOH/water (1:10). Further purified by sublimation in a vacuum or zone melting.

Indole-3-acetic acid [87-51-4] M 175.2, m 167-169°, pK\textsubscript{i} 6.13 (aq H\textsubscript{2}SO\textsubscript{4}), pK\textsubscript{i} 4.5 4 (CO\textsubscript{2}H). Recrystd from EtOH/water [James and Ware J Phys Chem 89 5450 1985].

3-Indoleacetonitrile [771-51-7] M 156.2, m 33-36°, 36-38°, b 157°/0.2mm, 158-160°/0.1mm, viscous oil n\textsubscript{D} 1.6097. Distil in very high vacuum and the viscous distillate crystallises on standing after a few days; the picrate has m 127-128° (from EtOH) [Coker et al. J Org Chem 27 850 1962; Thesing and Schüle Chem Ber 85 324 1952]. The N-acetate has m 118° (from MeOH) and has R\textsubscript{F} = 0.8, on Silica Gel F\textsubscript{254} in CHCl\textsubscript{3}-MeOH 19:1 [Buzas et al. Synthesis 129 1977].


Indolizine [pyrrocoline, pyrrolo(1,2-a)pyridine] [274-40-8] M 117, m 73-74°, 75°, pK\textsubscript{2} 3.94 (C-protonation). Purified through an alumina column in *C\textsubscript{6}H\textsubscript{6} and eluted with *C\textsubscript{6}H\textsubscript{6} (toluene could be used instead). The eluate contained in the fluorescent band (using UV light λ 365mm) was collected, evapd and the cryst residues sublimed twice at 40-50°/0.2-0.5mm. The colourless crystals darken on standing and should be stored in dark sealed containers. If the original sample is dark in color then it should be covered with water and steam dist. The crystals in the distillate are collected and, dried between filter paper and sublimed. It protonates on C3 in aqueous acid. It should give one fluorescent spot on paper chromatography (Whatman 1) in 3% aq ammonia and in n-BuOH, AcOH, H\textsubscript{2}O (4:1:1). The picrate has m 101° from EtOH. [Armarego J Chem Soc 226 1944; Armarego J Chem Soc (B) 191 1966; Scholtz Chem Ber 45 734 1912.]
(-)-Inosine  [58-63-9]  M 268.2, m 215°, \([\text{c 1, 0.1M NaOH}], \text{pK}^1 \text{25} 1.06, \text{pK}^2 \text{25} 8.96, \text{pK}^3 \text{15} 11.36. \text{Crystd from aqueous 80% EtOH.}


Inositol monophosphate  [15421-51-9]  M 260.1, m 195-197°(dec). \text{Crystd from water and EtOH.}

Iodinin  (1,6-phenazine-5,10-dioxide)  [68-81-5]  M 244.1, m 236°(dec), \text{pK} 12.5. \text{Crystd from CHCl}_3.


Iodoacetamide  [144-48-9]  M 185.0, m ca 143°(dec). \text{Crystd from water or CCl}_4.

Iodoacetic acid  [64-69-7]  M 160.6, m 78°, \text{pK}^1 \text{25} 3.19. \text{Crystd from pet ether (b 60-80°) or CHCl}_3/CCl.

2-Iodoaniline  [615-43-0]  M 219.0, m 60-61°, \text{pK}^1 \text{5} 2.54. \text{Distd with steam and crystd from benzene/pet ether.}

4-Iodoaniline  [540-37-4]  M 219.0, m 62-63°, \text{pK}^1 \text{5} 3.81. \text{Crystd from pet ether (b 60-80°) by refluxing, then cooling in an ice-salt bath freezing mixture. Dried in air. Also crystd from EtOH and dried in a vacuum for 6h at 40° [Edidin et al. J Am Chem Soc 109 3945 1987].}

4-Iodoanisole  [696-62-8]  M 234.0, m 51-52°, b 139°/35mm, 237°/726mm. \text{Crystd from aqueous EtOH.}

Iodobenzene  [591-50-4]  M 204.0, b 63-65°/10mm, 188°/atm, d 1.829, n^25 1.6169. \text{Washed with dilute aqueous Na}_2S_2O_3, then water. Dried with CaCl}_2 or CaSO}_4. Decolorised with charcoal. Distd under reduced pressure and stored with mercury or silver powder to stabilise it.

\(\alpha\)-Iodobenzoic acid  [88-67-5]  M 248.4, m 162°, \text{pK}^1 \text{5} 2.93. \text{Crystd repeatedly from water and EtOH. Sublimed under vacuum at 100°.}

\(m\)-Iodobenzoic acid  [618-51-9]  M 248.4, m 186.6-186.8°, \text{pK}^1 \text{5} 3.85. \text{Crystd repeatedly from water and EtOH. Sublimed under vacuum at 100°.}

\(p\)-Iodobenzoic acid  [619-58-9]  M 248.4, m 271-272°, \text{pK}^1 \text{5} 4.00. \text{Crystd repeatedly from water and EtOH. Sublimed under vacuum at 100°.}

4-Iodobiphenyl  [1591-31-7]  M 280.1, m 113.7-114.3°. \text{Crystd from EtOH/benzene and dried under vacuum over P}_2O}_5.

2-Iodobutane  [513-48-4]  M 184.0, b 120.0, d 1.50, n^25 1.4973. \text{Purified by shaking with conc H}_2S}_4, then washing with water, aq Na}_2SO}_3 and again with water. Dried with MgSO}_4 and distd. Alternatively, passed through a column of activated alumina before distn, or treated with elemental bromine, followed by extraction of the free halogen with aqueous Na}_2S}_2O}_3, thorough washing with water, drying and distilling. It is stored over silver powder and distd before use.

1-Iodo-2,4-dinitrobenzene  [709-49-9]  M 294.0, m 88°. \text{Crystd from ethyl acetate.}

Iodoform  [75-47-8]  M 393.7, m 119°. \text{Crystd from MeOH, EtOH or EtOH/EtOAc. Steam volatile.}

1-Iodo-4-nitrobenzene  [636-98-6]  M 249.0, m 171-172°. \text{Ppted from acetone by addition of water, then recrystd from EtOH.}

*p-Iodophenol* [540-38-5]  M 280.1, m 94°, 138-140°/5mm, pK$_{25}$ 9.30. Crystd from pet ether (b 80-100°) or distd in vacuo. If material has a brown or violet color, dissolve in CHCl$_3$, shake with 5% sodium thiosulfate soln until the CHCl$_3$ is colorless. Dry (Na$_2$SO$_4$), extract, evap and dist residue in vacuo. [Dains and Eberly *Org Synth* Coll Vol II, 355 1948.]

5-Iodosaliclyc acid (2-hydroxy-5-iodobenzoic acid) [119-30-2]  M 264.0, m 197° pK$_{15}$ 2.65, pK$_{25}$ 13.05. Crystd from water.

o-Iodosobenzoic acid [304-91-6]  M 264.0, m >200°, pK$_{25}$ ~2.6. Crystd from EtOH.


*p-Iodotoluene* [624-31-7]  M 218.0, m 35°, b 211-212°. Crystd from EtOH.

3-Iodo-L-tyrosine [70-78-0]  M 307.1, m 205-208°(dec), [α]$_D^{25}$ -4.4° (c 5, 1M HCl), pK$_{Est(2)}$-2.1, pK$_{Est(3)}$-6.4, pK$_{Est}$15 8.7. Likely impurities are tyrosine, diiodotyrosine and iodide. Crystd by soln in dilute ammonia, at room temperature, followed by addition of dilute acetic acid to pH 6. Stored at 0°.

α-Ionone [127-41-3]  M 192.3, b 131°/133mm, d 0.931, n 1.520, [α]$_D^{23}$ +347° (neat). Purified on a spinning band fractionating column.

β-Ionone [79-77-6]  M 192.3, b 150-151°/24mm, d 0.945, n 1.5211. ε$_{296nm}$ 10,700. Converted to the semicarbazone (m 149°) by adding 50g of semicarbazide hydrochloride and 44g of potassium acetate in 150mL of water to a soln of 85g of β-ionone in EtOH. (More EtOH was added to redissolve any β-ionone that pptd.) The semicarbazone crystallised on cooling in an ice-bath and was recrystallised from EtOH or 75% MeOH to constant m (148-149°). The semicarbazone (5g) was shaken at room temperature for several days with 20mL of pet ether and 48mL of M H$_2$SO$_4$, then the ether layer was washed with water and dilute aqueous NaHCO$_3$, dried and the solvent was evaporated. The β-ionone was distilled under vacuum. (The customary steam distillation of β-ionone semicarbazone did not increase the purity.) [Young et al. *J Am Chem Soc* 66 855 1944.]  

Iproniazid (isonicotinic acid 2-isopropylhydrazide) phosphate [303-33-9]  M 277.2, m 178-179°, 180-182°, pK$_{Est}$ ~3.5 (free base). Crystd from H$_2$O and Me$_2$CO. Free base has m 113-114° from *C$_6$H$_6$/pet ether.

(z)-Irone (6-methyl-ionone, z-trans-(α)-4t-[2,5,6,6-tetramethyl-cyclohex-2-yl]but-3-ene-2-one) [79-69-6]  M 206.3, b 85-86°/0.05mm, 109°/0.7mm, d$_D^{10}$ 0.9340, n$_D^{10}$ 1.4998. If large amounts are available then fractionate through a Podbielniak column (see p. 141) or an efficient spinning band column, but small amounts are distilled using a Kugelrohr apparatus. The 4-phenyl-semicarbazone has m 174-175° (165-165.5°). [IR: Seidel and Ruzocka *Helv Chim Acta* 35 1826 1952; Naves *Helv Chim Acta* 31 1280 1948; Lecomte and Naves *J Chim Phys* 53 462 1956.]

Isatin (indole-2,3-dione) [91-56-5]  M 147.1, m 201-203°, 205°, pK >12 (acidic NH). Crystd from amyl alcohol and sublimed at 180°/1mm. In aq NaOH the ring opens to yield sodium o-aminobenzoylformate.

Isatoic anhydride (3,1-benzoxazin-2,4[1-H]-dione) [118-48-9]  M 163.1, m 235-240°, 240-243°, 243°, 243-245°. Recryst from EtOH or 95% EtOH (30mL/g) or dioxane (10mL/g) and dried in a vacuum. [Wagner and Fegley *Org Synth* Coll Vol III 488 1953; Ben-Ishai and Katchalski *J Am Chem Soc* 74 3688 1952; UV: Zentmyer and Wagner *J Org Chem* 14 967 1949.]

Isoamyl acetate (1-butyl-3-methyl acetate) [123-92-2]  M 130.2, b 142.0°, d 0.871, n 1.40535. Dried with finely divided K$_2$CO$_3$ and fractionally distd.
Isoamyl alcohol (1-butyl-3-methyl alcohol) [123-31-3] M 88.2, b 132°/760mm, d15 0.8129, n15 1.4085. See 3-methyl-1-butanol on p. 290.

Isoamyl bromide (1-butyl-3-methyl bromide) [107-82-4] M 151.1, f -112°, b 119.2°/737mm, d 1.208, n 1.444. Shaken with conc H2SO4, washed with water, dried with K2CO3 and fractionally distd.

Isoamyl chloride (1-butyl-3-methyl chloride) [513-36-0] M 106.6, b 99°/734mm, d 0.8704, n 1.4084. Shaken vigorously with 95% H2SO4 until the acid layer no longer became coloured during 12h, then washed with water, saturated aq Na2CO3, and more water. Dried with MgSO4, filtered and fractionally distd. Alternatively, a stream of oxygen containing 5% of ozone was passed through the chloride for a time, three times longer than was necessary to cause the first coloration of starch iodide paper by the exit gas. Subsequent washing of the liquid with aqueous NaHCO3 hydrolysed the ozonides and removed organic acids. After drying and filtering, the isoamyl chloride was distd. [Chien and Willard J Am Chem Soc 75 6160 1953.]

Isoamyl ether [diisopentyl ether, di-(1-butyl-3-methyl) ether] [544-01-4] M 158.3, b 173.4°, d 0.778, n 1.40850. This is a mixture of 2- and 3-methylbutyl ether. It is purified by refluxing with sodium for 5h, then distilled under reduced pressure, to remove alcohols. Isoamyl ether can also be dried with CaCl2 and fractionally distd from P2O5.


Isobutane [75-28-5] M 58.1, b -10.2°, d 0.557. Olefines and moisture can be removed by passage at 65° through a bed of silica-alumina catalyst which has previously been evacuated at about 400°. Alternatively, water and CO2 can be taken out by passage through P2O5 then asbestos impregnated with NaOH. Treatment with anhydrous AlBr3 at 0° then removes traces of olefins. Inert gases can be separated by freezing the isobutane at -195° and evacuating out the system.

Isobutene [115-11-7] M 56.1, b -6.6°/760mm. Dried by passage through anhydrous CaSO4 at 0°. Purified by freeze-pump-thaw cycles and trap-to-trap distn.

Isobutyl alcohol (2-methyl-1-propanol) [78-83-1] M 74.1, b 108°/760mm, d 0.801, n 1.396. Dried with K2CO3, CaSO4 or CaCl2, filtered and fractionally distd. For further drying, the redist alcohol can be refluxed with the appropriate alkyl phthalate or succinate as described under ethanol (see also p. 271).

Isobutyl bromide (1-bromo-2-methylpropane) [78-77-3] M 137.0, b 91.2°, d 1.260, n 1.437. Partially hydrolysed to remove any tertiary alkyl halide, then fractionally distd, washed with conc H2SO4, water and aqueous K2CO3, then redistd from dry K2CO3. [Dunbar and Hammett J Am Chem Soc 72 109 1950.]

Isobutyl chloride (1-chloro-2-methylpropane) [513-36-0] M 92.3, b 68.8°/760mm, d 0.877, n 1.398. Same methods as described under isoamyl chloride.

Isobutyl formate  [542-55-2]  M 102.1, b 98.4°, d 0.885, n 1.38546. Washed with saturated aqueous NaHCO₃ in the presence of saturated NaCl, until no further reaction occurred, then with saturated aqueous NaCl, dried (MgSO₄) and fractionally distd.

Isobutyl iodide  (1-iodo-2-methylpropane)  [513-38-2]  M 184.0, b 83°/250mm, 120°/760mm, d 1.60, n 1.495. Shaken with conc H₂SO₄, and washed with water, aqueous Na₂S₀₃, and water, dried with MgSO₄ and distd. Alternatively, passed through a column of activated alumina before distn. Stored under nitrogen with mercury in a brown bottle or in the dark.

Isobutyl vinyl ether  [109-53-5]  M 88.1, b 154-154.5°, d 0.949, n 1.393, pK₂ 4.60. Distd from KMnO₄, then redistd from P₂O₅.

Isobutyraldehyde  [78-84-2]  M 72.1, b 62.0°, d 0.789, n 1.377. Dried with CaSO₄ and used immediately after distn because of the great difficulty in preventing oxidation. Can be purified through its acid bisulfite derivative.

Isobutyramide  [563-83-7]  M 87.1, m 128-129°, b 217-221°. Crystd from acetone, benzene, CHC₁₃ or water, then dried under vacuum over P₂O₅ or 99% H₂SO₄. Sublimed under vacuum.

Isobutyric acid  [79-31-2]  M 88.1, m 285-286° (dec), [cr]₂ 40.6° (6M HCl) pK₁ 2.66, pK₂ 5.60. Shaken with conc HCl (to remove isonitriles), then with water and aq NaHCO₃. After a preliminary drying with silica gel or Linde type 4A molecular sieves, it is shaken or stirred with CaH₂ until hydrogen evolution ceases, then decanted and distd from P₂O₅ (not more than 5g/L, to minimize gel formation). Finally it is refluxed with, and slowly distd from CaH₂ (5g/L), taking precautions to exclude moisture.


L-Isoleucine  [73-32-5]  M 131.2, m 285-286° (dec), [α]D 20° +40.6° (6M HCl) pK₁ 2.66, pK₂ 5.69. Crystd from water by addition of 4 volumes of EtOH.


Isolysergic acid  [478-95-5]  M 268.3, m 218° (dec), [α]D 20° +281° (c 1, pyridine) pK₁ 3.33, pK₂ 8.46. Crystd from water by addition of 4 volumes of EtOH.


Isonicotinic acid  (pyridine-4-carboxylic acid)  [55-22-1]  M 123.1, m 320°, pK₂ 4.90. Crystd repeatedly from water. Dried under vac at 110°.

Isonicotinic acid hydrazide  (isoniazide)  [54-85-3]  M 137.1, m 172°, pK₁ 1.75 (NHNH₂), pK₂ 3.57 (=N-), pK₃ 10.75 (=NH). Crystd from 95% EtOH.

1-Isonicotinyl-2-salicylidenehydrazide [495-84-1] M 241.2, m 223-223.5°. Crystd from EtOH.

Isonitrosocacetone (anti-pyruvic aldehyde-1-oxime) [31915-82-9] M 87.1, m 69°. Crystd from ether/pet ether or CCl₄.

Isonitrosocacetophenone (phenylglyoxaloxime) [532-54-7] M 149.2, m 126-128°. Crystd from water.

5-Isonitrosobarbituric acid (violuric acid) [26851-19-9] M 175.1, m 221-223°, 245-250°, pK₁ 4.41, pK₂ 9.66 (10.1). Crystd from water or EtOH.

Z,l-Dimethylvioluric acid, m 144-147° has pK 4.72 [Taylor and Robinson Tuluntu 8 518 1961].

Isononane [34464-40-9] M 128.3, b 142°/760mm. Passed through columns of activated silica gel and basic alumina (activity 1). Distd under high vacuum from Na/K alloy.

Isopentyl formate [110-45-2] M 116.2, b 121-123°/atm, 123-123.6°/atm, 123-124°/atm, d₂⁰ 0.8713, n₂⁰ 1.391. Colourless liquid which is soluble in 300 volumes of H₂O and is soluble in common organic solvents. It is purified by repeated distn using an efficient column at atmospheric pressure.

Isophorone [78-59-1] M 138.2, b 94°/16mm, d 0.921, n₂⁰ 1.4778. Washed with aqueous 5% Na₂CO₃ and then distd under reduced pressure, immediately before use. Alternatively, can be purified via the semicarbazone. [Erskine and Waight J Chem Soc 3425 1960.]

Isophthalic acid (benzene-1,3-dicarboxylic acid) [121-91-5] M 166.1, m 345-348°, pK₁ 3.70, pK₂ 5.60. Crystd from aqueous EtOH.

Isopinocampheol (pinan-3-ol, 2,6,6-trimethylbicyclo[3.1.1]heptan-3-ol) [1S,2S,3S,5R-(+)-27779-29-9; 1R,2R,3R,5S-(−)-25465-65-0] M 154.25, m 52-55°, 55-56°, 55-57°, b 103°/11mm, d₂⁰ 1.4832, [α]D²⁰ (+) and (-) 43°, [α]D¹⁰ (+) and (-) 36° (c 20, EtOH). Dissolve in Et₂O, dry MgSO₄, filter, evaporate, then recryst from pet ether. Also recryst from aqueous EtOH and has been distd in a vacuum. [Kergomard and Geneix Bull Soc Chim Fr 394 1958; Zweifel and Brown J Am Chem Soc 86 393 1964.] The 3,4-dinitrobenzoyl deriv has m 100-101°, the phenylcarbamoyl derivative has m 137-138° and the acid-phthalate has m 125-126°.

Isoprene (2-methyl-1,3-butadiene) [78-79-5] M 68.1, b 34.5-35°/762mm, d 0.681, n₂⁰ 1.4225. Refluxed with sodium. Distd from sodium or NaBH₄ under nitrogen, then passed through a column containing KOH, CaSO₄ and silica gel. tert-Butylcatechol (0.02% w/w) was added, and the isoprene was stored in this way until redistd before use. The inhibitor (tert-butylcatechol) in isoprene can be removed by several washings with dil NaOH and water. The isoprene is then dried over CaH₂, distd under nitrogen at atmospheric pressure, and the fraction distilling at 32° is collected. Stored under nitrogen at -15°.

Isopropanol [67-63-0] M 60.1, b 82.5°, d 0.783, n₂⁰ 1.3739, pK₁ 17.1. Isopropyl alcohol is prepared commercially by dissolution of propene in H₂SO₄, followed by hydrolysis of the sulfate ester. Major impurities are water, lower alcohols and oxidation products such as aldehydes and ketones. Purification of isopropanol follows substantially the same procedure as for n-propyl alcohol.

Isopropanol forms a constant-boiling mixture, b 80.3°, with water. Most of the water can be removed from this 91% isopropanol by refluxing with CaO (200g/L) for several hours, then distilling. The distillate can be dried further with CaH₂, magnesium ribbon, BaO, CaSO₄, calcium, anhydrous CuSO₄ or Linde type 5A molecular sieves. Distrn from sulfanilic acid removes ammonia and other basic impurities. Peroxides [indicated by liberation of iodine from weakly acid (HCl) solns of 2% KI] can be removed by refluxing with solid stannous chloride or with NaBH₄ then fractionally distilling. To obtain isopropanol containing only 0.002M of water, sodium (8g/L) has been dissolved in material dried by distn from CaSO₄, 35mL of isopropyl benzoate has been
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added and, after refluxing for 3h, the alcohol has been distd through a 50-cm Vigreux column. [Hine and Tanabe J Am Chem Soc 80 3002 1958.] Other purification steps for isopropanol include refluxing with solid aluminium isopropoxide, refluxing with NaBH₄ for 24h, and the removal of acetone by treatment with, and distn from 2,4-dinitrophenyldrazine. Peroxides re-form in isopropanol if it is stood for several days.


Isopropyl acetate [108-22-5] M 102.1, b 88.4°, d 0.873, n 1.3773. Washed with 50% aq K₂CO₃ (to remove acid), then with saturated aq CaCl₂ (to remove any alcohol). Dried with CaCl₂ and fractionally distd.

Isopropyl bromide (2-bromopropane) [75-26-3] M 123.0, b 0°/69.2mm, 59.4°/760mm, d 1.31, n₁⁰ 1.42847, n 1.4251. Washed with 95% H₂SO₄ (conc acid partially oxidised it) until a fresh portion of acid did not become coloured after several hours, then with water, aq NaHSO₃, aq 10% Na₂CO₃ and again with water. (The H₂SO₄ can be replaced by conc HCl.) Prior to this treatment, isopropyl bromide has been purified by bubbling a stream of oxygen containing 5% ozone through it for 1h, followed by shaking with 3% hydrogen peroxide soln, neutralising with aq Na₂CO₃, washing with distilled water and drying. Alternatively, it has been treated with elemental bromine and stored for 4 weeks, then extracted with aq NaHSO₃ and dried with MgSO₄. After the acid treatment, isopropyl bromide can be dried with Na₂SO₄, MgSO₄ or CaH₂, and fractionally distd.

N-Isopropylcarbazole [1484-09-9] M 209.3, m 120°. Crystd from isopropanol. Sublimed under vacuum. Zone refined. The picrate has m 143° after recrystn from EtOH.

Isopropyl chloride (2-chloropropane) [75-29-6] M 78.5, b 34.8°, d 0.864, n 1.3779, n²⁵ 1.3754. Purified with 95% H₂SO₄ as described for isopropyl bromide, then dried with MgSO₄, P₂O₅ or CaH₂, and fractionally distd from Na₂CO₃ or CaH₂. Alternatively, a stream of oxygen containing ca 5% ozone has been passed through the chloride for about three times as long as was necessary to obtain the first coloration of starch iodide paper by the exit gas, and the liquid was then washed with NaHCO₃ soln to hydrolyse ozonides and remove organic acids before drying and distilling.

Isopropyl ether (diisopropyl ether) [108-20-3] M 102.2, b 68.3°, d 0.719, n 1.3688, n²⁵ 1.36618. Common impurities are water and peroxides [detected by the liberation of iodine from weakly acid (HCl) solns of 2% KI]. Peroxides can be removed by shaking with aqueous Na₂SO₃ or with acidified ferrous sulfate (0.6g FeSO₄ and 6mL conc H₂SO₄ in 110mL of water, using 5-10g of soln per L of ether), or aqueous NaBH₄ soln. The ether is then washed with water, dried with CaCl₂ and distd. Alternatively, refluxing with LiAlH₄ or CaH₂, or drying with CaSO₄, then passage through an activated alumina column, can be used to remove water and peroxides. Other dehydrating agents used with isopropyl ether include P₂O₅, sodium amalgam and sodium wire. (The ether is often stored in brown bottles, or in the dark, with sodium wire.) Bonner and Goishi (J Am Chem Soc 83 85 1961) treated isopropyl ether with dil sodium dichromate/sulfuric acid soln, followed by repeated shaking with a 1:1 mixture of 6M NaOH and saturated KMnO₄. The ether was washed several times with water, dilute aqueous HCl and water, with a final washing with, and storage over, ferrous ammonium sulfate acidified with H₂SO₄. Blaustein and Gryder (J Am Chem Soc 79 540 1957), after washing with alkaline KMnO₄, then water, treated the ether with ceric nitrate in nitric acid, and again washed with water. Hydroquinone was added before drying with CaCl₂ and MgSO₄, and refluxing with sodium amalgam (108g Hg/100g Na) for 2h under nitrogen. The distillate (nitrogen atmosphere) was made 2 x 10⁻⁵M in hydroquinone to inhibit peroxide formation (which was negligible if the ether was stored in the dark). Catechol (pyrocatechol) and resorcinol are alternative inhibitors.

4,4'-Isopropylidenediphenol [80-05-7] M 228.3, m 158°, pKₑₐₑₓ ~-10.3. Crystd from acetic acid/water (1:1).

Isopropyl iodide (2-iodopropane) [75-30-9] M 170.0, b 88.9°, d 1.70, n 1.4987. Treated with bromine, followed by extraction of free halogen with aqueous Na₂S₂O₃ or NaHSO₃, washing with water, drying (MgSO₄ or CaCl₂) and distn. (The treatment with bromine is optional.) Other purification methods include
passage through activated alumina, or shaking with copper powder or mercury to remove iodine, drying with P2O5 and distillation. Washing with conc H2SO4 or conc HCl (to remove any alcohol), water, aqueous Na2SO3, water and aqueous Na2CO3 has also been used. Treatment with silica gel causes some liberation of iodine. Distillations should be carried out at slightly reduced pressure. Purified isopropyl iodide is stored in the dark in the presence of a little mercury.

**Isopropyl methyl ether** [598-53-8] M 74.1, b 32.5°/777 mm, d15 0.724, n 1.3576. Purified by drying with CaSO4, passage through a column of alumina (to remove peroxides) and fractional distillation. M 74.1, b 32.5°/777 mm, d15 0.724, n 1.3576.

**Isopropyl p-nitrobenzoate** [13756-40-6] M 209.2, m 105-106°. Dissolved in diethyl ether, washed with aqueous alkali, then water and dried. Evaporation of the ether and recrystallization from EtOH gave pure material.

**Isopropyl toluene** (p-cymene) [99-87-6] M 134.2, b 176.9°/744 mm, d 0.8569, n 1.4902. See entry on p. 183.

**Isoquinoline** [119-65-3] M 129.2, m 24°, b 120°/18 mm, d 1.0986, n 1.6148, pK 5.40. Dried with Linde type 5A molecular sieves or Na2SO4 and fractionally distilled at reduced pressure. Alternatively, it was refluxed with, and distilled from, BaO. Also purified by fractional crystallization from the melt and distilled from zinc dust. Converted to its phosphate (m 135°) or picrate (m 223°), which were purified by crystallization and the free base recovered and distilled. [Packer, Vaughn and Wong J Am Chem Soc 80 905 1958.] The procedure for purifying via the picrate comprises the addition of quinoline to picric acid dissolved in the minimum volume of 95% EtOH to yield yellow crystals which are washed with EtOH and air dried before recrystallization from acetonitrile. The crystals are dissolved in dimethyl sulfoxide (previously dried over 4A molecular sieves) and passed through a basic alumina column, on which picric acid is adsorbed. The free base in the effluent is extracted with n-pentane and distilled under vacuum. Traces of solvent are removed by vapour phase chromatography. [Mooman and Anton J Phys Chem 80 2243 1976.]

**Isovaleric acid** [502-74-2] M 102.1, b 176.5°/762 mm, d 0.927, n 15 1.4064, n 140331, pK 4.77. Dried with Na2SO4, then fractionally distilled.


**Isovanillin** (3-hydroxy-4-methoxybenzaldehyde) [621-59-0] M 152.2, m 117°, b 175°/14 mm, pK 8.89. Crystallized from H2O or C6H6. The oxime has m 147°.

**Isoviolanthrone** [128-64-3] M 456.5, m 510-511°(uncorrected). Dissolved in 98% H2SO4 and ppted by adding water to reduce the acid concentration to about 90%. Sublimes in vacuo. [Parkyns and Ubbelohde J Chem Soc 4188 1960.]

**Itaconic acid** (2-propen-1,2-dicarboxylic acid) [97-65-4] M 130.1, m 165-166°, pK 3.63, pK 5.60. Crystallized from EtOH, EtOH/water or EtOH/*benzene.

**Itaconic anhydride** (2-propen-1,2-dicarboxylic anhydride) [2170-03-8] M 112.1, m 66-68°, 67-68°, 68°, b 133-140°/30 mm. Crystallized from CHCl3/pet ether. Can be distilled under reduced pressure. Distillation at atm press. or prolonged distillation causes rearrangement to citraconic anhydride (2-methylmaleic anhydride). If the material (as seen in the IR spectrum) contains much free acid then heat with acetyl chloride or SOCl2, evaporate and distill at as high a vacuum as possible. The crude anhydride deposits crystals of itaconic acid on standing probably due to hydrolysis by H2O — store in sealed ampoules under dry N2. [Org Synth Coll Vol II 369 1943; IR: Nagai Bull Chem Soc Jpn 37 369 1964; Kelly and Segura J Am Chem Soc 56 2497 1934.]

**Janus Green B** (3-dimethylamino-7-[4-dimethylaminoazo]-5-phenylphenazonium chloride) [2869-83-2] M 511.1, m >200°. Dissolves in H2O to give a bluish violet soln which
becomes colourless when made 10M in NaOH. Dissolve in EtOH to give a blue-violet colour, filter from insoluble material then add dry Et2O whereby the dye separates out leaving a small amount of blue colour in soln. Filter off the solid and dry in vacuum. Store in a dark bottle.


**Julolidine** (2,3,6,7-tetrahydro-1H,5H-benzo[j]quinolizidine) [479-59-4] M 173.3, m 34-36°, 40°, b 105-110°/1mm, 155-156°/17mm, 280° (dec), pKb -7.0. Purified by dissolving in dilute HCl, steam is bubbled through the soln and the residual acidic soln is basified with 10N NaOH, extracted with Et2O, washed with H2O, dried (NaOH pellets), filtered, evaporated and distd in vacuo. The distillate crystallises on standing (m 39-40°). On standing in contact with air for several days it develops a red colour. The colour can be removed by distilling or dissolving in 2-3 parts of hexane, adding charcoal, filtering and cooling in Me2CO-Dry-ice when julolidine crystallises (85-90% yield). The hydrochloride [83646-41-7] has m 218° (239-242°), the picrate has m 165° and the methiodide crystallises from MeOH, m 186° [Glass and Weisberger Org Synth Coll Vol III 304 1955.]

**Kainic acid monohydrate** ([2S,3S,4S-2-carboxy-4-isoprenyl-3-pyrrolidine-acetic acid) [487-79-6] M 231.4, m 235-245° (dec), 251° (dec), [α]D 14.6° (c 1.46, HzO), pK1 2.09, pK2 4.58, pK3 10.21. Purified by adsorbing on to a strongly acidic ion exchange resin (Merck), elution of the diacid with aqueous M NaOH, the eluate is evaporated, H2O is added, and filtered through a weakly acidic ion exchange resin (Merck). The filtrate is then evaporated and recrystd from EtOH. Its solubility is 0.1g in 1mL of 0.5N HCl. (±)-α-Kainic acid recryst from H2O, m 230-260°. [Oppolzer and Andres Helv Chim Acta 62 2282 1979.]

**Kainic acid monohydrate** ([2S,3S,4S-2-carboxy-4-isoprenyl-3-pyrrolidine-acetic acid) [487-79-6] M 231.4, m 235-245° (dec), 251° (dec), [α]D 14.6° (c 1.46, HzO), pK1 2.09, pK2 4.58, pK3 10.21. Purified by adsorbing on to a strongly acidic ion exchange resin (Merck), elution of the diacid with aqueous M NaOH, the eluate is evaporated, H2O is added, and filtered through a weakly acidic ion exchange resin (Merck). The filtrate is then evaporated and recrystd from EtOH. Its solubility is 0.1g in 1mL of 0.5N HCl. (±)-α-Kainic acid recryst from H2O, m 230-260°. [Oppolzer and Andres Helv Chim Acta 62 2282 1979.]

**Kerosene** [8008-20-6] (mixture of hydrocarbons) b ~175-325°, d 0.75-0.82, n 1.443. Stirred with conc H2SO4 until a fresh portion of acid remains colourless, then washed with water, dried with solid KOH and distd in a Claisen flask. For more complete drying, the kerosene can be refluxed with and distd from Na.

**Ketanserine** [3(4-p-fluorobenzoylpiperidinyl-β-ethyl)quinazolin-2,4-dione] [74050-98-9] M 395.4, m 227-235°, pK 7.5. Solubility is 0.001% in H2O, 0.038% in EtOH and 2.34 in Me2NCHO. It has been purified by recrystn from 4-methyl-3-pentanone [Peeters et al. Cryst Structure Commun 11 375 1982; Kacprowicz et al. J Chromatogr 272 417 1983; Davies et al. J Chromatogr 275 232 1983].


**Khellin** ([4,9-dimethoxy-7-methyl-5-oxofuro[3,2-g]-1,2-chromene] [82-02-0] M 260.3, m 154-155°, b 180-200°/0.65mm. Cryst from MeOH or diethyl ether.
Kojic acid \[\{(2\text{-hydroxy-5-hydroxymethyl})-4H\text{-pyran-4-one}\}\] [501-30-4] M 142.1, m 154-155°, \(pK^\text{1}_{\text{D}}^{25}-1.38, \ pK^\text{2}_{\text{D}}^{25}7.66\). Crystd from MeOH (charcoal) by adding \(\text{Et}_2\text{O}\). Sublimed at 0.1 torr.

Kynurenic acid (4-hydroxyquinoline-2-carboxylic acid) [492-27-3] M 189.1, m 282-283°, \(pK_{\text{Em(1)}}{\text{-}2}, \ pK_{\text{Em(2)}}{\text{-}10}\). Crystd from absolute \(\text{EtOH}\).

L-Kynurenine [343-65-7] M 208.2, m 190°(dec), 210°(dec), [\(\alpha\)]\(\text{D}\) -30° (c 0.4, H\(_2\)O). \(pK^1_{\text{Em}}\) -1.38, \(pK^2_{\text{Em}}\) 7.66. Crystd from \(\text{H}_2\text{O}\) or aq \(\text{AcOH}\). 

L-Kynurenine sulfate (H\(_2\)O). Crystd from water by addition of \(\text{EtOH}\).

L(\(+\))-Lactic acid [79-33-4] M 90.1, m 52.8°, b 105°/0.1mm, [\(\alpha\)]\(\text{D}\)\(15\) +3.82° (H\(_2\)O), \(pK\)\(15\) 3.83. Purified by fractional distn at 0.1mm pressure, followed by fractional crystn from diethyl ether/isopropyl ether (1:1; dried with sodium). [Borsook, Huffman and Liu J Biol Chem 102 449 1933.] The solvent mixture, *benzene/diethyl ether (1:1) containing 5% pet ether (b 60-80°) has also been used.

Lactobionic acid [96-82-2] M 358.3, m 128-130°, [\(\alpha\)]\(\text{D}\)\(546\) +28° (c 3, after 24h in H\(_2\)O), \(pK_{\text{Est}}\) ~3.6. Crystd from water by addition of \(\text{EtOH}\).

\(\alpha\)-Lactose (\(\text{H}_2\text{O}\)) [63-42-3] M 360.3, m 220°(dec), [\(\alpha\)]\(\text{D}\)\(546\) +52.3° (c 4.2, H\(_2\)O), \(pK\) 12.2 (\(\text{OH}\)). Crystd from water below 93.5°.


Lanatoside A [17575-20-1] M 969.1, m 245-248°, [\(\alpha\)]\(\text{D}\)\(546\) +32° (\(\text{EtOH}\)). Crystd from MeOH.

Lanatoside B [17575-21-2] M 985.1, m 233°(dec), [\(\alpha\)]\(\text{D}\)\(546\) +35° (\(\text{MeOH}\)). Crystd from MeOH.

Lanatoside C [17575-22-3] M 297.1, m 246-248°, [\(\alpha\)]\(\text{D}\)\(546\) +34° (\(\text{EtOH}\)). Crystd from MeOH.

Lanosterol [79-63-0] M 426.7, m 138-140°, [\(\alpha\)]\(\text{D}\)\(546\) +62.0° (c 1, \(\text{CHCl}_3\)). Recrystd from anhydrous MeOH. Dried in \textit{vacuo} over P\(_2\)O\(_5\) for 3h at 90°. Purity checked by proton magnetic resonance.

Lanthanide shift reagents A variety of these reagents are available commercially and they are generally quite stable and should not deteriorate on long storage in a dry state and in the absence of light. [See G.R.Sullivan in Top Stereochem (Eliel and Allinger Eds) J Wiley & Sons Vol 10 287 1978; T.C.Morrill Ed. Lanthanide Shift Reagents Deerfield Beach Florida 1986, ISBN 0895731193.]

Lapachol [84-79-7] M 226.3, m 140°. Crystd from \(\text{EtOH}\) or diethyl ether.

dl- and l-Laudanosine [(\(\pm\)] 1699-51-0; (\(-\)) 2688-77-9] M 357.4, m 114-115°. Crystd from \(\text{EtOH}\). The (\(-\)-isomer has m 83-85° and [\(\alpha\)]\(\text{D}\)\(546\) -85° (c 0.5, \(\text{EtOH}\)).

Lauraldehyde (1-dodecanal) [112-54-9] M 184.3, b 99.5-100°/3.5mm, \(n^2\) 1.4328. Converted to the addition compound by shaking with saturated aqueous NaHS\(_2\)O\(_3\) for 1h. The ppt was filtered off, washed with ice cold water, \(\text{EtOH}\) and ether, then decomposed with aqueous Na\(_2\)CO\(_3\). The aldehyde was extracted into diethyl ether which, after drying and evap, gave an oil which was fractionally distd under vacuum.

Lauric acid (1-dodecanolic acid) [143-07-7] M 200.3, m 44.1°, b 141-142°/0.6-0.7mm, 225°/100mm, \(pK\)\(20\) 5.3. Vacuum distd. Crystd from absolute \(\text{EtOH}\), or from acetone at -25°.
Alternatively, purified via its methyl ester (b 140.0°/15mm), as described for capric acid. Also purified by zone melting.

Lauryl peroxide (dodecyl peroxide) \[105-74-8\] M 398.6, m 53-54°. Crystd from n-hexane or *benzene and stored below 0°. Potentially EXPLOSIVE.

L-Leucine \[61-90-5\] M 131.2, m 293-295°(dec), \([\alpha]^{25}_D +15.6°\) (5M HCl), pK$_1^{25}$ 2.33, pK$_2^{25}$ 9.74. Likely impurities are isoleucine, valine, and methionine. Crystd from water by adding 4 volumes of EtOH.

Leucomalachite Green \[129-73-7\] M 330.5, m 92-93°, pK$_2^{25}$ 6.90 (several pK's). Crystd from 95% EtOH (10mL/g), then from *benzene/EtOH, and finally from pet ether.

Lithocholic acid \[434-13-9\] M 376.6, m 184-186°, \([\alpha]^{25}_D +35°\) (c 1, EtOH), pK$_{Eest}$ -4.8. Crystd from EtOH or acetic acid.

Lumichrome \[1086-80-2\] M 242.2, m >290°, pK$_{Est}^{23}$ +35° (c 1, EtOH), pK$_{Est}^{23}$-9.9 (acidoic), Recrystd twice from glacial AcOH and dried at 100° in a vacuum.

Luminol (5-aminophthalazin-1,4-dione) \[521-31-3\] M 177.2, m 329-332°, pK$_1$ 3.37, pK$_2$ 6.35. Dissolved in KOH soln, treated with Norit (charcoal), filtered and ppted with conc HCl. [Hardy, Sietz and Hercules Tuluntu 24 297 1977.1 Stored in the dark in an inert atmosphere, because its structure changes during its luminescence. It has been recrystd from 0.1M KOH [Merenyi et al. J Am Chem Soc 108 77716 1984.

dl-Lupinane \[10248-30-3\] M 169.3, m 98-99°. Crystd from acetone.

Lupulon \[468-28-0\] M 414.6, m 92-94°. Crystd from 90% MeOH.

Lutein (\(\alpha\)-carotene-3,3'-diol, xanthophyll) \[127-40-2\] M 568.9, m 196°, \(e^{100\%}_{1cm} 1750\) (423nm), 2560 (446nm), 2340 (477.5nm) in EtOH; \(\lambda_{max}\) in CS$_2$ 446, 479 and 511nm. Crystd from MeOH (copper-coloured prisms) or from diethyl ether by adding MeOH. Also purified by chromatography on columns of magnesium or calcium hydroxide, and crystd from CS$_2$/EtOH. May be purified via the dipalmitate ester. Stored in the dark, in an inert atmosphere.


2,3-Lutidine \[583-61-9\] M 107.2, f -14.8°, b 160.6°, d 0.9464, n 1.50857, pK$_2^{25}$ 6.57. Steam distd from a soln containing about 1.2 equivalents of 20% H$_2$SO$_4$, until ca 10% of the base has been carried over with the non-basic impurities. The acid soln was then made alkaline, and the base was separated, dried over NaOH or BaO, and fractionally distd. The distd lutidine was converted to its urea complex by stirring 100g with 40g of urea in 75mL of H$_2$O, cooling to 5°, filtering at the pump, and washing with 75mL of H$_2$O. The complex, dissolved in 300mL of H$_2$O was steam distd until the distillate gave no turbidity with a little solid NaOH. The distillate was then treated with excess solid NaOH, and the upper layer was removed: the aqueous layer was then extracted with diethyl ether. The upper layer and the ether extract were combined, dried (K$_2$CO$_3$), and distd through a short column. Final purification was by fractional crystn using partial freezing. [Kyte, Jeffery and Vogel J Chem Soc 4454 1960]

2,4-Lutidine \[108-47-4\] M 107.2, b 157.8°, d 0.9305, n 1.50087, n$_{25}^{25}$ 1.4985, pK$_2^{25}$ 6.77. Dried with Linde type 5A molecular sieves, BaO or sodium, and fractionally distd. The distillate (200g) was heated with *benzene (500mL) and conc HCl (150mL) in a Dean and Stark apparatus on a water bath until water no longer separated, and the temperature just below the liquid reached 80°. When cold, the supernatant *benzene was decanted and the 2,4-lutidine hydrochloride, after washing with a little *benzene, was dissolved in water (350mL). After removing any *benzene by steam distn, an aqueous soln of NaOH (80g) was added, and the free
lutidine was steam distd. It was isolated by saturating the distillate with solid NaOH, and distd through a short column. The pptn cycle was repeated, then the final distillate was partly frozen in an apparatus at -67.8-68.5° (cooled by acetone/CO₂). The crystals were then melted and distd. [Kyte, Jeffery and Vogel J Chem Soc 4454 1960.] Alternative purifications are via the picrate [Clarke and Rothwell J Chem Soc 188 1960], or the hydrobromide [Warnhoff J Org Chem 27 4587 1962]. The latter is pptd from a soln of lutidine in *benzene by passing dry HBr gas: the salt is recrystd from CHCl₃/methyl ethyl ketone, then decomposed with NaOH, and the free base is extracted into diethyl ether, dried, evaporated and the residue distd.

2,5-Lutidine [589-93-5] M 107.2, m -15.3°, b 156.7°/759mm, d 0.927, n² 1.4982, pK² 6.40. Steam distd from a soln containing 1-2 equivalents of 20% H₂SO₄ until about 10% of the base had been carried over with the non-basic impurities, then the acid soln was made alkaline, and the base separated, dried with NaOH and fractionally distd twice. Dried with Na and fractionally distd through a Todd column packed with glass helices (see p. 174).

2,6-Lutidine [108-48-5] M 107.2, m -59°, b 144.0°, d 0.92257, n 1.49779, pK² 6.72. Likely contaminants include 3- and 4-picoline (similar boiling points). However, they are removed by using BF₃, with which they react preferentially, by adding 4mL of BF₃ to 100mL of dry fractionally distd 2,6-lutidine and redistilling. Distn of commercial material from AlCl₃ (14g per 100mL) can also be used to remove picolines (and water). Alternatively, lutidine (100mL) can be refluxed with ethyl benzenesulfonate (20g) or ethyl p-toluenesulfonate (20g) for 1h, then the upper layer is cooled, separated and distd. The distillate is refluxed with BaO or CaH₂, then fractionally distd, through a glass helices-packed column.

2,6-Lutidine can be dried with KOH or sodium, or by refluxing with (and distilling from) BaO, prior to distn. For purification via its picrate, 2,6-lutidine, dissolved in abs EtOH, is treated with an excess of warm ethanolic picric acid. The ppte is filtered off, recrystd from acetone (to give m 163-164.5°), and partitioned between ammonia and CHCl₃/diethyl ether. The organic soln, after washing with dilute aqueous KOH, is dried with Na₂SO₄ and fractionally distd. [Warnhoff J Org Chem 27 4587 1962.] Alternatively, 2,6-lutidine can be purified via its urea complex, as described under 2,3-lutidine. Other purification procedures include azeotropic distn with phenol [Coulson et al. J Appl Chem (London) 271 1952], fractional crystn by partial freezing, and vapour-phase chromatography using a 180-cm column of polyethylene glycol-400 (Shell, 5%) on Embacel (May and Baker) at 100°, with argon as carrier gas [Bamford and Block J Chem Soc 4989 1961].

3,5-Lutidine [591-22-0] M 107.2, I -6.3°, b 172.0°/767mm, d 0.9419, n 1.50613, n² 1.5035, pK² 6.15. Dried with sodium and fractionally distd through a Todd column packed with glass helices (see p. 174). Dissolved (100mL) in dil HCl (1:4) and steam distd until 1L of distillate was collected. Excess conc NaOH was added to the residue which was again steam distd. The base was extracted from the distillate, using diethyl ether. The extract was dried with K₂CO₃, and distd. It was then fractionally crystd by partial freezing.

Lycopene [502-65-8] M 536.9, m 172-173°, ε 1 cm⁻¹ 2250 (446nm), 3450 (472nm), 3150 (505nm) in pet ether. Crystd from CS₂/MeOH, diethyl ether/pet ether, or acetone/pet ether, and purified by column chromatography on deactivated alumina, CaCO₃, calcium hydroxide or magnesia. Stored in the dark, in an inert atmosphere.

Lycorine [476-28-8] M 552.9, m 275-280°(dec) [α] D -130° (c 0.16, EtOH). Crystd from EtOH.

Lycoxanthin (Ψ,Ψ'-carotene-16-ol) [19891-74-8] M 268.3, m 173-174°, ε 1 cm⁻¹ 3360 (472.5nm), also λ max 444 and 503nm in pet ether. Crystd from diethyl ether/light petroleum, *benzene/pet ether or CS₂. Purified by chromatography on columns of CaCO₃, Ca(OH)₂ or deactivated alumina, washing with *benzene and eluting with 3:1 *benzene/MeOH. Stored in the dark, in an inert atmosphere, at -20°.

L-Lysine  [56-87-1]  M 146.2, m >210°(dec), pK1 2.18, pK2 8.95, pK3 10.53. Crystd from aqueous EtOH.


L-Lysine monohydrochloride  [657-27-2]  M 182.7, [α]^20^+25.9° (c 4, H2O). Crystd from EtOH or aqueous 80% EtOH. Likely impurities are arginine, D-lysine, 2,6-diaminoheptane-dioic acid and glutamic acid. Crystd from water at pH 4-6 by adding 4 volumes of EtOH. Above 60% relative humidity it forms a dihydrate.

β-D-Lyxose  [1114-34-7]  M 150.1, m 118-119°, [α]_D^20 -14° (c 4, H2O). Crystd from EtOH or Malachite Green (carbinol)  [510-13-4]  M 346.4, m 112-114°, CI 42000, pK^"ci" 6.84. The oxalate was recrystd from hot water and dried in air. The carbinol was pptd from the oxalate (1g) in distd water (100mL) by adding M NaOH (10mL). The ppt was filtered off, recrystd from 95% EtOH containing a little dissolved KOH, then washed with ether, and crystd from pet ether. Dried in a vacuum at 40°.


Maleimide (pyrrol-2,5-dione)  [541-59-3]  M 97.1, m 91-93°, 92.6-93°, d^1^0^5^5 1.2493, n^D^1^0^5^5 1.49256. Purified by sublimation in a vacuum. The UV has λ_max at 216 and 280nm in EtOH. [de Wolf and van de Straete Bull Soc Chim Belg 44 288 1935; UV: Rondestvedt et al. J Am Chem Soc 78 6115 1956; IR: Chiorboli and Mirone Ann Chim (Rome) 42 681 1952.]


dl-Malic acid  [617-48-1 and 6915-15-7]  M 134.1, m 128-129°. Crystd from acetone, then from acetone/CCl₄, or from ethyl acetate by adding pet ether (b 60-70°). Dried at 35° under 1mm pressure to avoid formation of the anhydride.

L-Malic acid  [97-67-6]  M 134.1, m 104.5-106°, [α]_D^20 -2.3° (c 8.5, H₂O), pK^1^25 3.46, pK^2^25 5.10. Crystd (charcoal) from ethyl acetate/pet ether (b 55-56°), keeping the temperature below 65°. Or, dissolved by refluxing in fifteen parts of anhydrous diethyl ether, decanted, concentrated to one-third volume and crystd at 0°, repeatedly to constant melting point.


Malonic acid  [141-82-2]  M 104.1, m 136°, pK^1^25 2.58, pK^2^25 5.69. Crystd from benzene/diethyl ether (1:1) containing 5% of pet ether (b 60-80°), washed with diethyl ether, then recrystd from H₂O or acetone. Dried under vac over cone H₂SO₄.

Maltol (3-hydroxy-2-methyl-4-pyrone) \[118-71-8\] M 126.1, m 161-162°. Crystd from CHCl₃ or aqueous 50% EtOH. Volatile in steam. It can be readily sublimed in a vacuum.

Maltose (H₂O) \[6363-53-7\] M 360.3, m 118°. Purified by chromatography from aqueous soln on to a charcoal/Celite (1:1) column, washed with water to remove glucose and other monosaccharides, then eluted with aqueous 75% EtOH. Crystd from water, aqueous EtOH or EtOH containing 1% nitric acid. Dried as the monohydrate at room temperature under vacuum over H₂SO₄ or P₂O₅.

Mandelic acid (α-hydroxyphenylacetic acid) \[S-(+)-17199-29-0; R-(−)-611-71-2\] M 152.2, m 130-133°, 133°, 133.1° (evacuated capillary), 133-133.5°, \([α]_{D}^{20}+180°\) (c 5, H₂O), \([α]_{D}^{20}+180°\) (c 5, H₂O) and \([α]_{D}^{20}+180°\) (c 5, Me₂CO), pK₂ 3.41. Purified by recrystn from H₂O, *C₆H₆ or CHCl₃, [Roger J Chem Soc 2168 1932; Jamison and Turner J Chem Soc 61 11942.] They have solubilities in H₂O of ca 11% at 25°. [Banks and Davies J Chem Soc 73 1938.] The S-benzylisothiuronium salt has m 180° (from H₂O) and \([α]_{D}^{20}+57°\) (c 20, EtOH) [El Masri et al. Biochem J 68 1958].

RS-(±)-Mandelic acid \[61-72-3\] M 152.2, m 118°, 120-121°. Purified by Soxhlet extraction with *benzene (about 6mL/g), allowing the extract to crystallise. Also crystallises from CHCl₃. The S-benzylisothiuronium salt has m 169° (166°) (from H₂O). Dry at room temperature under vacuum.

D-Mannitol \[69-65-8\] M 182.2, m 166.1°, \([α]_{D}^{20}+29°\) (c 10, after 1h in 8% borax soln). Crystd from EtOH or distilled waer and dried at 100°.

Mannitol hexanitrate \[15825-70-4\] M 452.2, m 112-113°. Crystd from EtOH. EXPLOSIVE (on detonation).

α-D-Mannose \[3458-28-4\] M 180.2, m 132°, \([α]_{D}^{20}+14.1°\) (c 4, H₂O). Crystd repeatedly from EtOH or aq 80% EtOH, then dried under vacuum over P₂O₅ at 60°.

Meconic acid (3-hydroxy-γ-pyrene-2,6-dicarboxylic acid) \[497-59-6\] M 200.1, m 100° (loses H₂O), pK₁ 1.83, pK₂ 2.3, pK₃ 10.10. Crystd from water and dried at 100° for 20min.

Melamine (2,4,6-triamino-1,3,5-triazine) \[108-78-1\] M 126.1, m 353°, pK₂ 5.00. Crystd from water or dilute aqueous NaOH.

D(+)-Melezitose (H₂O) \[587-12-6\] M 540.5, m 153-154°(dec), 2H₂O m 160°(dec), \([α]_{D}^{20}+88°\) (c 4, H₂O). Crystallises from water as the dihydrate, then dried under vacuum at 110° (anhydrous).

D(+)-Melibiose (2H₂O) \[585-99-9, 66009-10-7\] M 360.3, m 84-85°, \([α]_{D}^{20}+135°\) (c 5, after 10h H₂O). Crystallises as a hydrate from water or aqueous EtOH.


Melphalan (4-[bis-(2-chloroethyl)amino]-L-phenylalanine) \[148-82-3\] M 305.2, m 182-183° (dec), 183-185°, \([α]_{D}^{20}+7.5°\) (c 1.33, 1.0 N HCl), \([α]_{D}^{20}+28°\) (c 0.8, MeOH), pK₂ 5.00 -6.4. Purified by recrystn from MeOH and its solubility is 5% in 95% EtOH containing one drop of 6N HCl.
It is soluble in EtOH and propylene glycol but is almost insoluble in H$_2$O. The RS-form has m 180-181° and the R-form crystallises from MeOH with a m 181.5-182° and [α]$^\text{D}$ +7.5° (c 1.26, 1.0 N HCl). [Bergel and Stock J Chem Soc 2409 1954.]

(-)-Menthol [2216-51-5] M 156.3, m 44-46.5°, [α]$_{D}^{}$ 50° (c 10, EtOH). Crystd from CHCl$_3$, pet ether or EtOH/water.

1R-(+)-Menthyl chloride (1S,2R,4R-2-chloro-1-isopropyl-1-methylcyclohexane) [16052-42-9] M 174.7, m -20.1° to -16.5°, b 88.5°/12.5 mm, 101-105°/21 mm, d$_{25}^{1}$ 0.936, n$_{D}^{1}$ 1.463 (neat). Dissolve in pet ether (b 40-60°), wash with H$_2$O, conc H$_2$SO$_4$ until no discoloration of the organic layer occurs (care with the use of conc H$_2$SO$_4$ during shaking in a separating funnel), again with H$_2$O and dry over MgSO$_4$. Evaporate the pet ether and dist the residual oil through a Claisen head with a Vigreux neck (head) of ca 40 cm length. [Smith and Wright J Org Chem 17 1116 1952; Barton et al. J Chem Soc 453 1952.]


2-Mercaptobenzimidazole [583-39-1] M 150.2, m 302-304°, 312°, pK$_{a}$ 10.24. Crystd from acetone/H$_2$O or *benzene. Complexes with Ag, Au, Bi, Cd, Hg, Ir, Pt, and Tl.

2-Mercaptobenzothiazole [149-30-4] M 167.2, m 182°, pK$_{a}$ 7.5 (50% aq AcOH). Crystd repeatedly from 95% EtOH, or purified by incomplete pptn by dilute H$_2$SO$_4$ from a basic soln, followed by several crystns from acetone/H$_2$O or *benzene. Complexes with Ag, Au, Bi, Cd, Hg, Ir, Pt, and Tl.

2-Mercaptoethanol [60-24-2] M 78.1, b 44°/4 mm, 53.5°/10 mm, 58°/12 mm, 68°/20 mm, 78.5°/40 mm, 96-97° (92°)/100 mm, 157°/748 mm, d$_{25}^{1}$ 1.114, n$_{D}^{1}$ 1.500, pK$_{a}$ 9.72 (9.43). Purified by distn in a vacuum. Distn at atmospheric pressure causes some oxidation and should be done in an inert atmosphere. [Woodward J Chem Soc 1892 1948.] It has a foul odour, is irritating to the eyes, nose and skin — should be handled in an efficient fume cupboard. It is miscible with H$_2$O, EtOH, Et$_2$O and *C$_6$H$_6$ and has a UV max at 235nm. The 2,4-dinitrophenyl rhioether has m 101-102° (from EtOH or aq MeOH) [Grogen et al. J Org Chem 20 50 1955.]


2-Mercaptotimidazole [872-35-5] M 100.1, m 221-222°, pK$_{a}^{1}$ 1.6, pK$_{a}^{2}$ 11.6. Crystd from H$_2$O.

2-Mercapto-1-methylimidazole [60-56-0] M 114.2, m 145-147°, pK$_{a}^{1}$ 2.0, pK$_{a}^{2}$ 11.9. Crystd from EtOH.

6-Mercaptopurine (H$_2$O) [6112-76-1] M 170.2, m >315° (dec), pK$_{a}^{1}$ 0.5, pK$_{a}^{2}$ 7.77, pK$_{a}^{3}$ 10.8. Crystd from pyridine (30 mL/g), washed with pyridine, then triturated with water (25 mL/g), adjusting to pH 5 by adding M HCl. Recrystd by heating, then cooling, the soln. Filtered, washed with water and dried at 110°. Has also been crystall from water (charcoal).

8-Mercaptoquinoline (2H$_2$O, thioxine) [491-33-8] M 197.3, m 58-59°, pK$_{a}^{1}$ 2.0, pK$_{a}^{2}$ 8.40. Easily oxidised in air to give diquinolyl-8,8'-disulfide (which is stable). It is more convenient to make 8-mercaptoquinoline by reduction of the material. [Nakamura and Sekido Talanta 17 515 1970.]

Mesaconic acid (methylfumaric acid) [498-24-8] M 130.1, m 204-205°, pK$_{a}^{18}$ 4.82. Crystd from water or EtOH [Katakis et al. J Chem Soc, Dalton Trans 1491 1986].

Mescaline sulfate [2-(3,4,5-trimethoxyphenyl)ethylamine sulfate] [5967-42-0] M 309.3, m 183-184°, pK$_{a}^{1}$ -9.7. Crystd from water.
**Purification of Organic Chemicals**

**Mesitylene** (1,3,5-trimethylbenzene)  
M 120.2, m -44.7°, b 99.0-99.8°/100mm, 166.5-167°/760mm, n^25 1.4967, d 0.865. Dried with CaCl₂ and distd from Na in a glass helices packed column. Treated with silica gel and redistd. Alternative purifications include vapour-phase chromatography, or fractional distn followed by azetropic distn with 2-methoxyethanol (which is subsequently washed out with H₂O), drying and fractional distn. More exhaustive purification uses sulfonation by dissolving in two volumes of conc H₂SO₄, precipitating with four volumes of conc HCl at 0°, washing with conc HCl and recrystallising from CHCl₃. The mesitylene sulfonic acid is hydrolysed with boiling 20% HCl and steam distd. The separated mesitylene is dried (MgSO₄ or CaSO₄) and distilled. It can also be fractionally crystd from the melt at low temperatures.

**Mesityl oxide**  
M 98.2, b 112°/760mm, n^24 1.4412, d 0.854, pK₂⁻⁻ -5.36 (H₂O scale, aq H₂SO₄). Purified via the semicarbazone (m 165°). [Erskine and Waight J Chem Soc 3425 1960.]

**Metalphthalein** (H₂O) (o-cresolcomplexon)  
M 636.6, m 186°(dec). See o-cresolphthalein complexone on p. 173.

**Metanilic acid** (3-aminobenzenesulfonic acid)  
M 173.2, m <300°(dec), pK₂⁻⁻ < 1, pK₂⁻⁻ 3.74. Crystd from water (as the hydrate), under CO₂ in a semi-darkened room. (The soln is photosensitive.) Dried over 90% H₂SO₄ in a vac desiccator.

**α-Methacraldehyde**  
M 68.1, b 68.4°, d 0.849, n 1.416. Fractionally distd under nitrogen through a short Vigreux column. Stored in sealed ampoules. (Slight polymerisation may occur.)

**Methacrylamide**  
M 85.1, m 111-112°. Crystd from *benzene or ethyl acetate and dried under vacuum at room temperature.

**Methacrylic acid**  
M 86.1, b 72°/14mm, 160°/760mm, d 1.015, n 1.431, pK 4.65. Aq methacrylic acid (90%) was satd with NaCl (to remove the bulk of the water), then the organic phase was dried with CaCl₂ and distd under vacuum. Polymerisation inhibitors include 0.25% p-methoxyphenol, 0.1% hydroquinone, or 0.05% N,N'-diphenyl-p-phenylenediamine.

**Methacrylic anhydride**  
M 154.2, b 65°/2mm, d 1.040, n 1.454. Distd at 2mm pressure, immediately before use, in the presence of hydroquinone.

**Methacrylonitrile**  
M 67.1, b 90.3°, d 0.800, n 1.4007, n^30 1.3954. Washed (to remove inhibitors such as p-tert-butylcatechol) with satd aq NaHSO₃, 1% NaOH in saturated NaCl and then with saturated NaCl. Dried with CaCl₂ and fractionally distd under nitrogen to separate from impurities such as methacrolein and acetone.

**Methane**  
M 16.0, m -184°, b -164°/760mm, -130°/6.7atm, d^164 0.466 (air 1). Dried by passage over CaCl₂ and P₂O₅, then passed through a Dry-ice trap and fractionally distd from a liquid-nitrogen trap. Oxygen can be removed by prior passage in a stream of hydrogen over reduced copper oxide at 500°, and higher hydrocarbons can be removed by chlorinating about 10% of the sample: the hydrocarbons, chlorides and HCl are readily separated from the methane by condensing the sample in the liquid-nitrogen trap and fractionally distilling it. Methane has also been washed with conc H₂SO₄, then solid NaOH and then 30% NaOH soln. It was dried with CaCl₂, then P₂O₅, and condensed in a trap at liquid air temp, then transferred to another trap cooled in liquid nitrogen. CO₂, O₂, N₂ and higher hydrocarbons can be removed from methane by adsorption on charcoal. [Eiseman and Potter J Res Nat Bur Stand 58 213 1957.] HIGHLY FLAMMABLE.

**Methanesulfonic acid**  
M 96.1, m 20°, b 134.5-135°/3mm, d 1.483, n 1.432, pK₂⁻⁻ -1.86 (-1.2). Dried, either by azetropic removal of water with *benzene or toluene, or by stirring 20g of P₂O₅ with 500mL of the acid at 100° for 0.5h. Then distd under vacuum and fractionally crystd by partial
freezing. Sulfuric acid, if present, can be removed by prior addition of Ba(OH)$_2$ to a dilute soln, filtering off the BaSO$_4$ and concentrating under reduced pressure, and is sufficiently pure for most applications.

**Methanesulfonyl chloride**  [124-63-0]  M 114.5.  b 55°/11mmm, d 1.474, n 1.452.  Distd from P$_2$O$_5$ under vacuum.

**Methanol**  [67-56-1]  M 32.0, b 64.5°, d$^{15}$ 0.79609, d$^{25}$ 1.32663, n$^{15}$ 1.33057, n$^{25}$ 1.32663, pK$^+$ 15.5.  Almost all methanol is now obtained synthetically.  Likely impurities are water, acetone, formaldehyde, ethanol, methyl formate and traces of dimethyl ether, methylal, methyl acetate, acetaldehyde, carbon dioxide and ammonia.  Most of the water (down to about 0.01%) can be removed by fractional distn.  Drying with CaO is unnecessary and wasteful.  Anhydrous methanol can be obtained from "absolute" material by passage through Linde type 4A molecular sieves, or by drying with CaH$_2$, CaSO$_4$, or with just a little more sodium than required to react with the water present; in all cases the methanol is then distd.  Two treatments with sodium reduces the water content to about $5 \times 10^{-5}$%.  [Friedman, Gill and Doty *J Am Chem Soc* 83 4050 1961]  Lund and Bjerrum  [Chem Ber 64 210 1931]  warmed clean dry magnesium turnings (5g) and iodine (0.5g) with 50-75mL of "absolute" methanol in a flask until the iodine disappeared and all the magnesium was converted to methoxide.  Up to 1L of methanol was added and, after refluxing for 2-3h, it was distd off, excluding moisture from the system.  Redistn from tribromobenzoic acid removes basic impurities and traces of magnesium oxides, and leaves conductivity-quality material.  The method of Hartley and Raikes  [J Chem Soc 127 524 1925]  gives a slightly better product.  This consists of an initial fractional distn, followed by distn from aluminium methoxide, and then ammonia and other volatile impurities are removed by refluxing for 6h with freshly dehydrated CuSO$_4$ (2g/L) while dry air is passed through: the methanol is finally distd.  (The aluminium methoxide is prepared by warming with aluminium amalgam (3gL) until all the aluminium has reacted.  The amalgam is obtained by warming pieces of sheet aluminium with a soln of HgCl$_2$ in dry methanol.)  This treatment also removes aldehydes.

If acetone is present in the methanol, it is usually removed prior to drying.  Bates, Mullaly and Hartley  [*J Chem Soc* 401 1923]  dissolved 25g of iodine in 1L of methanol and then poured the soln, with constant stirring, into 500mL of M NaOH.  Addition of 150mL of water ppted iodoform.  The soln was stood overnight, filtered, then boiled under reflux until the odour of iodoform disappeared, and fractionally distd.  (This treatment also removes formaldehyde.)  Morton and Mark  [*Ind Eng Chem (Anal Ed)* 6 151 1934]  refluxed methanol (1L) with furfural (50mL) and 10% NaOH soln (120mL) for 6-12h, the refluxing resin carrying down with it the acetone and other carbonyl-containing impurities.  The alcohol was then fractionally distd.  Evers and Knox  [*J Am Chem Soc* 73 1739 1951]  after refluxing 4.5L of methanol for 24h with 50g of magnesium, distd off 4L of it, which they then refluxed with AgNO$_3$ for 24h in the absence of moisture or CO$_2$.  The methanol was again distd, shaken for 24h with activated alumina before being filtered through a glass sinter and distd under nitrogen in an all-glass still.  Material suitable for conductivity work was obtained.

Variations of the above methods have also been used.  For example, a sodium hydroxide soln containing iodine has been added to methanol and, after standing for 1day, the soln has been poured slowly into about a quarter of its volume of 10% AgNO$_3$, shaken for several hours, then distd.  Sulfanilic acid has been used instead of tribromobenzoic acid in Lund and Bjerrum's method.  A soln of 15g of magnesium in 500mL of methanol has been heated under reflux, under nitrogen, with hydroquinone (30g), before degassing and distilling the methanol, which was subsequently stored with magnesium (2g) and hydroquinone (4g per 100mL).  Refluxing for about 12h removes the bulk of the formaldehyde from methanol: further purification has been obtained by subsequent distn, refluxing for 12h with dinitrophenylhydrazine (5g) and H$_2$SO$_4$ (2g/L), and again fractionally distilling.

**Rapid purification:**  Methanol purification is the same as for Ethanol.  Another simple purification procedure consists of adding 2g of NaBH$_4$ to 1.5L methanol, gently bubbling with argon and refluxing for a day at 30°, then adding 2g of freshly cut sodium (washed with methanol) and refluxing for 1day before distilling.  The middle fraction is taken.  [Jou and Freeman  *J Phys Chem* 81 909 1977.]


**L-Methionine**  [63-68-3]  M 149.2, m 283°(dec), [α]$^D_{25} +21.2°$ (0.2M HCl) pK$_1^{25}$ 2.13, pK$_2^{25}$ 9.73.  Crystd from aqueous EtOH.
Purification of Organic Chemicals

\[454-41-1, \text{62697-73-8}\] \(d\)-Methionine sulfoxide \(\text{M} 165.2, m > 240^\circ\text{(dec)}\). Likely impurities are \(d\)-methionine sulfoxide and \(d\)-methionine. Crystd from water by adding EtOH in excess.

\[625-45-6\] Methoxyacetic acid \(\text{M} 90.1, b 97^\circ/13-14\text{mm}, d 1.175, n 1.417, pK^2 3.57.\) Fractionally crystd by repeated partial freezing, then fractionally distd under vacuum through a vacuum-jacketed Vigreux column 20cm long.

\[100-06-1\] \(p\)-Methoxyacetophenone \(\text{M} 150.2, m 39^\circ, b 139^\circ/15\text{mm}, 264^\circ/736\text{mm}\). Crystd from diethyl ether/pet ether.

\[593-56-6\] Methoxyamine hydrochloride \(\text{M} 83.5, m 151-152^\circ, pK^2 4.60.\) Crystd from absolute EtOH or EtOH by addition of diethyl ether. [Kovach et al. \textit{J Am Chem Soc} 107 7360 1985.]

\[2396-60-3\] \(p\)-Methoxyazobenzene \(\text{M} 212.3, m 54-56^\circ.\) Crystd from EtOH.

\[3688-79-7\] \(3\)-Methoxybenzantrone \(\text{M} 274.3, m 173^\circ.\) Crystd from \(*\)benzene, EtOH or Me\(\text{CO}\) as yellow needles.

\[586-38-9\] \(m\)-Methoxybenzoic acid (m-anisic acid) \(\text{M} 152.2, m 110^\circ, pK^2 4.09.\) Crystd from EtOH/water.

\[67488-50-0\] \(4\)-Methoxybenzyl chloride (anisyl chloride) \(\text{M} 156.6, m -1^\circ, b 76^\circ/0.1\text{mm}, 95^\circ/5\text{mm}, 110^\circ/10\text{mm}, 117^\circ/5^\circ/14\text{mm}, 117^\circ/18\text{mm}, d^2 1.15491, n^2_D 1.55478.\) Purified by fractional distn under vacuum and the middle fraction is redistd at mm at room temperature by intermittent cooling of the receiver in liquid N\(\text{2}\), and the middle fraction is collected. [Mohammed and Kosower \textit{J Am Chem Soc} 93 2709 1971.]

\[824-94-2\] \(3\)-Methoxycarbonyl-2,5-dihydrothiophen-1,1-dioxide \(\text{M} 176.1, m 57-58^\circ, 60-62^\circ.\) If IR show CO bands then dissolve in CHCl\(_3\), wash with aqueous Na\(_2\)CO\(_3\) and H\(_2\)O, dry over MgSO\(_4\), filter, evaporate and wash the residue with cold Et\(_2\)O and dry \textit{in vacuo}. NMR (CDCl\(_3\)): \(\delta 7.00 \text{(m lH)}, 3.98 \text{(bs 4H)}\) and \(3.80 \text{(s Me)}.\) [Mcintosh and Sieber \textit{J Org Chem} 43 4431 1978.]

\[72-43-5\] "Methoxychlor", \(1,1\)-Bis\((p\text{-methoxyphenyl})-2,2,2\)-trichloroethane (dimorphic) \(\text{M} 345.7, m 78-78.2^\circ,\) or 86-88\(^\circ.\) Freed from \(1,1\)-bis\((p\text{-chlorophenyl})-2,2,2\)-trichloroethane by crystn from EtOH.

\[830-09-1\] \(2\)-Methoxyethanol (methylcellosolve) \(\text{M} 76.1, b 124.4^\circ, d 0.964, n 1.4017, pK^2 14.8.\) Peroxides can be removed by refluxing with stannous chloride or by filtration under slight pressure through a column of activated alumina. 2-Methoxyethanol can be dried with K\(_2\)CO\(_3\), CaSO\(_4\), MgSO\(_4\) or silica gel, with a final distn from sodium. Aliphatic ketones (and water) can be removed by making the solvent 0.1% in 2,4-dinitrophenylhydrazine and allowing to stand overnight with silica gel before fractionally distilling.

\[13970-21-6\] 2-Methoxyethoxymethylchloride (MEMCl) \(\text{M} 124.6, b 140-145^\circ/\text{atm}, d 1.092, n 1.427.\) Possible impurities are methoxyethanol (b 124\(^\circ/\text{atm})\), HCHO and HCl which can be removed below the b of MEMCl. Purify by fractional distn in a vacuum. If too impure, prepare from methoxyethanol (152g) and s-trioxane (66g) by bubbling a stream of dry HCl (with stirring) until a clear mixt is obtained. Dilute with pentane (900mL), dry (3h over 100g MgSO\(_4\), at 5\(^\circ\)), evaporate and the residue is distd in a vac. It is \textit{MOISTURE SENSITIVE} and \textit{TOXIC}. The MEM.NEt\(_3\)+Cl\(-\) salt, prepared by reactn with
1.3 equivs of Et₃N (16h/25°) and dried in vac has m 58-61°, and is moisture sensitive. [Corey et al. Tetrahedron Lett 809 1976.]

β-Methoxyethylamine  [109-85-3]  M 75.1, b 94°, d 0.874, n 1.407, pK₂ 9.40. An aqueous 70% soln was dehydrated by azotropic distn with *benzene or methylene chloride and the amine was distilled twice from zinc dust. Store in a tight container as it absorbs CO₂ from the atmosphere.


5-Methoxyindole  [1006-94-6]  M 147.2, m 55°, 57°, b 176-178°/17mm, pKₑᵢₚ ~0. Crystd from cyclohexane pet ether or pet ether/ Et₂O.


1-Methoxy-4-nitronaphthalene  gel and recrystd from MeOH. [Bunce et al. J Org Chem 52 4214 1987.]


m-Methoxyphenylacetic acid  [1798-09-0]  M 166.2, m 71.0-71.2°, pKₑᵢₚ -4.3. Crystd from H₂O, or aq EtOH.


5-(p-Methoxyphenyl)-1,2-dithiole-3-thione  [42766-10-9]  M 240.2, m 111°. Crystd from butyl acetate.

N-(p-Methoxyphenyl)-p-phenylenediamine  [101-64-4]  M 214.3, m 102°, b 238°/12mm, pK 6.6 (5.9). Crystd from ligroin.

8-Methoxypsoralen see xanthotoxin p. 577 in Chapter 6.

α-Methoxy-α-trifluoromethylphenylacetic acid (MTPA, Mosher’s acid)  [R(+)- 20445-31-2; S(-)- 17257-71-5]  M 234.2, m 43-45°, 90°/0.1mm, 105-107°/1mm, [α]D²₀ (+) and (-) 87°, [α]D²₀ (+) and (-) 73° (c 2, MeOH), pKₑᵢₚ -2.5. A likely impurity is phenylethylamine from the

α-Methoxy-α-trifluoromethylphenylacetyl chloride \( \{R-(\cdot)\ \text{or} \ S-(\cdot)\ \text{or} \ 20445-33-4\} \ M 252.6, b 54-55°/1mm, 213-214°/atm, d²⁰ 1.353, nD²⁰ 1.468, \{α\}²⁵ D (\cdot) \text{and} \ (+) 167°, [α]²⁰ D (\cdot) \text{and} \ (+) 137° \text{(c 4, CCl₄)}, [α]Ι²⁵ (\cdot) \text{and} \ (+) 10.0° \text{(neat)}. The most likely impurity is the free acid due to hydrolysis and should be checked by IR. If free from acid then distil taking care to keep moisture out of the apparatus. Otherwise add SOCl₂ and reflux for 50h and distil. Note that shorter reflux times resulted in a higher boiling fraction (b 130-155°/1mm) which has been identified as the anhydride. [Dale et al. J Org Chem 34 2543 1969; for enantiomeric purity see J Am Chem Soc 97 512 1973.]

N-Methylacetamide \{79-16-3\} M 149.2, m 30°, b 70-71°/2.5-3mm, pK₃²⁵ 3.70, pK₅²⁵ 0.42. Fractionally distd under vacuum, then fractionally crystd twice from its melt. Impurities include acetic acid, methyl amine and H₂O. For detailed purification procedure, see Knecht and Kolthoff, Inorg Chem 1 195 1962. Although N-methylacetamide is commercially available it is often extensively contaminated with acetic acid, methylanime, water and an unidentified impurity. The recommended procedure is to synthesize it in the laboratory by direct reaction. The gaseous amine is passed into hot glacial acetic acid, to give a partially aq soh of methylammonium acetate which is heated to ca 130° to expel water. Chemical methods of purification such as extractn by pet ether, treatment with H₂SO₄, K₂CO₃ or CaO can be used but are more laborious. Tests for purity include the Karl Fischer titration for water; this can be applied directly. Acetic acid and methylanime can be detected polarographically. In addition to the above, purification of N-methylacetamide can be achieved by fractional freezing, including zone melting, repeated many times, or by chemical treatment with vacuum distn under reduced pressures. For details of zone melting techniques, see Knecht in Recommended Methods for Purification of Solvents and Tests for Impurities, Coetzee Ed. Pergamon Press 1982.

N-Methylacetonilide \{759-10-2\} M 149.2, m 102-104°. Crystd from water, ether or pet ether (b 80-100°).

Methyl acetate \{79-20-9\} M 74.1, b 56.7-57.2°, d 0.934, n 1.36193, n²⁵ 1.3538, pK₃²⁵ 7.28 \( \text{Hg scale, aq H₂SO₄}\). Methanol in methyl acetate can be detected by measuring solubility in water. At 20°, the solubility of methyl acetate in water is ca 35g per 100mL, but 1% MeOH confers miscibility. Methanol can be removed by conversion to methyl acetate, using refluxing for 6h with acetic anhydride (85mL/L), followed by fractional distn. Acidic impurities can be removed by shaking with anhydrous K₂CO₃ and distilling. An alternative treatment is with acetyl chloride, followed by washing with conc NaCl and drying with CaO or MgSO₄. (Solid CaCl₂ cannot be used because it forms a crystalline addition compound.) Distn from copper stearate destroys peroxides. Free alcohol or acid can be eliminated from methyl acetate by shaking with strong aq Na₂CO₃ or K₂CO₃ (three times), then with aq 50% CaCl₂ (three times), satd aq NaCl (twice), drying with K₂CO₃ and distn from P₂O₅.

Methyl acetimidate hydrochloride \{14777-27-6\} M 109.6, m 93-95°, 105°(dec), pKₑ₅ 5.5. Crystd from methanol by adding dry ether to a ratio of 1:1 and cooled at 0°. Filter off the crystals in a cold room, wash with methanol/ether (1:2), then dry in a vacuum. [Hunter and Ludwig J Am Chem Soc 84 3491 1962.] The free base has b 90-91°/765mm, d 0.867, n 1.403 [Hunter and Ludwig Methods Enzymol 25 585 1973.]

p-Methylacetophenone \{122-00-9\} M 134.2, m 22-24°, b 93.5°/7mm, 110°/14mm, d 1.000, n 1.5335. Impurities, including the o- and m-isomers, were removed by forming the semicarbazone which, after repeated crystn, was hydrolysed to the ketone. [Brown and Marino J Am Chem Soc 84 1236 1962.] Also purified by distn under reduced pressure, followed by low temperature crystn from isopentane.

Methyl acrylate \{96-33-3\} M 86.1, b 80°, d 0.9535, n 1.4040. Washed repeatedly with aqueous NaOH until free from inhibitors (such as hydroquinone), then washed with distd water, dried (CaCl₂) and fractionally distd under reduced pressure in an all-glass apparatus. Sealed under nitrogen and stored at 0° in the dark. [Bamford and Han J Chem Soc, Faraday Trans 1 78 855 1982.]
1-Methyladamantane [768-91-2] M 150.2, m 103°. Purified by zone melting and sublimes at 90-95°/12mm.


1-Methylaminoanthraquinone [82-38-2] M 237.3, m 166.5°, pK25 1.97. Crystd to constant melting point from butan-1-ol, then crystd from EtOH. It can be sublimed under vacuum.

N-Methyl-α-aminobenzoic acid (N-methylantranilic acid) [119-68-6] M 151.2, m 178.5°, pK25 1.97, pK12 5.34. Crystd from water or EtOH.


N-Methylaniline [100-61-8] M 107.2, b 57°/4mm, 81-82°/14mm, d 0.985, n 1.570, pK2 4.56. Dried with KOH pellets and fractionally distd under vacuum. Acetylated and the acetyl derivative was recrystd to constant melting point (m 101-102°), then hydrolysed with aqueous HCl and distd from zinc dust under reduced pressure. [Hammond and Parks J Am Chem Soc 77 340 1955].

N-Methylaniline hydrochloride [2739-12-0] M 143.7, m 123.0-123.1°. Crystd from dry *benzene/CHCl3 and dried under vacuum.

Methyl p-anisate [121-98-2] M 166.2, m 48°. Crystd from EtOH.

4-Methyl anisole [104-93-8] M 122.2, b 175-176°, d15 0.9757, n 1.512. Dissolved in diethyl ether, washed with M NaOH, water, dried (Na2CO3), evaporated and the residue distd under vacuum.


2-Methylanthraquinone [84-54-8] M 222.3, m 176°. Crystd from EtOH, then sublimed.

Methyl benzoate [93-58-3] M 136.2, b 104-105°/39mm, 199.5°/760mm, d 1.087, n1.5 1.52049, n 1.51701, pK20 -8.11, -6.51 (H2 scale, aq H2SO4). Washed with dilute aqueous NaHCO3, then water, dried with Na2SO4 and fractionally distd under reduced pressure.


Methyl-1,4-benzoquinone [553-97-9] M 122.1, m 68-69°. Crystd from heptane or EtOH, dried rapidly (vacuum over P2O5) and stored under vacuum.


2-Methyl-3,4-benzphenanthrene [652-04-0] M 242.3, m 70°. Crystd from EtOH.

dl-α-Methylbenzyl alcohol [13323-81-4] M 122.2, b 60.5-61.0°/3mm. See dl-1-phenylethanol on p. 330.


p-Methylbenzyl bromide [104-81-4]. See α-bromo-p-xylene on p. 143.

p-Methylbenzyl chloride [104-82-5] M 140.6, b 80°/2mm, d 1.085, n 1.543. Dried with CaSO4 and fractionally distd under vacuum.


Methyl bromide [74-83-9] M 94.9, b 3.6°. Purified by bubbling through conc H2SO4, followed by passage through a tube containing glass beads coated with P2O5. Also purified by distn from AlBr3 at -80°, by passage through a tower of KOH pellets and by partial condensation.

Methyl o-bromobenzoate [610-94-6] M 215.1, b 122°/17mm, 234-244°/760mm. Soln in ether is washed with 10% aqueous Na2CO3, water, then dried and distd.

Methyl p-bromobenzoate [619-42-1] M 215.1, m 79.5-80.5°. Crystd from MeOH.

2-Methylbutane (isopentane) [78-78-4] M 72.2, b 27.9°, d 0.621, n 1.3573, n25 1.35088. Stirred for several hours in the cold with conc H2SO4 (to remove olefinic impurities), then washed with H2O, aqueous Na2CO3 and H2O again. Dried with MgSO4 and fractionally distd using a Todd column packed with glass helices (see p. 174). Material transparent down to 180nm was obtained by distilling from sodium wire, and passing through a column of silica gel which had previously been dried in place at 350° for 12h before use. [Potts J Phys Chem 20 809 1952].

2-Methyl-1-butanol [137-32-6; RS 34713-94-5; S(-) 1565-80-6] M 88.2, b 130°(RS), 128.6°(S), [α]D25 -5.8° (neat), d 0.809, n25 1.4082. Refluxed with CaO, distd, refluxed with magnesium and again fractionally distd. A small sample of highly purified material was obtained by fractional crysrt after conversion into a suitable ester such as the trinitrophthalate or the 3-nitrophthalate. The latter was converted to the cinchonine salt in acetone and recrystd from CHCl3 by adding pentane. The salt was saponified, extracted with ether, and fractionally distd. [Terry et al. J Chem Eng Data 5 403 1960.]
3-Methyl-1-butanol \([123-51-3]\) M 88.2, b 128°/750mm, 132°/760mm, \(d^{15}\) 0.8129, \(n^{15}\) 1.4085, n 1.4075. Dried by heating with CaO and fractionally distilling, then heating with BaO and redistilling. Alternatively, boiled with conc KOH, washed with dilute H\(_3\)PO\(_4\), and dried with K\(_2\)CO\(_3\), then anhydrous CuSO\(_4\), before fractionally distilling. If very dry alcohol is required, the distillate can be refluxed with the appropriate alkyl phthalate or succinate as described for ethanol. It is separated from 2-methyl-1-butanol by fractional distillation, fractional crystallization and preparative gas chromatography.

3-Methyl-2-butanol \([598-75-4]\) M 88.2, b 111.5°, d 0.807, n 1.4095, n\(_{25}\) 1.4076. Refluxed with magnesium, then fractionally distilled.

3-Methyl-2-butanone (methyl isopropyl ketone) \([563-80-4]\) M 86.1, b 93-94°/752mm, d 0.818, \(n^{25}\) 1.410, pK\(_{25}\) -7.1 (aq H\(_2\)SO\(_4\)). Refluxed with a little KMnO\(_4\). Fractionated on a spinning-band column, dried with CaSO\(_4\) and distilled.

2-Methyl-2-butene \([513-35-9]\) M 70.1, f -133.8°, b 38.4°/760mm, \(d^{15}\) 0.66708, \(d^{25}\) 0.65694, \(n^{15}\) 1.3908. Distilled from sodium.

Methyl n-butyrate \([623-42-7]\) M 102.1, b 102.3°/760mm, d 0.898, n 1.389. Treated with anhydrous CuSO\(_4\), then distilled under dry nitrogen.

S-(+)-2-Methylbutyric acid \([730-91-2]\) M 102.1, b 64°/2mm, 78°/15mm, 90-94°/23mm, 174-175°/atm, \(d^{25}\) 0.938, \(\alpha^{15}\) +23°, \(\alpha^{25}\) +19.8° (neat), \(\alpha^{15}\) +18.3° (c 6, EtOH), pK\(_{25}\) 4.76 (for RS). Purified by distillation in vacuo [Sax and Bergmann J Am Chem Soc 77 1910 1955; Doering and Aschner J Am Chem Soc 75 393 1953]. The methyl ester is formed by addition of diazomethane and has b 112-115°/atm, \(\alpha^{25}\) +21.1° (c 1.7, MeOH).

Methyl carbamate \([598-55-0]\) M 75.1, m 54.4-54.8°. Crystallized from *benzene.

9-Methylcarbazole \([1484-12-4]\) M 181.2, m 89°. Purified by zone melting.

4-Methylcatechol \([452-86-8]\) M 124.1. See 3,4-dihydroxytoluene on p. 208.

Methyl chloride \([74-87-3]\) M 50.5, b -24.1°. Bubbled through a sintered-glass disc dipping into conc H\(_2\)SO\(_4\), then washed with water, condensed at low temperature and fractionally distilled. Has been distilled from AlCl\(_3\) at -80°. Alternatively, passed through towers containing AlCl\(_3\), soda-lime and P\(_2\)O\(_5\), then condensed and fractionally distilled. Stored as a gas.

Methyl chloroacetate \([96-34-4]\) M 108.5, b 129-130°, d 1.230, n 1.423. Shaken with satd aq Na\(_2\)CO\(_3\) (three times), aq 50% CaCl\(_2\) (three times), satd aq NaCl (twice), dried (Na\(_2\)SO\(_4\)) and fractionally distilled.

R-(+) Methyl 2-chloropropionate \([77287-29-7]\) M 122.6, b 49-50°/35mm, 78°-80°/120mm, 132-134°/760mm, \(d^{25}\) 1.152, \(n^{25}\) 1.417, \(\alpha^{25}\) +26° (19.0°) (neat). Purified by repeated distillation [Walker J Chem Soc 67 916 1895; Walden Chem Ber 28 1293 1905; see also Gless Synth Commun 16 633 1986].

3-Methylcholanthrene \([56-49-5]\) M 268.4, m 179-180°. Crystallized from *benzene and diethyl ether. CARCINOGEN.

Methyl cyanoacetate \([105-34-0]\) M 99.1, f -13°, b 205°, d 1.128, n 1.420. Purified by shaking with 10% Na\(_2\)CO\(_3\) soln, washing well with water, drying with anhydrous Na\(_2\)SO\(_4\), and distilling.

Methyl cyanoformate \([7640-15-2]\) M 85.1, b 81°/47mm, 97°/751mm, 100-101°/760mm, \(d^{25}\) 1.072, \(n^{25}\) 1.37387. Purified by fractionation through a 45cm glass helices packed column and with a 30cm spinning band column. [Sheppard J Org Chem 27 3756 1962]. It has been distilled through a short Vigreux column.
column, and further purified by recryst from Et₂O at -40° as white crystals which melt at room temperature. NMR: δ 4.0 (CH₃), and IR: 2250 (CN) and 1750 (CO) cm⁻¹. [Childes and Weber J Org Chem 41 3486 1976.]

**Methylcyclohexane** [108-87-2] M 98.2, b 100.9°, d²⁵ 0.7650, n 1.4231, n²⁵ 1.42058. Passage through a column of activated silica gel gives material transparent down to 220nm. Also purified by passage through a column of activated basic alumina, or by azeotropic distn with MeOH, followed by washing out the MeOH with H₂O, drying and distilling. Methylcyclohexane can be dried with CaSO₄, CaH₂ or sodium. Has also been purified by shaking with a mixture of conc H₂SO₄ and HNO₃ in the cold, washing with H₂O, drying with CaSO₄ and fractionally distilling from potassium. Percolation through a Celite column impregnated with 2,4-dinitrophenylhydrazine (DNPH), phosphoric acid and H₂O (prepared by grinding 0.5g DNPH with 6mL 85% H₃PO₄, then mixing with 4mL of distilled H₂O and 10g of Celite) removes carbonyl-containing impurities.

2-Methylcyclohexanol [583-59-5] M 114.2, b 65°/20mm, 167.6°/760mm, d 0.922, n 1.46085. Dried with Na₂SO₄ and distd under vacuum.

cis- and trans-3-Methylcyclohexanol [591-23-1] M 114.2, b 69°/16mm, 172°/760mm, d 0.930, n 1.45757, n²⁵ 1.45444. Dried with Na₂SO₄ and distd under vacuum.

4-Methylcyclohexanone [589-92-4] M 112.2, b 165.5°/743mm, d 0.914, n 1.44506. Dried with CaSO₄, then fractionally distd.

1-Methylcyclohexene [591-49-1] M 96.2, b 107.4-108°/atm, 110-111°/760mm, d 0.813, n 1.451. Freed from hydroperoxides by passing through a column containing basic alumina or refluxing with cupric stearate, filtered and fractionally distd from sodium.

**Methylcyclopentane** [96-37-7] M 84.2, b 71.8°, d 0.749, n 1.40970, n²⁵ 1.40700. Purification procedures include passage through columns of silica gel (prepared by heating in nitrogen to 350° prior to use) and activated basic alumina, distn from sodium-potassium alloy, and azeotropic distn with MeOH, followed by washing out the methanol with water, drying and distilling. It can be stored with CaH₂ or sodium.

3'-Methyl-1,2-cyclopentenophenanthrene [549-38-2] M 232.3, m 126-127°. Crystd from AcOH.

S-Methyl-L-cysteine [1187-84-4] M 135.2, m 207-210°, [α]D²⁶ -32.0° (c 5, H₂O), pK₁ 1.94 (COOH), pK₂ 8.73 (NH₂). Likely impurities are cysteine and S-methyl-dL-cysteine. Crystd from water by adding 4 volumes of EtOH.

5-Methylcytosine [4-amino-5-methylpyrimidin-2(1H)-one] [554-01-8] M 125.1, m 270°(dec), pK₁ 4.6, pK₂ 12.4. Crystd from water (sol 3.4%).

**Methyl decanoate** [110-42-9] M 186.3, b 114°/15mm, 224°/760mm, d 0.874, n 1.426. Passed through alumina before use.

**Methyl 2,4-dichlorophenoxyacetate** [1928-38-7] M 235.1, m 43°, b 119°/11mm. Crystd from MeOH.

m-Methyl-N,N-dimethylaniline [121-72-2] M 135.2, b 72-74°/5mm, 215°/760mm, pK₂ 5.22. Refluxed for 3h with 2 molar equivalents of acetic anhydride, then fractionally distd under reduced pressure. Also dried over BaO, distd and stored over KOH. Methods described for N,N-dimethylaniline are applicable.

p-Methyl-N,N-dimethylaniline [99-97-8] M 135.2, b 76.5-77.5°/4mm, 211°/760mm, pK₂ 4.76. Refluxed for 3h with 2 molar equivalents of acetic anhydride, then fractionally distd under reduced pressure. Also dried over BaO, distd and stored over KOH. Methods described for N,N-dimethylaniline are applicable.
2-Methyl-1,3-dithiane [6007-26-7] M 134.3, b 53-54°/1.1mm, 66°/5mm, 79-80°/8-10mm, 85°/12mm, d₂⁰ 1.121, n₂⁰ 1.560. Wash with H₂O, 2.5 M aqueous NaOH, H₂O, brine, dried over K₂CO₃ (use toluene as solvent if volume of reagent is small), filter, evaporate and distil the colourless residue. IR film: 1455, 1371 and 1060 (all medium and CH₃), 1451m, 1422s, 1412m. 1275m, 1236m, 1190m, 1171w, 918m and 866w (all dithiane) cm⁻¹ [Corey and Erickson J Org Chem 36 3553 1971; Seebach and Corey J Org Chem 40 231 1975].

Methyl dodecanoate [111-82-0] M 214.4, m 5°, b 141°/15mm, d 0.870, n₅0 1.4199. Passed through alumina before use.

N-Methyleneaminoacetonitrile [109-82-0] M 68.1, m 129°. Crystd from EtOH or acetone.

p,p'-Methylene-bis-(N,N-dimethylaniline) [101-61-1] M 254.4, m 89.5°. See p,p'-tetramethyldiaminodiphenylmethane on p. 364.

Methylene Blue [3,7-bis-(dimethylamino)phenothiazin-5-iun chloride [61-73-4] M 319.9, CI 52015, εₑ₅₄ 94.000 (EtOH), εₑ₆₄ 81.000 (H₂O), pK₂5 3.8. Crystd from 0.1M HCl (16mL/g), the crystals were separated by centrifugation, washed with chilled EtOH and diethyl ether and dried under vacuum. Crystd from 50% aqueous EtOH, washed with absolute EtOH, and dried at 50-55° for 24h. Also crystd from *benzene-MeOH (3:1). Salted out with NaCl from a commercial conc aqueous soln, then crystd from water, dried at 100° in an oven for 8-10h.


3,4-Methylenedioxyacinnamic acid [2373-80-0] M 192.2, m 243-244°(dec), pKₑ₅₈ ~4.6. Crystd from glacial acetic acid.


Methylene Green [3,7-bis-(dimethylamino)-4-nitrophenothiazin-5-iun chloride] [2679-01-8] M 364.9, m >200°(dec), CI 52020, pK₂5 3.2. Crystd three times from water (18mL/g).

N-Methylphedrine (2-dimethylamino-1-phenylpropanol) [1S,2R-(+)-42151-56-4; 1R,2S(-)-552-79-4] M 179.3, m 85-86°, 87-87.5°, 90°, b 115°/2mm, [α]₂⁰⁺⁰ (+) and (-) 35°, [α]₂⁰⁺⁰ (+) and (-) 30° (c 4.5, MeOH), pK₂⁶ 9.22. It has been recrystd from Et₂O, pet ether, of aq EtOH or aq MeOH and has been distilled under reduced pressure. [Smith J Chem Soc 2056 1927; Tanaka and Sugawa Yakugaku Zasshi (J Pharm Soc Japan) 72 1548 1952 (Chem Abstr 47 8682 1953); Takamatsu Yakugaku Zasshi (J Pharm Soc Japan) 76 1227 1956, Chem Abstr 51 4304 1957.] The hydrochloride has m 192-193° and [α]₂⁰⁺³⁰ (c 5, H₂O).[Prelog and Hüflicher Helv Chim Acta 33 2021 1950].

Methyl ether (dimethyl ether) [115-10-6] M 46.1, b -63.5°/96.5mm. Dried by passing over alumina and then BaO, or over CaH₂, followed by fractional distn at low temperatures.

N-Methyl ethylamine hydrochloride [624-60-2] M 95.6, m 126-130°, pK 10.9 (free base). Crystd from absolute EtOH or diethyl ether.

N-Methyl formamide [123-39-7] M 59.1, m -3.5°, b 100.5°/25mm, d 1.005., n₂⁰ 1.4306 Dried with molecular sieves for 2days, then distd under reduced pressure through a column packed with glass helices. Fractionally crystd by partial freezing and the solid portion was vac distd.

Methyl formate [107-31-3] M 60.1, b 31.5°, d 0.971, n₁⁵ 1.34648, n 1.34332. Washed with strong aq Na₂CO₃, dried with solid Na₂CO₃ and distd from P₂O₅. (Procedure removes free alcohol or acid.)
2-Methylfuran [534-22-5] M 82.1, b 62.7-62.8°/731mm, d 0.917, n 1.436. Washed with acidified satd ferrous sulfate soln (to remove peroxides), separated, dried with CaSO₄ or CaCl₂, and fractionally distd from KOH immediately before use. To reduce the possibility of spontaneous polymerisation, addition of about one-third of its volume of heavy mineral oil to 2-methylfuran prior to distn has been recommended.


α-Methylglutaric acid [18069-17-5] M 146.1, m 79°, pKₐ 4.36, pKₐ 5.37. Crystd from distd water, then dried under vacuum over conc H₂SO₄.

β-Methylglutaric acid [626-51-7] M 146.1, m 87°, pKₐ 4.35, pKₐ 5.44. Crystd from distd water, then dried under vacuum over conc H₂SO₄.

Methylglyoxal [78-98-8] M 72.1, b ca 72°/760mm. Commercial 30% (w/v) aqueous soln was diluted to about 10% and distd twice, taking the fraction boiling below 50°/20mm Hg. (This treatment does not remove lactic acid).

Methyl Green [82-94-0, 7114-03-6 (ZnCl₂ salt)] M 458.5, m >200°(dec). Crystd from hot water.


2-Methylhexane [591-76-4] M 100.2, b 90.1°, d 0.678, n 1.38485, n² 1.38227. Purified by azeotropic distn with MeOH, then washed with water (to remove MeOH), dried over type 4A molecular sieves and distd.

3-Methylhexane [589-34-4] M 100.2, b 91.9°, d 0.687, n 1.38664, n² 1.38609. Purification as for 2-methylhexene.

Methyl hexanoate [106-70-7] M 130.2, b 52°/15mm, 150°/760mm, d 0.885, n 1.410. Passed through alumina before use.

Methylhydrazine [60-34-4] M 46.1, b 87°/745mm, d 0.876, n 1.436, pKₐ 7.87. Dried with BaO, then vacuum distd. Stored under nitrogen.

Methyl hydrazinocarboxylate [6294-89-9] M 90.1, m 70-73°. To remove impurities, the material was melted and pumped under vacuum until the vapours were spectroscopically pure [Caminati et al. J Am Chem Soc 108 4364 1986].

Methyl 4-hydroxybenzoate [99-76-3] M 152.2, m 127.5°, pKₐ 9.3. Fractionally crystallized from its melt, recrystd from *benzene, then from *benzene/MeOH and dried over CaCl₂ in a vacuum desiccator.

**N-Methylimidazole** [616-47-7] M 82.1, b 81-84°C/27mm, 197-198°C/760mm, d 1.032, n 1.496, pK₂ 7.25. Dried with sodium metal and then distd. Stored at 0°C under dry argon.

**2-Methylimidazole** [693-98-1] M 82.1, m 140-141°C, b 267°C/760mm, pK₂ 7.86. Recrystd from *benzene or pet ether.

**4-Methylimidazole** [822-36-6] M 82.1, m 47-48°C, b 263°C/760mm, pK₂ 7.61. Recrystd from *benzene or pet ether.

**2-Methylindole** Crystd from *benzene. Purified by zone melting.

**3-Methylindole (skatole)** [83-34-1] M 131.2, m 95°C, b 101.5-102.5°C/0.3mm, 163-165°C/16mm, d 1.147, n 1.641, pK₂ 4.05. Purified by fractional distn in an inert atmosphere. [Bordwell and Cooper *J Am Chem Soc* 74 1058 1952]. The *N*-acetyl derivative has m 78-78°C (after recrystn from aq EtOH).


**Methyl methacrylate** [80-62-6] M 100.1, f -50°C, b 46°C/100mm, d 0.937, n 1.4144. Washed twice with aqueous 5% NaOH (to remove inhibitors such as hydroquinone) and twice with water. Dried with CaCl₂, Na₂CO₃, Na₂SO₄ or MgSO₄, then with CaH₂ under nitrogen at reduced pressure. The distillate is stored at low temperatures and redistd before use. Prior to distn, inhibitors such as β-naphthylamine (0.2%) or di-β-naphthol are sometimes added. Also purified by boiling aqueous H₃PO₄ soln and finally with saturated NaCl soln. It was dried for 24h over anhydrous CaSO₄, distd at 0.1mm Hg at room temperature and stored at -30°C [Albeck et al. *J Chem Soc, Faraday Trans 1* 1488 1978].

**Methyl methanesulfonate** [66-27-3] M 110.3, b 59°C/0.6mm, 96-98°C/19mm, d 1.300, n 1.4140. Purified by careful fractionation and collecting the middle fraction. Suspected CARCINOGEN. Note that MeSO₃H has b 134.5-135°C, 167-167.5°C/10mm and methanesulfonic anhydride has b 138°C/10mm — both are possible impurities.
Methyl methanethiolsulfonate [2949-92-0] M 126.2, b 69-71°/0.4mm, 96-97°/4.5mm, 104-105°/10mm, 119°/16mm, d 1.226, n 1.515. Purified by fractional distillation under reduced pressure. IR: v = 1350, 750 cm⁻¹. [Applegate et al. J Org Chem 38:943 (1973).]


S-Methyl-L-methionine chloride (Vitamin U) [1115-84-0] M 199.5, αD +33° (0.2M HCl), pK₁ 1.9, pK₂ 7.9. Likely impurities are methionine, methionine sulfoxide and methionine sulfone. Crystallized from water by adding a large excess of EtOH. Stored in a cool, dry place, protected from light.

N-Methylmorpholine [109-02-4] M 101.2, b 116-117°/764mm, d 0.919, n 1.436, pK₂ 7.38. Dried by refluxing with BaO or sodium, then fractionally distilled through a helices-packed column.

4-Methylmorpholine-4-oxide monohydrate [7529-22-8] M 135.2, m 71-73°. When dried for 2-3h at high vacuum it dehydrates. Add MeOH to the oxide and distill off the solvent under vacuum until the temperature is ca 95°. Then add Me₂CO at reflux then cool to 20°. The crystals are filtered off washed with Me₂CO and dried. The degree of hydration may vary and may be important for the desired reactions. [van Rheenan et al. Tetrahedron Lett 1973 1076; Schneider and Hanze US Pat 2 769 823; see also Sharpless et al. Tetrahedron Lett 2503 1976.]

1-Methylnaphthalene [90-12-0] M 142.2, f -30°, b 244.6°, d 1.021, n 1.6108. Dried for several days with CaCl₂ or by prolonged refluxing with BaO. Fractionally distilled through a glass helices-packed column from sodium. Purified further by soln in MeOH and pptn of its picrate complex by adding to a saturated soln of picric acid in MeOH. The picrate, after crystallization to constant melting point (m 140-141°) from MeOH, was dissolved in *benzene and extracted with aqueous 10% LiOH until the extract was colourless. Evaporation of the *benzene under vacuum gave 1-methylnaphthalene [Kloetzel and Herzog J Am Chem Soc 72 1991 1950]. However, neither the picrate nor the styphnate complexes satisfactorily separates 1- and 2-methylnaphthalenes. To achieve this, 2-methylnaphthalene (10.7g) in 95% EtOH (50mL) has been ppted with 1,3,5-trinitrobenzene (7.8g) and the complex has been crystallized from MeOH to m 153-153.5° (m of the 2-methyl isomer is 124°). [Alternatively, 2,4,7-trinitrofluorenone in hot glacial acetic acid could be used, and the derivative (m 163-164°) recrystallized from glacial acetic acid]. The 1-methylnaphthalene was regenerated by passing a soln of the complex in dry *benzene through a 15-in column of activated alumina and washing with *benzene/pet ether (b 35-60°) until the coloured band of the nitro compound had moved down near the end of the column. The complex can also be decomposed using tin and acetic-hydrochloric acids, followed by extraction with diethyl ether and *benzene; the extracts were washed successively with dilute HCl, strongly alkaline sodium hypophosphite, water, dilute HCl and water. [Soffer and Stewart J Am Chem Soc 74:567 1952.]

2-Methylnaphthalene [91-57-6] M 142.2, m 34.7-34.9°, b 129-130°/25mm. Fractionally crystallized repeatedly from its melt, then fractionally distilled under reduced pressure. Crystallized from *benzene and dried under vacuum in an Abderhalden pistol. Purified via its picrate (m 114-115°) as described for 1-methylnaphthalene.


Methyl 1-naphthyl ether [2216-69-5] M 158.2, b 90-91°/2mm, d 1.059, n25 1.6210. Steam distilled from alkali. The distillate was extracted with diethyl ether. After drying (MgSO₄) the extract and evaporating diethyl ether, the methyl naphthyl ether was then fractionated under reduced pressure from CaH₂.

Methyl nitrate [598-58-3] M 77.0, b 65°/760mm, d5 1.2322, d15 1.2167, d25 1.2032. Distilled at -80°. The middle fraction was subjected to several freeze-pump-thaw cycles. VAPOUR EXPLODES ON HEATING.
Methyl nitrite [624-91-9] M 61.0, b -12°, d 15 (liq) 0.991. Condensed in a liquid nitrogen trap. Distd under vacuum, first trap containing dry Na₂CO₃ to free it from acid impurities then into further Na₂CO₃ traps before collection.

N-Methyl-4-nitroaniline [100-15-2] M 152.2, m 152.2°, pK² 0.55. Crystd from aqueous EtOH.

2-Methyl-5-nitroaniline [99-55-8] M 152.2, m 109°, pK² 2.35. Acetylated, and the acetyl derivative crystd to constant melting point, then hydrolysed with 70% H₂SO₄ and the free base regenerated by treatment with ammonia [Bevan, Fayiga and Hirst J Chem Soc 4284 1956].

4-Methyl-3-nitroaniline [119-32-4] M 152.2, m 81.5°, pK² 3.02. Crystd from hot water (charcoal), then ethanol and dried in a vacuum desiccator.

Methyl 3-nitrobenzoate [618-95-1] M 181.2, m 78°. Crystd from MeOH (1g/mL).

Methyl 4-nitrobenzoate [619-50-1] M 181.2, m 95.5°. Dissolved in diethyl ether, then washed with aqueous alkali, the ether was evaporated and the ester was recrystd from EtOH.


Methylnorbornene-2,3-dicarboxylic anhydride (5-methylnorborn-5-ene-2-endo-3-endo-dicarboxylic anhydride) [25134-21-8] M 178.2, m 88.5-89°. Purified by thin layer chromatography on Al₂O₃ (previously boiled in EtOAc) and eluted with hexane-*C₆H₆ (1:2) then recrystd from *C₆H₆-hexane. The free acid has m 118.5-119.5°. [Miranov et al. Tetrahedron 19 1939 1963.]


Methyl octanoate (methyl caprylate) [111-11-5] M 158.2, b 83°/15mm, 193-194°/760mm, d 0.877, n 1.419. Passed through alumina before use.

Methyl oleate [112-62-9] M 296.5, f -19.9°, b 217°/16mm, d 0.874, n 1.4522. Purified by fractional distn under reduced pressure, and by low temperature crystn from acetone.

3-Methyl-2-oxazolidone [19836-78-3] M 101.1, m 15°, b 88-91°/1mm, d 1.172, n 1.455. Purified by successive fractional freezing, then dried in a dry-box over 4A molecular sieves for 2 days.

3-Methyl-3-oxetanemethanol (3-hydroxymethyl-3-methyloxetane) [3143-02-0] M 102.1, b 80°/4mm, 92-93°/12mm, d 2° 1.033, n 2° 1.4449. Purified by fractionation through a glass column [Pattison J Am Chem Soc 79 3455 1977].

Methylpentane (mixture of isomers). Passage through a long column of activated silica gel (or alumina) gave material transparent down to 200nm by UV.

2-Methylpentane [107-83-5] M 86.2, b 60.3°, d 0.655, n 1.37145, n 25 1.36873. Purified by azeotropic distn with MeOH, followed by washing out the MeOH with water, drying (CaCl₂, then sodium), and distn. [Forziati et al. J Res Nat Bur Stand 36 129 1946.]
3-Methylpentane [96-14-0] M 86.2, b 63.3\(^\circ\), d 0.664, n 1.37652, n\(25^\circ\) 1.37384. Purified by azeotropic distillation with MeOH, as for 2-methylpentane. Purified for ultraviolet spectroscopy by passage through columns of silica gel or alumina activated by heating for 8 h at 210\(^\circ\) under a stream of nitrogen. Has also been treated with conc (or fuming) H\(_2\)SO\(_4\), then washed with water, aqueous 5\% NaOH, water again, then dried (CaCl\(_2\), then sodium), and distill through a long, glass helices-packed column.

2-Methyl-2,4-pentanediol [107-41-5] M 118.2, b 107.5-108.5\(^\circ\)/25 mm, d 0.922, n\(25^\circ\) 1.4265. Dried with Na\(_2\)SO\(_4\), then CaH\(_2\) and fractionally distill under reduced pressure through a packed column, taking precautions to avoid absorption of water.

2-Methyl-1-pentanol [105-30-6] M 102.2, b 65-66\(^\circ\)/60 mm, 146-147\(^\circ\)/760 mm, d 0.827, n 1.420. Dried with Na\(_2\)SO\(_4\) and distill.

4-Methyl-2-pentanol [108-11-2] M 102.2, b 131-132\(^\circ\), d 0.810, n 1.413. Washed with aqueous NaHCO\(_3\), dried and distill. Further purified by conversion to the phthalate ester by adding 120 mL of dry pyridine and 67 g of phthalic anhydride per mole of alcohol, purifying the ester and steam distilling it in the presence of NaOH. The distillate was extracted with ether, and the extract was dried and fractionally distill.

[Levine and Walti J Biol Chem 94 367 19311.]

3-Methyl-3-pentanol carbamate (Emylcamate) [78-28-4] M 145.2, m 56-58.5\(^\circ\). Crystallized from 30\% EtOH.

4-Methyl-2-pentanone (methyl isobutyl ketone) [108-10-1] M 100.2, b 115.7\(^\circ\), d 0.801, n 1.3958, n\(25^\circ\) 1.3938. Refluxed with little KMnO\(_4\), washed with aqueous NaHCO\(_3\), dried with CaSO\(_4\) and distill. Acidic impurities were removed by passage through a small column of activated alumina.

2-Methyl-1-pentene [763-29-1] M 84.2, b 61.5-62\(^\circ\), d 0.680, n 1.395. Water was removed, and peroxide formation prevented by several vacuum distill from sodium, followed by storage with sodium-potassium alloy.

cis-4-Methyl-2-pentene [691-38-3] M 84.2, m -134.4\(^\circ\), b 57.7-58.5\(^\circ\), d 0.672, n 1.388. Dried with CaH\(_2\), and distill.

trans-4-Methyl-2-pentene [674-76-0] M 84.2, m -140.8\(^\circ\), b 58.5\(^\circ\), d 0.669, n 1.389. Dried with CaH\(_2\), and distill.

5-Methyl-1,10-phenanthroline [3002-78-6] M 194.2, m 113\(^\circ\) (anhyd), pK\(25^\circ\) 5.28. Crystallized from *benzene/pet ether.  

N-Methylphenazonium methosulfate see 5-methylphenazinium methyl sulfate on p. 547 in Chapter 6. 


4-Methylphenylacetic acid [622-47-9] M 150.2, m 94\(^\circ\), pK\(25^\circ\) 4.37. Crystallized from heptane or water.


3-Methyl-1-phenyl-5-pyrazolone [89-25-8] M 174.2, m 127\(^\circ\). Crystallized from hot H\(_2\)O, or EtOH/water (1:1).


1-Methyl-4-piperidone [1445-73-4] M 113.2, b 53-56°/0.5mm, 54-56°/9mm, 68-71°/17mm, 85-87°/45mm, d25 0.972, n25 1.4588, pK2 7.9. It is best purified by fractional distn. The hydrochloride of the hydrate (4-diol) has m 94.7-95°, but the anhydrous hydrochloride which crystallises from CHCl3-Et2O and has m 165-168° (1 64-167°) and can also be obtained by sublimation at 120°/2mm. The oxime has m 130-132° (from Me2CO). The methiodide crystallises from MeOH and the crystals with lMeOH has m 202-204° dec. [Lyle et al. J Org Chem 24 342 1959; Bowden and Green J Chem Soc 1164 1952; Tomita Yakugaku Zasshi (J Pharm Soc Japan) 71 1053 1951.]

2-Methylpropane-1,2-diamine (1,2-diamino-2-methylpropane) [811-93-8] M 88.2, b 47-48°/17mm, d 0.839, n25 1.4430, pK2 9.42. Dried with sodium for 2 days, then distd under reduced pressure from sodium.

2-Methylpropane-1-thiol [513-44-0] M 90.2, b 41.2°/142mm, d25 0.972, n25 1.43588, pK2 7.9. It is best purified by fractional distn. The hydrochloride of the hydrate (4-diol) has m 94.7-95°, but the anhydrous hydrochloride which crystallises from CHCl3-Et2O and has m 165-168° (164-167°) and can also be obtained by sublimation at 120°/2mm. The oxime has m 130-132° (from Me2CO). The methiodide crystallises from MeOH and the crystals with lMeOH has m 202-204° dec. [Lyle et al. J Org Chem 24 342 1959; Bowden and Green J Chem Soc 1164 1952; Tomita Yakugaku Zasshi (J Pharm Soc Japan) 71 1053 1951.]

1-Methyl-4-piperidone [1445-73-4] M 113.2, b 53-56°/0.5mm, 54-56°/9mm, 68-71°/17mm, 85-87°/45mm, d25 0.972, n25 1.4588, pK2 7.9. It is best purified by fractional distn. The hydrochloride of the hydrate (4-diol) has m 94.7-95°, but the anhydrous hydrochloride which crystallises from CHCl3-Et2O and has m 165-168° (1 64-167°) and can also be obtained by sublimation at 120°/2mm. The oxime has m 130-132° (from Me2CO). The methiodide crystallises from MeOH and the crystals with lMeOH has m 202-204° dec. [Lyle et al. J Org Chem 24 342 1959; Bowden and Green J Chem Soc 1164 1952; Tomita Yakugaku Zasshi (J Pharm Soc Japan) 71 1053 1951.]

2-Methylpropane-1,2-diamine (1,2-diamino-2-methylpropane) [811-93-8] M 88.2, b 47-48°/17mm, d 0.839, n25 1.4430, pK2 9.42. Dried with sodium for 2 days, then distd under reduced pressure from sodium.

2-Methylpropane-1-thiol [513-44-0] M 90.2, b 41.2°/142mm, d25 0.972, n25 1.43588, pK2 7.9. It is best purified by fractional distn. The hydrochloride of the hydrate (4-diol) has m 94.7-95°, but the anhydrous hydrochloride which crystallises from CHCl3-Et2O and has m 165-168° (164-167°) and can also be obtained by sublimation at 120°/2mm. The oxime has m 130-132° (from Me2CO). The methiodide crystallises from MeOH and the crystals with lMeOH has m 202-204° dec. [Lyle et al. J Org Chem 24 342 1959; Bowden and Green J Chem Soc 1164 1952; Tomita Yakugaku Zasshi (J Pharm Soc Japan) 71 1053 1951.]

2-Methylpropane-1-thiol [75-66-1] M 90.2, b 61.6°/701mm, d25 0.79426, n25 1.41984, pK2 11.22. Dried for several days with CaO, then distd from CaO. Purified as for 2-methylpropane-1-thiol.

2-Methyl-1-propanol (isobutanol) [78-83-1] M 74.1, b 107.9°, d 0.804, n15 1.39768, n25 1.3939. Dried by refluxing with CaO and BaO for several hours, followed by treatment with calcium or aluminium amalgam, then fractional distn from sulfanilic or tartaric acids. More exhaustive purifications involve formation of phthalate or borate esters. Heating with phthalic anhydride gives the acid phthalate which, after crystn to constant melting point (m 65°) from pet ether, is hydrolysed with aqueous 15% KOH. The alcohol is distd as the water azeotrope and dried with K2CO3, then anhydrous CuSO4, and finally magnesium turnings, followed by fractional distn. [Huckel and Ackermann J Prakt Chem 136 15 1933.]

Methyl propiolate [922-67-8] M 84.1, b 100°/atm, 102°/atm, 103-105°/atm, d 0.945, n 1.4080. Purified by fractional distn and collecting the middle fraction; note that propiolic acid has a high b [144°(dec)/atm]. LACHRYMATORY.

N-Methylpropionamide [1187-58-2] M 87.1, f -30.9°, b 103°/12-13mm, d 0.934, n25 1.4356. A colourless, odourless, neutral liquid at room temperature with a high dielectric constant. The amount of water present can be determined directly by Karl Fischer titration; GLC and NMR have been used to detect unreacted propionic acid. Commercial material of high quality is available, probably from the condensation of anhydrous methylamine with 50% excess of propionic acid. Rapid heating to 120-140° with stirring favours the reaction by removing water either directly or as the ternary xylene azeotrope. The quality of the distillate improves during the distn.
The propionamide can be dried over CaO. H₂O and unreacted propionic acid were removed as their xylene azeotropes. It was vacuum dried. Material used as an electrolyte solvent (specific conductance less than 10⁻⁶ ohm⁻¹ cm⁻¹) was obtained by fractional distillation under reduced pressure, and stored over BaO or molecular sieves because it readily absorbs moisture from the atmosphere on prolonged storage. [Hoover Pure Appl Chem 37 581 1974; Recommended Methods for Purification of Solvents and Tests for Impurities, Coetzee Ed., Pergamon Press, 1982.]

**Methyl propionate** [554-12-1] M 88.1, b 79.7⁰. Washed with satd aq NaCl, then dried with Na₂CO₃ and distill from P₂O₅. (This removes any free acid and alcohol.) It has also been dried with anhydrous CuSO₄.

**Methyl n-propyl ether** [557-17-5] M 74.1, b 39⁰, d 0.736, n₁₄ 1.3602, pK₂⁻⁵ -3.79 (aq H₂SO₄). Dried with CaSO₄, then passed through a column of alumina (to remove peroxides) and fractionally distilled.

**Methyl n-propyl ketone** [107-87-9] M 86.1, b 102.4⁰, d 0.807, n 1.3903. Refluxed with a little KMnO₄, dried with CaSO₄ and distill. It was converted to its bisulfite addition compound by shaking with excess saturated aqueous NaHSO₃ at room temperature, cooling to 0⁰, filtering, washing with diethyl ether and drying. Steam distillation gave a distillate from which the ketone was recovered, washed with aq NaHCO₃ and distilled water, dried (K₂CO₃) and fractionally distilled. [Waring and Garik J Am Chem Soc 78 5198 1956.]

**3-Methyl-1-propyn-3-01 carbamate** [302-66-9] M 141.2, m 55.8-57⁰. Crystallised from ether/pet ether or cyclohexane.


**2-Methylpyridine (2-picoline)** [109-06-8] M 93.1, b 129.4⁰, d 0.9444, n 1.50102, pK₂⁻⁵ 5.96. Biddiscome and Handley [J Chem Soc 1957 1954] steam distill a boiling soln of the base in 1.2 equivalents of 20% H₂SO₄ until about 10% of the base had been carried over, along with non-basic impurities. Excess aqueous NaOH was then added to the residue, the free base was separated, dried with solid NaOH and fractionally distilled.

2-Methylpyridine can also be dried with BaO, CaO, CaH₂, LiAlH₄, sodium or Linde type 5A molecular sieves. An alternative purification is via the ZnCl₂ adduct, which is formed by adding 2-methylpyridine (90mL) to a soln of anhydrous ZnCl₂ (168g) and 42mL conc HCl in absolute EtOH (200mL). Crystals of the complex are filtered off, recrystallised twice from absolute EtOH (to give m 118.5-119.5⁰), and the free base is liberated by addition of excess aqueous NaOH. It is steam distill, and solid NaOH added to the distillate to form two layers, the upper one of which is then dried with KOH pellets, stored for several days with BaO and fractionally distilled. Instead of ZnCl₂, HgCl₂ (430g in 2.4L of hot water) can be used. The complex, which separates on cooling, can be dried at 110⁰ and recrystallised from 1% HCl (to m 156-157⁰).

**3-Methylpyridine (3-picoline)** [108-99-6] M 93.1, m -18.5⁰, b 144⁰/767mm, d 0.957, n 1.5069, pK₂⁻⁵ 5.70. In general, the same methods of purification that are described for 2-methylpyridine can be used. However, 3-methylpyridine often contains 4-methylpyridine and 2,6-lutidine, neither of which can be removed satisfactorily by drying and fractionation, or by using the ZnCl₂ complex. Biddiscome and Handley [J Chem Soc 1957 1954] after steam distillation for 2-methylpyridine, treated the residue with urea to remove 2,6-lutidine, then azeotropically distill with acetic acid (the azeotrope had b 114.5⁰/712mm), and recovered the base by adding excess of aqueous 30% NaOH, drying with solid NaOH and carefully fractionally distilling. The distillate was then fractionally crystallised by slow partial freezing. An alternative treatment [Reithof et al. Ind Eng Chem (Anal Edn) 18 458 1946] is to reflux the crude base (500mL) for 20-24h with a mixture of acetic anhydride (125g) and phthalic anhydride (125g) followed by distillation until phthalic anhydride begins to pass over. The distillate was treated with NaOH (250g in 1.5L of water) and then steam distill. Addition of solid NaOH (250g) to this distillate (ca 2L) led to the separation of 3-methylpyridine which was removed, dried (K₂CO₃, then BaO) and fractionally distilled. (Subsequent fractional freezing would probably be advantageous.)
4-Methylpyridine (4-picoline)  [108-89-4]  M 93.1, m 4.25°, b 145.0°/765mm, d 0.955, n 1.5058, pK_a 4.99. Can be purified as for 2-methylpyridine. Biddecome and Handley's method for 3-methylpyridine is also applicable. Lidstone [J Chem Soc 242 1940] purified via the oxalate (m 137-138°) by heating 100mL of 4-methylpyridine to 80° and adding slowly 110g of anhydrous oxalic acid, followed by 150mL of boiling EtOH. After cooling and filtering, the ppt was washed with a little EtOH, then recrystd from EtOH, dissolved in the minimum quantity of water and distd with excess 50% KOH. The distillate was dried with solid KOH and again distd. Hydrocarbons can be removed from 4-methylpyridine by converting the latter to its hydrochloride, crystallising from EtOH/diethyl ether, regenerating the free base by adding alkali and distilling. As a final purification step, 4-methylpyridine can be fractionally crystd by partial freezing to effect a separation from 3-methylpyridine. Contamination by 2,6-lutidine is detected by its strong absorption at 270nm.


N-Methylpyrrole  [96-54-8]  M 81.1, b 115-116°/756mm, d 0.908, n 1.487, pK_a -3.4 (-2.90). Dried with CaSO_4, then fractionally distd from KOH immediately before use.

2-Methylquinoline (quinaldine)  [91-63-4]  M 143.2, b 86-87°/1mm, 155°/12mm, 246-247°/760mm, d 1.058, n 1.6126, pK_a 5.65. Dried with Na_2SO_4 or by refluxing with BaO, then fractionally distd under reduced pressure. Redistd from zinc dust. Purified by conversion to its phosphate (m 220°) or picrate (m 192°) from which after recrystn, the free base was regenerated. [Packer, Vaughan and Wong J Am Chem Soc 80 905 1958.]


8-Methylquinoline  [611-32-5]  M 143.2, b 122.5°/16mm, 247.8°/760mm, d 1.703, n 1.61631, pK_a 4.60. Purified as for 2-methylquinoline. The phosphate and picrate have m 158° and m 201° respectively.

Methyl Red (4-dimethylaminoazobenzene-2'-carboxylic acid)  [493-52-7]  M 269.3, m 181-182°, CI 13020, pK_a 5.2, 2.30, pK_a 4.82. The acid is extracted with boiling toluene using a Soxhlet apparatus. The crystals which separated on slow cooling to room temperature are filtered off, washed with a little toluene and recrystd from glacial acetic acid, *benzene or toluene followed by pyridine/water. Alternatively, dissolved in aq 5% NaHCO_3 soln, and ppted from hot soln by dropwise addition of aq HCl. Repeated until the extinction coefficients did not increase.

Methyl salicylate (methyl 2-hydroxybenzoate)  [119-36-8]  M 152.2, m -8.6°, b 79°/6mm, 104-105°/14mm, 223.3°/atm, h 1.1149, n 1.5380, pK_a 10.19. Dilute with Et_2O, wash with satd NaHCO_3 (it may effervesce due to the presence of free acid), brine, dry MgSO_4, filter, evaporate and distil.
Its solubility is 1g/1.5L of H₂O. The benzoyl derivative has m 92° (b 270-280°/120mm), and the 3,5-dinitrobenzoate has m 107.5°, and the 3,5-dinitrocarbamoyl derivative has m 180-181°. [Hallas J Chem Soc 5770 1965.]

Methyl stearate [122-61-8] M 298.5, m 41-43°, b 181-182°/4mm. Crystd from pet ether or distd.

α-Methylstyrrene (monomer) [98-83-9] M 118.2, b 57°/15mm, d 0.910, n 1.5368. Washed three times with aqueous 10% NaOH (to remove inhibitors such as quinol), then six times with distd water, dried with CaCl₂ and distd under vacuum. The distillate is kept under nitrogen, in the cold, and redistd if kept for more than 48h before use. It can also be dried with CaH₂.


4-Methylstyrrene [622-97-9] M 118.2, b 60°/12mm, 106°/10mm, d₄ 0.9173, nD 1.542. Purified as the above styrenes and add a small amount of antioxidant if it is to be stored, UV in EtOH h-max 285nm (log E 3.07), and in EtOH + HCl 295nm (log E 2.84) and 252nm (log E 4.23). [Schwartzman and Carson J Am Chem Soc 78 322 1956; Joy and Orchin J Am Chem Soc 81 305 1959; Buck et al. J Chem Soc 23771949.]


(*)-3-Methylsulfolane (3-methyl-tetrahydrothiophene-1,1-dioxide) [872-93-5] M 134.2, m 0.5°, b 101°/2mm, 125-130°/12mm, 278-282°/763.5mm, d₄ 1.1885, nD 1.4770. Distil under vacuum and recryst from Et₂O at -60° to -70°. IR film has strong bands at 570 and 500 cm⁻¹. [Eigenberger J Prakt Chem [2] 131 289 1931; Freaheller and Katon Spectrochim Acta 20 1099 1964.]

Methyltetradecanoate (methyl myristate) [124-10-7] M 382.7, m 18.5°, b 155-157°/7mm. Passed through alumina before use.

2-Methyltetrahydrofuran [96-47-9] M 86.1, b 80.0°, d₄ 0.856, nD 1.4053. Likely impurities are 2-methylfuran, methylidihydrofurans and hydroquinone (stabiliser, which is removed by distn under reduced pressures). It was washed with 10% aqueous NaOH, dried, vacuum distd from CaH₂, passed through freshly activated alumina under nitrogen, and refluxed over sodium metal under vacuum. Stored over sodium. [Ling and Kevan J Phys Chem 80 592 1976.] Vacuum distd from sodium, and stored with sodium-potassium alloy. (Treatment removes water and prevents the formation of peroxides.) Alternatively, it can be freed from peroxides by treatment with ferrous sulfate and sodium bisulfate, then solid KOH, followed by drying with, and distilling from, sodium, or type 4A molecular sieves under argon. It may be difficult to remove benzene if it is present as an impurity (can be readily detected by its ultraviolet absorption in the 249-268nm region). [Ichikawa and Yoshida J Phys Chem 88 3199 1984.] It has also been purified by percolating through Al₂O₃ and fractionated collecting fraction b 79.5-80°. After degassing, the material was distd onto degassed molecular sieves, then distd onto anthracene and a sodium mirror. The solvent was distd from the green soln onto potassium mirror or sodium-potassium alloy, from which it was distilled again. [Mohammad and Kosower J Am Chem Soc 93 2713 1971.] It should be stored in the presence of 0.1% of hydroquinone as stabiliser. HARMFUL VAPOURS.

N-Methylthioacetamide [5310-10-1] M 89.1, m 59°. Recrystd from benzene.

3-Methylthiophene [616-44-4] M 98.2, b 111-113°, d 1.024, n 1.531. Dried with Na₂SO₄, then distd from sodium.
6(4)-Methyl-2-thiouracil  [56-04-2]  M 142.2, m 330°(dec), 299-303° (dec), 323-324° (dec), pKa 8.1. Crystd from a large volume of H₂O. Purified by dissolving in base adding charcoal, filtering and acidifying with AcOH. Suspend the wet solid (ca 100g) in boiling H₂O (1L), stir and add AcOH (20mL), stir and refrigerate. Collect the product, wash with cold H₂O (4 x 200mL), drain for several hours then place in an oven at 70° to constant weight. [IR: Short and Thompson J Chem Soc 168 1952; Foster and Snyder Org Synth Coll Vol IV 638 1063.]

Methyl 4-toluenesulfonate  [80-48-8]  M 186.2, m 25-28°, 28°, b 146.6-145.2°/5mm, 168-170°/13mm, d⁴ 1.23. It is purified by distn in vacuo and could be crystd from pet ether or Et₂O-pet ether at low temperature. It is a powerful methylating agent and is TOXIC and a skin irritant, so it is better to purify by repeated distn. [IR: Schreiber Anal Chem 21 1168 1949; Buehler et al. J Org Chem 2 167 1937; Roos et al. Org Synth Coll Vol I 145 1948.]

4-Methyl-1,2,4-triazoline-3,5-dione (MTAD)  [13274-43-6]  M 113.1, m 103-104°, m 107-109°. Obtained as pink needles by sublimation at 40-50°/0.1mm (see 4-phenyl-1,2,4-triazoline-3,5-dione, PTAD below). [Cookson et al. Org Synth 51 121 1971; Cheng et al. J Org Chem 49 2910 1984.]

2-Methyltricycloquinazoline  [2642-52-6]  M 334.4, m >300°. Purified by vac sublimation. CARCINOGEN.

Methyl trifluoromethanesulfonate (methyl triflate)  [333-27-7]  M 164.1, b 97-97.5°/736mm, 99°/atm, 100-102°/atm, d⁴ 1.496, n⁰ 1.3238. It is a strong methylating agent but is corrosive and POISONOUS. Fractionate carefully and collecting the middle fraction (use efficient fume cupboard) and keep away from moisture. It is POWERFUL ALKYLATING AGENT and a strong IRRITANT. [IR: Gramstad and Haszeldine J Chem Soc 173 1956, 4069 1957. Trifluoromethanesulfonic acid (triflic acid)  [1493-13-6]  M 151.1, boils higher (b 162°/atm), has a pKa of 3.10, and is TOXIC and hygroscopic. [Hansen J Org Chem 30 4322 1965; Kurz and El-Nasr J Am Chem Soc 104 5823 1982.]

N-Methyltryptophan (L-abrine)  [526-31-8]  M 218.3, m 295°(dec), [α]D 21 +44.4° (c 2.8, 0.5M HCl), pKₑₒₓ(1) 2.3, pKₑₒₓ(2) 9.7. Crystd from water.

dl-5-Methyltryptophan  [951-55-3]  M 218.3, m 275°(dec) [pK see tryptophan]. Crystd from aqueous EtOH. Picrate has m 202° (dec).


7-Methyluric acid  [30409-21-3]  M 182.1, m >380°, pK₁ 5.6, pK₂ 10.3. Crystd from water.


Methyl vinyl ketone  [78-94-4]  M 70.1, b 62-68°/400mm, 79-80°/760mm, d 0.845, n 1.413. Forms an 85% azetotrope with water. After drying with K₂CO₃ and CaCl₂ (with cooling), the ketone is distd at low pressures.

Methyl vinyl sulfone  [3680-02-2]  M 106.1, b 116-118°/20mm, d 1.215, n 1.461. Passed through a column of alumina, then degassed and distd on a vacuum line and stored at -190° until required.

Methyl Violet 2B [4,4'-bis-(diethylamino)-4'-methyliminotriphenylmethyl hydrochloride)  [8004-87-3]  M 394.0, m 137°(dec), CI 42535, max ~580nm. Crystd from absolute EtOH by pptn with diethyl ether during cooling in an ice-bath. Filtered off and dried at 105°.
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3-Methylxanthine [1076-22-8] M 166.1, m >360° pK_1^{20} 8.45, pK_2^{20} 11.92. Crystd from water.


9-Methylxanthine [11198-33-0] M 166.1, m 384°(dec), pK_1^{20} 2.0, pK_2^{20} 6.12, pK_3^{20} 10.5 (>13). Crystd from water.

Metrazol (Cardiazol, Leptazol, 3a,4,5,6,7,8-hexahydro-1,2,3,3a-tetraaza-azulene, 1,5-pentamethylene-1,2,3,4-tetrazole) [54-95-5] M 138.2, m 61°, b 194°/12mm, pK_{Est} <0. Crystd from diethyl ether. Dried under vacuum over P_2O_5.

Michler's ketone [4,4'-bis(dimethylamino)benzophenone] [90-94-8] M 268.4, m 179°, pK_1^{25} 9.84. Dissolved in dilute HCl, filtered and ppted by adding ammonia (to remove water-insoluble impurities such as benzophenone). Then crystd from EtOH or pet ether. [Suppan J Chem Soc, Faraday Trans 71 539 1975.] It was also purified by dissolving in benzene, then washed with water until the aqueous phase was colourless. The benzene was evaporated off and the residue recrystd three times from benzene and EtOH [Hoshino and Kogure J Phys Chem 72 417 1988].

Monensin [17090-79-8] M 670.9, m 103-105° (1 H_2O), [a]_D +47.7°, pK_{Est} ~ 4.6, pK 6.6 (66% Me_2NCHO). Purified by chromatography, stable in aq alkaline soln. Slightly sol in H_2O but sol in EtOH, EtOAc and Et_2O.


N-Monoethyl urea [625-52-5] M 88.1, m 92-95°. Crystd from EtOH/water, then dried under vacuum at room temperature.

N-Monomethyl urea [598-50-5] M 74.1, m 93-95°. Crystd from EtOH/water, then dried under vacuum at room temperature.

Monopropyl urea [627-06-5] M 102.1, m 110°. Crystd from EtOH.

Morin (hydrate) (2',3,4',5,7-pentahydroxyflavone) [480-16-0] M 302.2, m 289-292°, pK_1 5.3, pK_2 8.74. Stirred at room temperature with ten times its weight of absolute EtOH, then left overnight to settle. Filtered, and evaporated under a heat lamp to one-tenth its volume. An equal volume of water was added, and the ppted morin was filtered off, dissolved in the minimum amount of EtOH and again ppted with an equal volume of water. The ppted was filtered, washed with water and dried at 110° for 1h. (Yield ca 2.5%.) [Perkins and Kalkwarf Anal Chem 28 1989 1956.] Complexes with W and Zr.

Morphine (H_2O) [57-27-2] M 302.2, m 230°(dec), [α]_D^{23} -130.9° (MeOH), pK_1 8.31, pK_2 9.51. Crystd from MeOH.

Morpholine [110-91-8] M 87.1, f -4.9°, b 128.9°, d 1.0007, n 1.4540, n_25 1.4533, pK_1^{25} 8.33. Dried with KOH, fractionally distd, then refluxed with Na, and again fractionally distd. Dermer and Dermer [J Am Chem Soc 59 1148 1937] ppted as the oxalate by adding slowly to slightly more than 1 molar equivalent of oxalic acid in EtOH. The ppted was filtered and recrystd twice from 60% EtOH. Addition of the oxalate to conc aq NaOH regenerated the base, which was separated and dried with solid KOH, then sodium, before being fractionally distd. § A polystyrene supported morpholine is commercially available.
2-(N-Morpholino)ethanesulfonic acid (MES) [4432-31-9] M 213.3, m >300°(dec), pK_2^+ 6.15. Crystd from hot EtOH containing a little water.

Muchochloric acid (2,3-dichloro-4-oxo-2-butenoic acid) [87-56-9] M 169.0, m 124-126°, pK_2^+ 4.20. Cryst twice from water (charcoal).

*trans,trans*-Muconic acid (hexa-2,4-dienedioic acid) [3588-17-8] M 142.1, m 300°, pK_2 4.51, for cis,cis pK_2^+ 4.49. Cryst from H_2O.


Murexide (ammonium purpurate) [3051-09-0] M 284.2, m >300°, λ_max 520nm (ε 12,000), pK_2 9.2, pK_3 10.9. The sample may be grossly contaminated with uramil, alloxanthine, etc. Difficult to purify. It is better to synthesise it from pure alloxanthine [Davidson J Am Chem Soc 58 1821 1936]. Crystd from water.

Myristic acid (tetradecanoic acid) [544-63-8] M 228.4, m 58°, pK_2^+ 6.3 (50% EtOH), pK_2 4.9 (H_2O). Purified via the methyl ester (b 153-154°/10mm, n_25 1.4350), as for capric acid. [Trachtman and Miller J Am Chem Soc 84 4828 1962]. Also purified by zone melting. Crystd from pet ether and dried in a vacuum desiccator containing shredded wax.

Naphthacene (benz[b]anthracene, 2,3-benzanthracene, rubene) [92-24-0] M 228.3, m >300°, 341°(open capillary), 349°, 357°. Cryst from EtOH or *benzene. Dissolved in sodium-dried *benzene and passed through a column of alumina. The *benzene was evaporated under vacuum, and the chromatography was repeated using fresh *benzene. Finally, the naphthacene was sublimed under vacuum. [Martin and Ubbelhode J Chem Soc 4948 1961]. Also recrysts in orange needles from xylene and sublimes in vacuo at 186°. [UV: Chem Ber 65 517 1932, 69 607 1936; IR: Spectrochim Acta 4 373 1951.]

2-Naphthaldehyde [66-99-9] M 156.2, m 59°, b 260°/19mm, pK_2^+ 7.04 (aq H_2SO_4). Distilled with steam and cryst from water or EtOH.

Naphthalene [91-20-3] M 128.2, m 80.3°, b 87.5°/10mm, 218.0°/atm, d 1.0253, d_10^0 0.9625, n_55 1.5590. Crystd one or more times from the following solvents: EtOH, MeOH, CCl_4, *benzene, glacial acetic acid, acetone or diethyl ether, followed by drying at 60° in an Abderhalden drying apparatus. Also purified by vacuum sublimation and by fractional cryst from its melt. Other purification procedures include refluxing in EtOH over Raney Ni, and chromatography of a CCl_4 soln on alumina with *benzene as eluting solvent. Baly and Tuck [J Chem Soc 1902 1908] purified naphthalene for spectroscopy by heating with conc H_2SO_4 and MnO_2, followed by steam distn (repeating the process), and formation of the picrate which, after recrystallisation, was decomposed and the naphthalene was steam distd. It was then cryst from dilute EtOH. It can be dried over P_2O_5 under vacuum. Also purified by sublimation and subsequent cryst from cyclohexane. Alternatively, it has been washed at 85° with 10% NaOH to remove phenols, with 50% NaOH to remove nitriles, with 10% H_2SO_4 to remove organic bases, and with 0.8g AlCl_3 to remove thianaphthalenes and various alkyl derivatives. Then it was treated with 20% H_2SO_4, 15% Na_2CO_3 and finally distd. [Gorman et al. J Am Chem Soc 107 4404 1985.]

Zone refining purified naphthalene from anthracene, 2,4-dinitrophenylhydrazine, methyl violet, benzoic acid, methyl red, chrysene, pentacene and indole.

Naphthalene-2,5-disulfonic acid [92-41-1] M 288.2, pK_2^+ <0. Crystd from conc HCl.

Naphthalene-1-sulfonic acid [85-47-2] M 208.2, m (2H_2O) 90°, (anhydrous) 139-140°, pK_2^+ -0.17. Crystd from conc HCl and twice from water.

Naphthalene-1-sulfonic acid chloride [85-46-1] M 226.7, m 64-67°, 68°, b 147.5°/0.9 mm, 147.5°/13 mm. If the IR indicates the presence of OH then treat with an equal weight of PCl<sub>5</sub> and heat at ca 100°F for 3 h, cool and pour into H<sub>2</sub>O, stir well and filter off the solid. Wash the solid with cold H<sub>2</sub>O and dry the solid in a vacuum desiccator over P<sub>2</sub>O<sub>5</sub> + solid KOH. Extract the solid with pet ether (b 40-60°), filter off any insoluble solid and cool. Collect the crystalline sulfonyl chloride and recryst from pet ether or C<sub>6</sub>H<sub>6</sub> + pet ether. If large quantities are available then it can be distd under high vacuum. [Fierz-David and Weissenbach Helv Chim Acta 3 2312 1920.] The sulfonamide has m 150° (from EtOH or H<sub>2</sub>O).

Naphthalene-2-sulfonyl chloride [93-11-8] M 226.7, m 74-76°, 78°, 79°, b 147°/0.6 mm, 201°/13 mm. Crystd (twice) from benzene/pet ether (1:1 v:v). Purified as the 2-sulfonyl chloride. [Fierz-David and Weissenbach Helv Chim Acta 3 2312 1920.] The sulfonamide has m 217° (from EtOH).

1,8-Naphthalic acid (naphthalene-1,8-dicarboxylic acid) [518-05-8] M 216.9, m 270°, pK<sub>Em</sub>(1) = 2.1, pK<sub>Em</sub>(2) = 4.5. Crystd from EtOH or aq EtOH.

1,8-Naphthalic anhydride remove free acid, then crystd from acetic anhydride. [81-84-5] M 198.2, m 274°. Extracted with cold aqueous Na<sub>2</sub>CO<sub>3</sub> to remove free acid, then crystd from acetic anhydride.

Naphthamide [2243-82-5] M 171.2, m 195°, pK<sup>2</sup> = 2.30 (H<sub>2</sub>O scale, aq H<sub>2</sub>SO<sub>4</sub>). Crystd from EtOH.

Naphthazarin (5,8-dihydroxy-1,4-naphthoquinone) [475-38-7] M 190.2, m ~ 220-230° (dec), m 225-230°, pK<sub>Em</sub>(1) = 9.5, pK<sub>Em</sub>(2) = 11.1. Red-brown needles with a green shine from EtOH. Also recrystd from hexane and purified by vacuum sublimation. [Huppert et al. J Phys Chem 89 5811 1985.] It is sparingly soluble in H<sub>2</sub>O but soluble in alkalis. It sublimes at 2-10 mm. The diacetate forms golden yellow prisms from CHCl<sub>3</sub>, m 192-193° and the 5,8-dimethoxy derivative has m 157° (155°) (from pet ether) [Bruce and Thompson J Chem Soc 1089 1955; IR: Schmand and Boldt J Am Chem Soc 97 447 1975; NMR: Brockmann and Zeeck Chem Ber 101 4221 1968]. The monothiosemicarbazone has m 168° (dec) from EtOH [Gardner et al. J Am Chem Soc 74 2106 1952].

Naphthionic acid (4-aminonaphthalene-1-sulfonic acid) [84-86-6] M 223.3, m > 300° (dec), pK<sup>2</sup> = 2.68. It crystallises from H<sub>2</sub>O as needles of the 0.5 hydrate. Salt solns fluoresce strongly blue.

1-Naphthoic acid [86-55-5] M 172.2, m 162.5-163.0°, pK<sup>2</sup> = 3.60. Crystd from toluene (3 mL/g) (charcoal), pet ether (b 80-100°), or aqueous 50% EtOH.

2-Naphthoic acid [93-09-4] M 172.2, m 184-185°, pK<sup>2</sup> = 4.14. Crystd from EtOH (4 mL/g), or aqueous 50% EtOH. Dried at 100°.

1-Naphthol [90-15-3] M 144.2, m 95.5-96°, pK<sup>2</sup> = 9.34. Sublimed, then crystd from aqueous MeOH (charcoal), aq 25% or 50% EtOH, *benzene, cyclohexane, heptane, CCl<sub>4</sub> or boiling water. Dried over P<sub>2</sub>O<sub>5</sub> under vacuum. [Shizuka et al. J Am Chem Soc 107 7816 1985.]

2-Naphthol [135-19-3] M 144.2, m 122.5-123.5°, pK<sup>2</sup> = 9.57. Crystd from aqueous 25% EtOH (charcoal), water, *benzene, toluene or CCl<sub>4</sub>, e.g. by repeated extraction with small amounts of EtOH, followed by dissolution in a minimum amount of EtOH and ptt with distilled water, then drying over P<sub>2</sub>O<sub>5</sub> under vacuum. Has also been dissolved in aqueous NaOH, and ppted by adding acid (repeated several times), then ppted from *benzene by addition of heptane. Final purification can be by zone melting or sublimation in vacuo. [Bardez et al. J Phys Chem 89 5031 1985; Kikuchi et al. J Phys Chem 91 574 1987.]

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chloroacetyl chloride *naphthol* AS-D-chloroacetate is obtained [Moloney et al. *J Histochem Cytochem* 8 200 1960; Burstone *Arch Pathology* 63 164 1957].

α-Naphtholbenzein [bis-(α-(4-hydroxynaphth-1-yl))-benzyl alcohol] [6948-88-5]  M 392.5,  m 122-125°, pK_{Est} ~ 9.3. Crystd from EtOH, aqueous EtOH or glacial acetic acid.


2-Naphthol-3-carboxylic acid (2-hydroxy-3-naphthoic acid) [92-70-6]  M 188.2,  m 222-223°, pK_{1} ^{25} 2.79, pK_{2} ^{25} 12.84. Crystd from water or acetic acid.

1,2-Naphthoquinone  [524-42-5]  M 158.2,  m 140-142°(dec). Crystd from ether (red needles) or *benzene (orange leaflets).


β-Naphthoyltrifluoroacetone (4,4,4-trifluoro-2-naphthylbutan-1,3-dione) [893-33-4]  M 266.2,  m 70-71°, 74-76°, pK_{20} 6.35. Crystd from EtOH. The *mono oxime* crystd from H_{2}O or aq EtOH has m 137-138°. [Reid and Calvin *J Am Chem Soc* 72 2948 1950]

Naphthvalene [34305-47-0]  M 104.1,  m dec at 175° to benzvalene. Purified by chromatography on alumina and eluting with pentane. It is stable at room temp [Abelt et al. *J Am Chem Soc* 107 4148 1985]. The 1H NMR in CCl_{4} has τ 3.18 (4H), 6.17 (t J 1.5Hz, 2H), 7.60 (t J 1.5Hz 2H).

1-Naphthyl acetate [830-81-9]  M 186.2,  m 45-46°. Chromatographed on silica gel and crystd as the 2-isomer below.

2-Naphthyl acetate [1523-11-1]  M 186.2,  m 71°. Crystd from pet ether (b 60-80°) or dilute aq EtOH.

1-Naphthylacetic acid [86-87-3]  M 186.2,  m 132°, pK_{25} 4.23. Crystd from EtOH or water.


1-Naphthylamine [134-32-7]  M 143.2,  m 50.8-51.2°, b 160°, pK_{25} 3.94. Sublimed at 120° in a stream of nitrogen, then crystd from pet ether (b 60-80°), or abs EtOH then diethyl ether. Dried under vacuum in an Abderhalden pistol. Has also been purified by crystn of its hydrochloride from water, followed by liberation of the free base and distn; finally purified by zone melting. CARCINOGEN.


1-Naphthylamine-5-sulfonic acid [84-89-9]  M 223.3,  m >200°(dec), pK_{Est(1)} < 1, pK_{2} ^{25} 3.69 (NH_{2}) Crystd under nitrogen from boiling water and dried in a steam oven [Bryson *Trans Faraday Soc* 47 522, 527 1951].
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2-Naphthylamine-1-sulfonic acid [81-16-3] M 223.3, m >200°(dec), pK<sub>1</sub><sup>2</sup> < 1, pK<sub>2</sub><sup>2</sup> 2.35 (NH<sub>2</sub>). Crystd under nitrogen from boiling water and dried in a steam oven [Bryson Trans Faraday Soc 47 522, 527 1951].

2-Naphthylamine-6-sulfonic acid [93-00-5] M 223.3, m >200°(dec). Crystd from a large volume of hot water.


1-(1-Naphthyl)ethylamine [R-(+)- 3886-70-2; S-(-)- 10420-89-0] M 171.2, b 153°/11mm, 178-181°/20mm, d<sub>2</sub><sup>19</sup> 1.067, n<sub>D</sub> <sup>19</sup> 1.624, [α]<sub>B</sub> <sup>20</sup> (+) and (-) 65°, [α]<sub>D</sub> <sup>20</sup> (+) and (-) 55° (c 2, MeOH); [α]<sub>D</sub> <sup>17</sup> (+) and (-) 82.8° (neat), pK<sub>Em</sub> ~9.3. Purified by distn in a good vacuum. [Mori et al. Tetrahedron 37 1343 1981; cf Wilson in Top Stereochem (Allinger and Eliel eds) vol 6 135 1971; Fredga et al. Acta Chem Scand 11 1609 1957]. The hydrochlorides crystallises from H<sub>2</sub>O [α]<sub>B</sub> <sup>18</sup> ±3.9° (c 3, H<sub>2</sub>O) and the sulfates recrystallises from H<sub>2</sub>O as tetrahydrates m 230-232°. The RS-amine has b 153°/11mm, 156°/15mm, 183.5°/41mm [Blickie and Maxwell J Am Chem Soc 61 1780 1939].

2-Naphthylethylene (2-vinynaphthalene) [827-54-3] M 154.2, m 66°, b 95-96°/2.1mm, 135-137°/18mm. Crystd from aqueous EtOH.

N-(α-Naphthyl)ethylenediamine dihydrochloride [1465-25-4] M 291.2, m 188-190°, pK<sub>Em</sub>(1) ~3.8, pK<sub>Em</sub>(2) ~9.4. Crystd from water.

1-Naphthyl isocyanate [86-84-0] M 169.2, m 3-5°, b 269-270°/atm, d<sub>4</sub><sup>19</sup> 1.18. Distd at atmospheric pressure or in a vacuum. Can be crystd from pet ether (b 60-70°) at low temperature. It has a pungent odour, is TOXIC and is absorbed through the skin.

1-Naphthyl thiocyanate [551-06-4] M 185.3, m 58-59°. Crystd from hexane (1g in 9 mL). White needles soluble in most organic solvents but is insoluble in H<sub>2</sub>O. It is absorbed through the skin and may cause dermatitis. [Org Synth Coll Vol IV 700 1963].

2-Naphthyl lactate [93-43-6] M 216.2. Crystd from EtOH.

2-(2-Naphthoxy)ethanol [93-20-9] M 188.2, m 76.7°. Crystd from *benzene/pet ether.

2-Naphthyl salicylate [613-78-5] M 264.3, m 95°, pK<sub>Em</sub> ~10.0. Crystd from EtOH.

1-Naphthyl thiourea (ANTU) [86-88-4] M 202.2, m 198°. Crystd from EtOH.

1-Naphthyl urea [6950-84-1] M 186.2, m 215-220°. Crystd from EtOH.


1,5-Naphthyridine [254-79-5] M 130.1, m 75°, b 112°/15mm, pK<sub>2</sub> 2.84. Purified by repeated sublimation.
Narcein \(6\text{-}[6\text{-}(2\text{-dimethylaminoethy}1)\text{-}2\text{-methoxy}3,4\text{-}(methylenedioxy)phenylacetyl]\text{-}2,3\text{-dimethoxybenzoic acid}\) \[31-28-2\] \(M 445.4, m 176\text{-}177° (145° anhydrous), pK_{1}^{\text{H}} 3.5, pK_{2}^{\text{H}} 9.3\). Crystd from water (as trihydrate).

Naringenin \((4',5,7\text{-trihydroxyflavanone})\) \[480-41-1\] \(M 272.3, m 251° (phenolic pKs-8\text{-}11)\). Crystd from aqueous EtOH.

Naringin \((\text{naringenin 7-rhamnoglucoside})\) \[10236-47-2\] \(M 580.5, m 171° (2H_{2}O), [\alpha]_{D}^{25} -90°\) (c 1, EtOH), [\alpha]_{D}^{546} -107° (c 1, EtOH). Crystd from water. Dried at 110°(to give the dihydrate).

Neopentane \((2,2\text{-dimethylpropane})\) \[463-82-1\] \(M 72.2, b 79.3°, d 0.6737, n 1.38273\). Purified from isobutene by passage over conc H_{2}SO_{4} or P_{2}O_{5}, and through silica gel.

Neostigmine \([(3\text{-dimethylcarbamoylphenyl})\text{-trimethylammonium}]\text{-bromide}\) \[114-80-7\] \(M 303.2, m 176°(dec). Crystd from EtOH\text{-}diethyl ether. (Highly TOXIC).

Neostigmine methyl sulfate \[51-60-5\] \(M 334.4, m 142\text{-}145°. Crystd from EtOH. (Highly TOXIC.)

Nerolidol \((3,7,11\text{-trimethyl-1,6,10\text{-dodecatrien-3-ol})}\) \[7212-44-4\] \(M 222.4, b 122°/3mm, n 1.477, d 0.73, [\alpha]_{D}^{70} 379°/0.1mm, [\alpha]_{D}^{40716} 78°/0.2mm, 145-146°/2mm. Purified by TLC on plates of Kieselguhr G [McSweeney J Chromatogr 17 183 196.5] or silica gel impregnated with AgNO_{3}, using 1,2-CH_{2}C_{12}/CHCl_{3}/EtOAc/PrOH (10:10:1) as solvent system. Also by GLC on butanediol succinate (20%) on Chromosorb W. Stored under N_{2} at -5° in the dark.

Neutral Red \((2\text{-amino-8\text{-dimethylamino-3-methylphenazine HCl, Basic Red 5, CI 50040)}\) \[553-24-2\] \(M 288.8, m 290°(dec), pK_{2}^{\text{H}} 6.5\). Crystd from *benzene\text{-}MeOH (1:1). In aq sol it is red at pH 6.8 and yellow at pH 8.0.

Nicotinaldehyde thiosemicarbazone \[3608-75-1\] \(M 180.2, m 222\text{-}223°. Crystd from water.

Nicotinamide \[98-92-0\] \(M 122.1, m 128\text{-}131°, pK_{1}^{\text{H}} 2.0, pK_{2}^{\text{H}} 3.33\). Crystd from *benzene.

Nicotinic acid \((\text{niacin, 2-ypidine-3-carboxylic acid})\) \[59-67-6\] \(M 123.1, m 232\text{-}234°, pK_{1}^{\text{H}} 2.0, pK_{2}^{\text{H}} 4.82\). Crystd from *benzene.

Nicotinic acid hydrazide \[553-53-7\] \(M 137.1, m 158\text{-}159°, pK_{1}^{\text{H}} 3.3, pK_{2}^{\text{H}} 11.49\text{(NH)}. Crystd from aqueous EtOH or *benzene.

Nile Blue A \((\text{a benzophenoxazinium sulfate dye})\) \[3625-57-8\] \(M 415.5, m >300°(dec), CI 51180, pK_{20}^{\text{H}} 2.4\). Crystd from pet ether.

Ninhydrin \((1,2,3\text{-triketohydrindene hydrate})\) \[485-47-2\] \(M 178.1, m 241\text{-}243°(dec), pK_{3}^{\text{H}} 8.82\). Crystd from hot water (charcoal). Dried under vacuum and stored in a sealed brown container.

Nitrilotriacetic acid \([\text{tris(carboxymethyl)amine, NTA, Complexone 1)}\) \[139-13-9\] \(M 191.1, m 247°(dec), pK_{1}^{\text{H}} 0.8, pK_{2}^{\text{H}} 1.71, pK_{3}^{\text{H}} 2.47, pK_{4} 9.71\). Crystd from water. Dried at 110°.

2-Nitroacetanilide \[552-32-9\] \(M 180.2, m 93\text{-}94°, pK_{\text{Et}}^{\text{H}} <0\). Crystd from water.

4-Nitroacetanilide \[104-04-1\] \(M 180.2, m 217°, pK_{\text{Et}}^{\text{H}} <0\). Ppted from 80% H_{2}SO_{4} by adding ice, then washed with water, and crystd from EtOH. Dried in air.

3-Nitroacetophenone \[121-89-1\] \(M 165.2, m 81°, b 167°/18mm, 202°/760mm\). Distilled in steam and crystd from EtOH.
4-Nitroacetophenone [100-19-6] M 165.2, m 80-81°, b 145-152°/760mm. Crystd from EtOH or aqueous EtOH.

3-Nitroalizarin (1,2-dihydroxy-3-nitro-9,10-anthraquinone, Alizarin Orange) [568-93-4] M 285.2, m 244° (dec), pH_{EtOH}^2 4.6, pH_{EtOH}^2 9.6. Crystd from acetic acid.

o-Nitroaniline [88-74-4] M 138.1, m 72.5-73.0°, pH^1 4.6, pH^2 9.6. Crystd from hot water (charcoal), then crystd from water, aqueous 50% EtOH, or EtOH, and dried in a vacuum desiccator. Has also been chromatographed on alumina, then recrystd from *benzene.

m-Nitroaniline [99-09-2] M 138.1, m 114°, pH^2 2.46. Purified as for o-nitroaniline. Warning: it is absorbed through the skin.


p-Nitroanisole (4-methoxynitrobenzene) [100-17-4] M 153.1, m 54°. Crystd from pet ether or hexane and dried in vacuo.

9-Nitroanthracene [602-60-8] M 223.2, m 142-143°. Purified by recrystn from EtOH or MeOH. Further purified by sublimation or TLC.


o-Nitrobenzaldehyde [552-89-6] M 151.1, m 44-45°, b 120-144°/3.6mm. Crystd from toluene (2-2.5mL/g) by addition of 7mL pet ether (b 40-60°) for 1mL of soln. Can also be distd at reduced pressures.

m-Nitrobenzaldehyde [99-61-6] M 151.1, m 58°. Crystd from water or EtOH/water, then sublimed twice at 2mm pressure at a temperature slightly above its melting point.


Nitrobenzene [98-95-3] M 123.1, f 5.8°, b 84-86.5°/6.5-8mm, 210.8°/760mm, d 1.206, n^1 1.555457, n^2 1.55257, pH^1 -11.26 (aq H_2SO_4). Common impurities include nitrotoluene, dinitrothiophene, dinitrobenzene and aniline. Most impurities can be removed by steam distn in the presence of dilute H_2SO_4, followed by drying with CaCl_2, and shaking with, then distilling at low pressure from BaO, P_2O_5, AlCl_3 or activated alumina. It can also be purified by fractional crystn from absolute EtOH (by refrigeration). Another purification process includes extraction with aqueous 2M NaOH, then water, dilute HCl, and water, followed by drying (CaCl_2, MgSO_4 or CaSO_4) and fractional distn under reduced pressure. The pure material is stored in a brown bottle, in contact with silica gel or CaH_2. It is very hygroscopic.


2-Nitrobenzenesulfonyl chloride (NPS-Cl) [7669-54-7] M 189.6, m 73-74.5°, 74.5-75°, 74-76°. Recrystd from CCl_4 (2mL/g), filter off the soln at 50° (recovery 75%). Also recrystd from pet ether (b 40-60°), dried rapidly at 50° and stored in a brown glass bottle, sealed well and stored away from moisture. [Hubacher Org Synth Coll Vol II 455 1943; Ito et al. Chem Pharm Bull (Jpn) 26 296 1978.]

4-Nitrobenzhydrazide [606-26-8] M 181.1, m 213-214°. Crystd from EtOH.

4'-Nitrobenzo-18-crown-6 [53408-96-1] M 357.4, m 83-84°, 83-84°. If impure and discoloured then chromatograph on Al₂O₃ and eluting with *C₆H₆ (1: 1) with 1% MeOH added. The fractions are followed by TLC on Al₂O₃ (using detection with Dragendorff's reagent RF 0.6 in the above solvent system). Recrystallise the residues from the fractions containing the product from *C₆H₆-hexane to give yellowish leaflets. It complexes with Na or K ions with logK_Na 3.95 and logK_K 4.71. [Petranek and Ryba Collect Chem Czech Chem Commun 39 2033 1974].


3-Nitrobenzoic acid [121-92-6] M 167.1, m 143-143.5°, pK₂ 3.46. Crystd from *benzene, water, EtOH (charcoal), glacial acetic acid or MeOH/water. Dried and stored in a vacuum desiccator.


4-Nitrobenzoyl chloride [122-04-3] M 185.6, m 75°, b 155°/20mm. Crystd from dry pet ether (b 60-80°) or CCl₄. Distilled under vacuum. Irritant.

4-Nitrobenzyl alcohol [619-73-8] M 153.1, m 93°. Crystd from EtOH and sublimed in a vacuum. Purity should be at least 99.5%. Sublimed samples should be stored in the dark over anhydrous CaSO₄ (Drierite). It the IR contains OH bands then the sample should be resublimed before use. [Mohammed and Kosower J Am Chem Soc 93 2709 1979].

4-Nitrobenzyl bromide [100-11-8] M 216.0, m 98.5-99.0°. Recrystd four times from abs EtOH, then twice from cyclohexane/hexane/*benzene (1:1:1), followed by vac sublimation at 0.1mm and a final recrystn from the same solvent mixture. [Lichtin and Rao J Am Chem Soc 83 2417 1961.] Has also been crystd from pet ether (b 80-100°, 10mL/g, charcoal). It slowly decomposes even when stored in a desiccator in the dark. IRRENTANT.

m-Nitrobenzyl chloride [619-23-8] M 171.6, m 45°. Crystd from pet ether (b 90-120°). IRRENTANT.

p-Nitrobenzyl chloride [100-14-1] M 171.6, m 72.5-73°. Crystd from CCl₄, dry diethyl ether, 95% EtOH or n-heptane, and dried under vacuum. IRRENTANT.


4-(4-Nitrobenzyl)pyridine (PNBP) [1083-48-3] M 214.2, m 70-71°, pK_{EtOH} ~5.0. Crystd from cyclohexane.

2-Nitrobiphenyl [86-00-0] M 199.2, m 36.7°. Crystd from EtOH (seeding required). Sublimed under vacuum.

3-Nitrocinnamic acid [555-68-0] M 193.2, m 200-201°, pK₂ 2.58 (trans). Crystd from *benzene or EtOH.

4-Nitrodiphenylamine  [836-30-6]  M 214.2, m 133-134°, pK<sup>25</sup> -2.5. Crystd from EtOH.

2-Nitrodiphenyl ether  [2216-12-8]  M 215.2, b 161-162°/4mm, 188-189°/12mm, 195-200°/25mm, d<sub>4</sub><sup>20</sup> 1.241, n<sub>D</sub><sup>20</sup> 1.600. Purified by fractional distn.

UV (EtOH): 255, 315nm (E<sub>6200</sub> and 2800); IR (CS<sub>2</sub>): 1350 (NO<sub>2</sub>) and 1245, 1265 (COC) cm<sup>-1</sup> [W, IR: Dahlgard and Brewster J Am Chem Soc 80 5861 1958; Tomita and Takase Yakugaku Zusshi (J Pharm Soc Japan) 75 1077 1955; Fox and Turner J Chem Soc 1115 1930, Henley J Chem Soc 1222 1930].

Nitrodurene (1-nitro-2,3,5,6-tetramethylbenzene)  [3463-36-3]  M 179.2, m 53-55°, b 143-144°/10mm. Crystd from EtOH, MeOH, acetic acid, pet ether or chloroform.

Nitroethane  [79-24-3]  M 75.1, b 115°, d 1.049, n 1.3920, n<sub>25</sub> 1.39015, pK<sup>2</sup> 8.60 (8.46, pH equilibrium requires ca 5 min). Purified as described for nitromethane. A spectroscopic impurity has been removed by shaking with activated alumina, decanting and rapidly distilling.


Nitroguanidine  [556-88-7]  M 104.1, m 246-246.5° (dec), 257°, pK<sup>1</sup><sup>25</sup> -0.55, pK<sup>2</sup><sup>25</sup> 12.20. Crystd from water (20mL/g).

5-Nitroindole  [6146-52-7]  M 162.1, m 141-142°, pK<sup>25</sup> -7.4 (aq H<sub>2</sub>SO<sub>4</sub>). Decolorised (charcoal) and recrystd twice from aqueous EtOH.

Nitromesitylene (2-nitro-1,3,5-trimethylbenzene)  [603-71-4]  M 165.2, m 44°, b 255°. Crystd from EtOH.

Nitromethane  [75-52-5]  M 61.0, f -28.5°, b 101.3°, d 1.13749, d<sub>30</sub> 1.12398, n 1.3819, n<sub>30</sub> 1.37730, pK<sub>1</sub><sup>25</sup> 10.21. Nitromethane is generally manufactured by gas-phase nitration of methane. The usual impurities include aldehydes, nitroethane, water and small amounts of alcohols. Most of these can be removed by drying with CaCl<sub>2</sub> or by distn to remove the water/nitromethane azeotrope, followed by drying with CaSO<sub>4</sub>. Phosphorus pentoxide is not suitable as a drying agent. [Wright et al. J Chem Soc 199 1936.] The purified material should be stored by dark bottles, away from strong light, in a cool place. Purifications using extraction are commonly used. For example, Van Looy and Hammett [J Am Chem Soc 81 3872 1959] mixed about 150mL of conc H<sub>2</sub>SO<sub>4</sub> with 1L of nitromethane and allowed it to stand for 1 or 2 days. The solvent was washed with water, aqueous Na<sub>2</sub>CO<sub>3</sub>, and again with water, then dried for several days with MgSO<sub>4</sub>, filtered again with CaSO<sub>4</sub>. It was fractionally distd before use. Smith, Fainberg and Weinstein [J Am Chem Soc 83 618 1961] washed successively with aqueous NaHCO<sub>3</sub>, aqueous NaHSO<sub>3</sub>, water, 5% H<sub>2</sub>SO<sub>4</sub>, water and dilute NaHCO<sub>3</sub>. The solvent was dried with CaSO<sub>4</sub>, then percolated through a column of Linde type 4A molecular sieves, followed by distn from some of this material (in powdered form). Buffagni and Dunn [J Chem Soc 5105 1961] refluxed for 24h with activated charcoal while bubbling a stream of nitrogen through the liquid. The suspension was filtered, dried (Na<sub>2</sub>SO<sub>4</sub>) and distd, then passed through an alumina column and redistd. It has also been refluxed over CaH<sub>2</sub>, distd and kept under argon over 4A molecular sieves. Can be purified by zone melting or by distn under vacuum at 0°, subjecting the middle fraction to several freeze-pump-thaw cycles. An impure sample containing higher nitroalkanes and traces of cyanoalkanes was purified (on the basis of its NMR spectrum) by crystn from diethyl ether at -60° (cooling in Dry-ice)[Parrett and Sun J Chem Educ 54 448 1977].

Fractional crystn was more effective than fractional distn from Drierite in purifying nitromethane for conductivity measurements. [Coetzee and Cunningham J Am Chem Soc 87 2529 1965.] Specific conductivities around 5 x 10<sup>-9</sup> ohm<sup>-1</sup>cm<sup>-1</sup> were obtained.
Purification of Organic Chemicals

Nitron [1,4-diphenyl-3-phenylamino-(1H)-1,2,4-triazolium (hydroxide) inner salt] [2218-94-2] M 312.4, m 189\(^\text{°C}\) (dec). Crystd from EtOH, chloroform or EtOH/**C\(_2\)H\(_6\).

1-Nitronaphthalene [86-57-7] M 173.2, m 57.3-58.3\(^\text{°C}\), b 30-40\(^\text{°C}\)/0.01mm. Fractionally distd under reduced pressure, then crystd from EtOH, aqueous EtOH or heptane. Chromatographed on alumina from *benzene/pet ether. Sublimes in vacuo.


2-Nitro-1-naphthol [607-24-9] M 189.2, m 127-128\(^\text{°C}\), pK\(_{25}\) 5.89. Crystd (repeatedly) from EtOH.


2-Nitrophenol M 139.1, m 44.5-45.5\(^\text{°C}\), pK\(_{25}\) 7.23. Crystd from EtOH/water, water, EtOH, *benzene or MeOH/pet ether (b 70-90\(^\text{°C}\)). Can be steam distd. Petrucchi and Weygandt [Anal Chem 33 275 1961] crystd from hot water (twice), then EtOH (twice), followed by fractional crystn from the melt (twice), drying over CaCl\(_2\) in a vacuum desiccator and then in an Abderhalden drying pistol.

3-Nitrophenol [554-84-7] M 139.1, m 96\(^\text{°C}\), b 160-165\(^\text{°C}\)/12mm, pK\(_{25}\) 8.36. Crystd from water, CHCl\(_3\), CS\(_2\), EtOH or pet ether (b 80-100\(^\text{°C}\)), and dried under vacuum over P\(_2\)O\(_5\) at room temperature. Can also be distd at low pressure.

4-Nitrophenol [100-02-7] M 139.1, m 113-114\(^\text{°C}\), pK\(_{25}\) 7.16. Crystd from water (which may be acidified, e.g. N H\(_2\)SO\(_4\) or 0.5N HCl), EtOH, aqueous MeOH, CHCl\(_3\), *benzene or pet ether, then dried under vacuum over P\(_2\)O\(_5\) at room temperature. Can be sublimed at 60\(^\text{°C}/10^{-2}\)mm.

2-Nitrophenoxycetic acid [1878-87-1] M 197.2, m 150-159\(^\text{°C}\), pK\(_{25}\) 2.90. Crystd from water, and dried over P\(_2\)O\(_5\) under vacuum.


4-Nitrophenylacetic acid [104-03-0] M 181.2, m 80.5\(^\text{°C}\), pK\(_{25}\) 3.92. Crystd from EtOH/water (1:1), then from sodium-dried diethyl ether and dried over P\(_2\)O\(_5\) under vacuum.

4-Nitro-1,2-phenylenediamine [99-56-9] M 153.1, m 201\(^\text{°C}\), pK\(_1\) 1.39 (1-NH\(_2\)), pK\(_2\) 2.61 (2-NH\(_2\)). Crystd from water.

\(1-(4\text{-Nitrophenyl})\)ethylamine hydrochloride [R-(+)- 57233-86-0; S-(+) 132873-57-5] M 202.6, m 225\(^\text{°C}\), 240-242\(^\text{°C}\) (dec), 243-245\(^\text{°C}\) (dec), 248-250\(^\text{°C}\), [\(\alpha\)]\(_D\)\(^\text{°}\) (+) and (-) 72\(^\text{°}\) (c 1, 0.05 M NaOH), (+) and (-) 0.39 (H\(_2\)O), pK\(_{\text{Em}}\) ≈ 8.6. To ensure dryness the hydrochloride (ca 175 g) is extracted with EtOH (3x 100mL) and evaporated to dryness (any residual H\(_2\)O increases the solubility in EtOH and lowers the yield). The hydrochloride residue is triturated with absolute EtOH and dried in vacuo. The product is further purified by refluxing with absolute EtOH (200 mL for 83g) for 1h, cool to 10\(^\text{°C}\) to give 76.6g of hydrochloride m 243-245\(^\text{°C}\) (dec). The free base is prepd by dissolving in N NaOH, extract with CH\(_2\)Cl\(_2\) (3 x 500mL), dry (Na\(_2\)CO\(_3\)), filter, evaporate and distil, m 27\(^\text{°C}\), b 119-120\(^\text{°C}/0.5\)mm (105-107\(^\text{°C}/0.5\)mm. 157-159\(^\text{°C}/9\)mm, d\(_{20}^\text{}\)
Purification of Organic Chemicals

1.1764, n \(_d^{10}\) 1.5688, [\(\alpha\)]\(_D^{14}\) \(\pm 17.7^\circ\) (neat)[Perry et al. *Synthesis* 492 1977; ORD: Nerdel and Liebig *Justus Liebigs Ann Chem* 621 142 1959].

4-Nitrophenylhydrazine [100-16-3] M 153.1, m 158°(dec), pK\(_1^{25}\) 9.2 (aq H\(_2\)SO\(_4\)), pK\(_2^{25}\) 3.70. Crystd from EtOH.


3-Nitrophthalic acid [603-11-2] M 211.1, m 216-218°, pK\(_2^{25}\) 3.93. Crystd from hot water (1.5mL/g). Air dried.


2-Nitropropane [79-46-9] M 89.1, b 120.3°, d 0.989, n 1.3949, n\(_{25}\) 1.39206, pK\(_2^{25}\) 7.68. Purified as nitromethane.


3-Nitro-2-pyridinesulfonyl chloride [68206-45-1] M 190.2, m 217-222°(dec). Crystallises as yellow needles from CH\(_2\)Cl\(_2\). When pure it is stable for several weeks at room temperature, and no decomposition was observed after 6 months at <0°. UV (MeCN) has \(\lambda_{max}\) at 231nm (\(\varepsilon\) 12,988), 264nm (\(\varepsilon\) 5,784) and 372nm (\(\varepsilon\) 3,117). [NMR and UV: Matsuda and Aiba *Chem Lett* 951 1978; Wagner et al. *Chem Ber* 75 935 1942.]

5-Nitroquinoline [607-34-1] M 174.2, m 70°, pK\(_2^{20}\) 2.69. Crystd from pentane, then from *benzene.


5-Nitosalicylic acid [96-97-9] M 183.1, m 233°, pK\(_1^{25}\) 2.32, pK\(_2^{25}\) 10.34. Crystd from acetone (charcoal), then twice more from acetone alone.
Purification of Organic Chemicals

Nitrosobenzene [586-96-9] M 107.1, m 67.5-68°, b 57-59°/18mm. Steam distd, then cryst from a small volume of EtOH with cooling below 0°, dried over CaCl₂ in a dessicator at atm pressure, and stored under N₂ at 0°. Alternatively it can be distd onto a cold finger cooled with brine at 0°, while heating in a water bath at 65-70° [Robertson and Vaughan J Chem Educ 27 605 1950].

N'-Nitrosodiethanolamine [1116-54-7] M 134.4, b 125°/0.01mm, n 1.485. Purified by dissolving the amine (0.5g) in 1-propanol (10mL) and 5g of anhydrous Na₂SO₄ added with stirring. After standing for 1-2h, it was filtered and passed through a chromatographic column packed with AG 50W x 8 (H⁺form, a strongly acidic cation exchanger). The eluent and washings were combined and evapd to dryness at 35° [Fukuda et al. Anal Chem 53 2000 1981]. Possible CARCINOGEN.

4-Nitroso-N,N-dimethylaniline [138-89-6] M 150.2, m 86-87°, 92.5-93.5°, b 191-192°/100mm, pKₓ 4.54. Recryst from pet ether or CHCl₃-CCl₄ and dried in air. Alternatively suspend in H₂O, heat to boiling and add HCl until it dissolves. Filter, cool and collect the hydrochloride [42344-05-8], m 177° after recrystn from H₂O containing a small amount of HCl. The hydrochloride (e.g. 30g) is made into a paste with H₂O (100mL) in a separating funnel. Add cold aq 2.5 NaOH or Na₂CO₃ to a pH of ~ 8.0 (green color due to free base) and extracted with toluene, CHCl₃ or Et₂O. Dry extract (K₂CO₃), filter, distil off the solvent, cool residue and collect the crystalline free base. Recryst as above and dried in air.


1-Nitroso-2-naphthol [131-91-9] M 173.2, m 110.4-110.8°, pKₓ 7.63. Cryst from pet ether (b 60-80°, 7.5mL/g).

2-Nitroso-1-naphthol [132-53-6] M 173.2, m 158°(dec), pKₓ 7.24. Purified by recrystn from pet ether (b 60-80°) or by dissolving in hot EtOH, followed by successive addition of small volumes of water.


2-Nitroso-1-naphthol-4-sulfonic acid (3H₂O) [3682-32-4] M 316.3, m 142-146°(dec), pKᵦ -6.3 (OH). Cryst from dilute HCl soln. Crystals were dried over CaCl₂ in a vacuum desiccator. Also purified by dissolution in aqueous alkaline and pptn by addition of water. Reagent for cobalt.


trans-β-Nitrostyrene [5153-67-3] M 149.2, m 60°. Cryst from absolute EtOH, or three times from *benzene/pet ether (b 60-80°) (1:1).

4-Nitrostyrene [100-13-0] M 149.2, m 20.5-21°. Cryst from CHCl₃/hexane. Purified by addition of MeOH to ppte the polymer, then cryst at ~40° from MeOH. Also cryst from EtOH. [Bernasconi et al. J Am Chem Soc 108 4541 1986.]


2-Nitrotoluene [88-72-2] M 137.1, m -9.55° (α-form), -3.85° (β-form), b 118°/16mm, d 1.163, 222.3°/760mm, n 1.545. Cryst (repeatedly) from absolute EtOH by cooling in a Dry-ice/alcohol mixture. Further purified by passage of an alcoholic soln through a column of alumina.

3-Nitrotoluene [99-08-1] M 137.1, m 16°, b 113-114°/15mm, 232.6°, d 1.156, n 1.544. Dried with P₂O₅ for 24h, then fractionally distd under reduced pressure. [Org. Synth Coll Vol I 416 1948.]
4-Nitrotoluene [99-99-0] M 137.1, m 52°. Crystd from EtOH, MeOH/water, EtOH/water (1:1) or MeOH. Air dried, then dried in a vac desiccator over H2SO4. [Wright and Gilliom J Am Chem Soc 108 2340 1986.]


Nitrourea [556-89-8] M 105.1, m 158.4-158.8° (dec). Crystd from EtOH/pet ether.

5-Nitrovanillin (nitroveratraldehyde) [6635-20-7] M 197.2, m 172-175°, 176°, 178°. Forms yellow plates from AcOH, and needles from EtOH [Slotta and Szyszke Chem Ber 68 184 1935]. With diazomethane, 5-nitro-3,4-dimethoxyacetophenone is formed [Brady and Manjunath J Chem Soc 125 1067 1924]. The methyl ether crystallises from EtOAc or AcOH, m 88°, 90-91°, and the phenylhydrazone has m 108-110° (from aqueous EtOH). [Finger and Schott J Prakt Chem 2 [2] 115 288 1927; For oxime m 216° (from EtOH or AcOH) and the oxime acetate has m 147° (fromaq EtOH) [Vogel Monatsh Chem 20 384 1899; Brady and Dunn J Chem Soc 107 1861 1915].

n-Nonane [111-84-2] M 126.3, b 150.8°, d 0.719, n 1.40542, n25 1.40311. Fractionally distd, then stirred with successive volumes of conc H2SO4 for 12h each until no further colouration was observed in the acid layer. Then washed with water, dried with MgSO4 and fractionally distd. Alternatively, it was purified by azeotropic distn with 2-ethoxyethanol, followed by washing out the alcohol with water, drying and distilling. [Forziati et al. J Res Nat Bur Stand 36 129 1946.]


cis-endo-5-Norbornene-2,3-dicarboxylic anhydride (carbic anhydride, 3α,4,7,7,αα-tetrahydro-4α,7α-methanosobenzofuran-1,3-dione) [129-64-6] M 164.2, m 164.1°, 164-165°, 164-167°, d 1.417. Forms crystals from pet ether, hexane or cyclohexane. It is hydrolysed by H2O to form the acid [Dielis and Alder Justus Liebigs Ann Chem 460 98 1928; Maitte Bull Soc Chim Fr 499 1959]. The exo-exo-isomer has m 142-143° (from *C6H6-pet ether) [Alder and Stein Justus Liebigs Ann Chem 504 216 1933].


Norleucine (α-amino-γ-caproic acid) [R(+) 327-56-0; S(-) 327-57-1] M 117.2, m 301° [α]20 1546 (+) and (-) 28° (c 5, SM HCl); RS: 616-06-81 m 297-300° (sublimes partially at ~280°), pK1 2.39, pK2 9.76 (for RS). Crystd from water.
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Norvaline (R-α-aminon-valeric acid) \([R(+)]^25o_2 -12.9; \quad S(-)^25o_2 -66.0\) M 117.2, m 305.9 (dec), \([\alpha]_250^\circ (+)\) and (-) 25° (c 10, 5M HCl), \(pK_a^2 2.36, \quad pK_b^2 9.87 (9.72).\) Crystd from aqueous EtOH or water.

Nylon powder. Pellets were dissolved in ethylene glycol under reflux. Then ppted as a white powder on addition of EtOH at room temperature. This was washed with EtOH and dried at 100° under vacuum.

- Octacosane \([630-02-4]\) M 394.8, m 62.5°. Purified by forming its adduct with urea, washing and crystallising from acetone/water. [McCubbin Trans Faraday Soc 58 2307 1962.] Crystd from hot, filtered isopropyl ether soln (10mL/g).

n-Octacosanol (octacosyl alcohol) \([557-61-9]\) M 410.8, m 83.4°, 84°. Recryst from large vols of Me₂CO. It sublimes at 200-250°/1mm instead of distilling.

n-Octadecane \([593-45-3]\) M 254.5, m 28.1°, b 173.5°/10mm, 316.1°/760mm, \(d^2 0.7768, \quad n 1.4390.\) Crystd from acetone and dist under reduced pressure from sodium.

Octadecyl acetate \([822-23-1]\) M 312.5, m 32.6°. Dist under vac, then cryst from diethyl ether/MeOH.

n-Octadecyl alcohol (stearyl alcohol) \([112-92-5]\) M 270.5, m 61°, b 153-154°/0.3mm. Crystd from MeOH, or dry diethyl ether and *benzene, then fractionally dist under reduced pressure. Purified by column chromatography. Freed from cetyl alcohol by zone melting.

Octadecyl ether (dioctadecyl ether) \([6297-03-6]\) M 523.0, m 59.4°. Vacuum disd, then cryst from M₂O/H₂O/benzene.

Octadecyltrimethylammonium bromide \([1120-02-1]\) M 392.5, m 250°(dec). See entry on p. 446 in Chapter 6.

2,3,7,8,12,13,17,18-Octaethyl-21H,23H-porphine \([2683-82-1]\) M 534.8, m 322.2, 326°. Chromatographed on SiO₂ using CHCl₃ as eluent. It crystallises from CHCl₃ (dark red), MeOH (blue violet), pyridine (m 318°) and *C₆H₆ (deep red). [Fischer and Bämler Justus Liebig's Ann Chem 468 58, 85 1929.]

Octafluoropropane (profluorane) \([76-19-7]\) M 188.0, m -183°, b -38°. Purified for pyrolysis studies by passage through a copper vessel containing CoF₃ at about 270°, then fractionally distd. [Steunenberg and Cady J Am Chem Soc 74 4165 1952.] Also purified by several trap-to-trap distns at low temperatures [Simons and Block J Am Chem Soc 59 1407 1937.]

1,2,3,4,6,7,8,9-Octahydroanthracene \([1079-71-6]\) M 186.3, m 78°. Crystd from EtOH, then purified by zone melting.

Octamethylcyclotetrasiloxane \([556-67-2]\) M 296.6, m 17.3°, b 175-176°, \(d^2 0.957, \quad n 1.396.\) Purified by zone melting.

Octan-1,8-diol (octamethylene glycol) \([629-41-4]\) M 146.2, m 59-61°, b 172°/20mm. Recrystd from EtOH and distd in a vac.

n-Octane \([111-65-9]\) M 114.2, b 126.5°, \(d^2 0.704, \quad n 1.39743, \quad n^2 1.39505.\) Extracted repeatedly with conc H₂SO₄ or chlorosulfonic acid, then washed with water, dried and distd. Also purified by azeotropic distn with EtOH, followed by washing with water to remove the EtOH, drying and distilling. For further details, see n-heptane. Also purified by zone melting.
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1-Octene [111-66-0] M 112.2, b 121°/742mm, d^2^0 0.716, n 1.4087. Distd under nitrogen from sodium which removes water and peroxides. Peroxides can also be removed by percolation through dried, acid washed alumina. Stored under nitrogen in the dark. [Strukul and Michelin J Am Chem Soc 107 7563 1985.]


n-Octyl alcohol [111-87-5] M 130.2, b 98°/19mm, 195.30/760mm, d 0.828, n 1.43018. Fractionally distd under reduced pressure. Dried with sodium and again fractionally distd or refluxed with boric anhydride and distd (b 195-205°/5mm), the distillate being neutralised with NaOH and again fractionally distd. Also purified by distn from Raney nickel and by preparative GLC.


n-Octylammonium hexadecanoate [88020-97-7] M 385.7, m 52-53°. Purified by several recrystns from n-hexane or ethyl acetate. The solid was then washed with cold anhydrous diethyl ether, and dried in vacuo over P_2O_5.

n-Octylammonium octadecanoate [32580-92-0] M 413.7, m 56-57°. Purified as for the hexadecanoate above.


4-Octylbenzoic acid [3575-31-3] M 234.3, m 99-100°, pK^25 6.5 (80% aq EtOH), pK_{EtOH} ~4.5 (H_2O). Crystd from EtOH has m 139°; crystd from aq EtOH has m 99-100°. Forms liquid crystals.

n-Octyl bromide [111-83-1] M 193.1, b 201.5°, d^2^0 1.118, n^2^5 1.4503. Shaken with H_2SO_4, washed with water, dried with K_2CO_3 and fractionally distd.

4-(tert-Octyl)phenol [140-66-9] M 206.3, m 85-86°, b 166°/20mm, pK_{EtOH} ~10.4. Crystd from n-hexane.

1-Octyne [629-05-0] M 110.2, b 126.2°/760mm, d^2^0 0.717, n^2^5 1.4159. Distd from NaBH_4 to remove peroxides.

α-Oestradiol [57-91-0] M 272.4, m 220-230°, [α]_D^2^0 +55° (c 1, dioxane). Crystd from aq EtOH.

β-Oestradiol-3-benzoate [50-50-0] M 376.5, m 194-195°, [α]_{446}^2^0 +70° (c 2, dioxane). Crystd from EtOH.

Oleic acid [112-80-1] M 282.5, m 16°, b 360°(dec), d^2^0 0.891, n^3^0 1.4571, pK^25 6.42 (50% aq EtOH), pK_{EtOH} ~4.8 (H_2O). Purified by fractional crystn from its melt, followed by molecular distn at 10-3mm, or by conversion to its methyl ester, the free acid can be crystd from acetone at -40° to -45° (12mL/g). For purification by the use of lead and lithium salts, see Keffer and McLean [J Soc Chem Ind (London) 54 176T 1935]. Purification based on direct crystn from acetone is described by Brown and Shinowara [J Am Chem Soc 59 6 1937; pK White J Am Chem Soc 72 1857 1950].
Oleyl alcohol [143-28-2] M 268.5, b 182-184°/1.5mm, d²₄ 0.847, n²⁰ 1.4582. Purified by fractional crystallization at -40° from acetone, then distilled under vacuum.


L-Ornithine [70-26-8] M 132.2, m 140°, [α]²⁰ +16° (c 0.5, H₂O), pK² 8.75, pK³ 10.73. Crystallized from water containing 1mM EDTA (to remove metal ions).

Orhanilic acid (2-aminobenzenesulfonic acid) [88-21-1] M 173.2, m >300° (dec), pK² 2.49. Crystallized from aqueous solution, containing 20mL of conc HCl per L, then crystallized from distilled water, and dried in a vacuum desiccator over fused CaCl₂.


Oxalic acid (2H₂O) [1645-56-6] M 90.0, m 101.5°; [anhydrous 144-62-7] m 189.5°, pK² 1.08 (1.37), pK² 3.55 (3.80). Crystallized from distilled water. Dried in vacuum over H₂SO₄. The anhydrous acid can be obtained by drying at 100° overnight.


2-Oxoglutaric acid (2-oxopentane-1,5-dioic, α-ketoglutaric acid) [328-50-7] M 146.1, m 114°, 115-117°, (pK⁵ see oxaloacetic acid above). Crystallized repeatedly from Me₂CO/*benzene, EtOAc or ethyl propionate.


2-Oxazolidinone [497-25-6] M 87.1, m 89-90°, 91°, b 152°/0.4mm. Crystallized from *benzene or dichloroethane.

Oxetane (1,3-trimethylene oxide) [503-30-0] M 58.1, b 45-46°/736mm, 47-49°/atm, 48°/760mm, d²⁰ 0.892, n²⁰ 1.395. Distilled twice from sodium metal and then fractionated through a small column at atmospheric pressure, b 47.0-47.2°. Also purified by preparative gas chromatography using a 2m silica gel column. Alternatively add KOH pellets (50g for 100g of oxetane) and distill through an efficient column or a column packed with 1/4in Berl Saddles and the main portion boiling at 45-50° is collected and redistilled over fused KOH. [Noller Org Synth Coll Vol III 835 1955; Dittmer et al. J Am Chem Soc 79 4431 1957.]
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Palmitic acid anhydride (hexadecanoic anhydride) [623-65-4] M 494.9, m 63-64°, d82 0.838, n68 1.436. It is moisture sensitive and hydrolyses in water. Purified by refluxing with acetic anhydride for 1hr, evaporating and freeing the residue of acetic acid and anhydride by drying the residue at high vac and crystallising from pet ether at low temperature.

[2.2]-Paracyclophane (tricyclo[8.2.2.24-7]hexadec-4,6,10,12,13,15-hexaene) [1633-22-3] M 208.3, m 284°, 285-287°, 286-288°. Purified by recrystn from AcOH.


Paraffin (oil) [8012-95-1] d 0.880, n 1.482. Treated with fuming H2SO4, then washed with water and dilute aqueous NaOH, then percolated through activated silica gel.

Paraffin Wax. Melted in the presence of NaOH, washed with water until all of the base had been removed. The paraffin was allowed to solidify after each wash. Finally, 5g of paraffin was melted by heating on a water-bath, then shaken for 20-30min with 100mL of boiling water and fractionally crystd.

Parafuchsin (4,4',4"-triaminotrityllium [triphenylmethane] carbonium ion, para-rosaniline, paramagenta) [467-62-9] M 305.4, pK 7.57 and free base has pK >13. Dissolve in EtOH (1.16g in 30mL), filter and add aqueous NH3 till neutral and ppte by adding H2O giving 0.8g m 247° dec (sintering at 230°). Dissolve in EtOH neutralise with NH3 add 0.1g of charcoal filter, and repeat, then add H2O (100mL) to ppte the colourless carbinol dry, m 257° dec (sintering at 232°). [Weissberger and Theile J Chem Soc 148 1934]. The carbinol (pseudo-base) was said to have m 232° (186° dec), and is slightly sol in H2O but sol in acids and EtOH [pK: Goldacre and Phillips J Chem Soc 172 1949]. The perchlorate (dark red with a green shine) has m 300° and explodes at 317° [Dilthey and Diaklage J Prakt Chem [2] 129 1931].

Paraldehyde (acetaldehyde trimer, 2,4,6-trimethyl-1,3,5-trioxane) [123-63-7] M 132.2, m 12.5°, 124°, d 0.995, n 1.407. Washed with water and fractionally distd.

Patulin (4-hydroxy-4'H-furo[3.2-c]pyran-2(6H)-one) [149-29-1] M 154.1, m 110°. Crystd from diethyl ether or chloroform. (Highly TOXIC).

Pavatrine hydrochloride [548-65-2] M 333.7, m 143-144°. Recrystd from isopropanol, and dried over P2O5 under vacuum.

Pelargonic acid (nonanoic acid) [112-05-0] M 158, m 15°, b 98.9°/1mm, 225°/760mm, pK25 4.96. Esterified with ethylene glycol and distd. (This removes dibasic acids as undistillable residues.) The acid was regenerated by hydrolysing the ester.

Pelargononitrile (octyl cyanide) [2243-27-8] M 139.2, m -34°, b 92°/10mm, 224°, d 0.818, n 1.4255. Stirred with P2O5 (~5%), distd from it and redistd under vac. IR should have CN but no OH bands.

Pelargonyl chloride (nonanoyl chloride) [764-85-2] M 176.7, b 89°/12mm, d 0.941, n 1.436. Refluxed with acetyl chloride (~ 3 vols) for 1h, then distill off the AcCl followed by the nanoyl chloride under reduced pressure. It is moisture sensitive and should be stored in sealed ampules.

Penicillic acid [90-65-3] M 158.2, m 58-64° (monohydrate), 83-84° (anhydrous, lactone). Crystd from water as the monohydrate, or from pet ether. Free acid is in equilibrium with the lactone.
Pentabromoacetone \([79-49-2]\) M 452.6, m 76°, pK 8.0 (MeOH), pK\textsubscript{EtOH} ~4.6 (H\textsubscript{2}O). Crystd from diethyl ether or EtOH and sublimes.

Pentabromophenol \([608-71-9]\) M 488.7, m 229°, pK\textsubscript{EtOH} ~4.5. Purified by crystn (charcoal) from toluene then from CCl\textsubscript{4}. Dried for 2 weeks at ca 75°.

1-Pentacene \([135-48-8]\) M 278.4, m 300°. Crystd from benzene.

Pentachloroethylene (pentalin) \([76-01-7]\) M 202.3, b 69°/37mm, 152.2°/64mm, 162.0°, d 1.678, n\textsubscript{D} 1.50542. Usual impurities include trichloroethylene. Partially decomposes if distd at atmospheric pressure. Drying with CaO, KOH or sodium is unsatisfactory because of the elimination of the elements of HCl. It can be purified by steam distn, or by washing with conc H\textsubscript{2}SO\textsubscript{4}, water, and then aqueous K\textsubscript{2}CO\textsubscript{3}, drying with solid K\textsubscript{2}CO\textsubscript{3} or CaSO\textsubscript{4}, and fractionally distd under reduced pressure. Usual impurities include trichloroethylene.

Pentachloronitrobenzene \([82-68-8]\) M 295.3, m 146°. Crystd from EtOH.

Pentachlorophenol Sublimed in vacuo. \([87-86-5]\) M 266.3, m 190-191°, pK\textsubscript{ZS} 4.8. Twice crystd from toluene/EtOH.

Pentachloropyridine \([2176-62-7]\) M 251.3, m 122-124°, 123°, 124°, 124-125°, 125-126°, b 279-280°/atm, pK -6.02 (as H\textsubscript{2}SO\textsubscript{4}). Purified by recryst from EtOH or aqueous EtOH. It sublimes at 150°/3mm. [den Hertog et al. Recl Trav Chim Pays-Bas 69 673 1950; Schikh et al. Chem Ber 69 2604 1936.]

Pentachlorothiophenol \([133-49-3]\) M 282.4, m between 228° and 235°, pK\textsubscript{ZS} -1.1. Crystd from benzene.

Pentadecafluoro octanoic acid (perfluorocaprylic acid) \([335-67-1]\) M 414.1, m 54.9-55.6°, b 189°/736mm, pK\textsubscript{EtOH} <0. Recrystd from CCl\textsubscript{4} and toluene, and can be distd. It forms micelles in H\textsubscript{2}O and the solubility is 1% in H\textsubscript{2}O. [Bernett and Zisman J Phys Chem 63 191 1959; IR: Bro and Sperati J Polym Sci 38 289 1959.]

Pentadecanoic acid \([1002-84-2]\) M 242.4, m 51-53°, 80°, b 158°/1mm, 257°/760mm, d\textsubscript{80} 0.8424, pK\textsubscript{EtOH} ~5.0. Cryst from Et\textsubscript{2}O and distd. Very hygroscopic. See purification of palmitic acid.

Pentadecanolide (1-oxacyclohexadecan-2-one, pentadecanoic-w-lactone, 15-hydroxypentadecanoic lactone, exaltolide, Tibetolide) \([106-02-5]\) M 240.4, m 34-36°, 37-37.5°, 37-38°, b 102-103°/0.03mm, 112-114°/0.2mm, 137°/2mm, 169°/10-11mm, d\textsubscript{83} 0.9401. It has been recrystd from MeOH (4 parts) at -15°. [Hundiecker and Erlbach Chem Ber 80 135 1947; Galli and Mandolini Org Synth 58 100 1978; Demole and Enggist Helv Chim Acta 11 2318 1978.]

Penta-1,3-diene \(\text{cis}: 1574-41-0; \text{trans}: 2004-70-8\) M 68.1, b 42°, d 0.680, n 1.4316. Distd from NaBH\textsubscript{4}. Purified by preparative gas chromatography. [Reimann et al. J Am Chem Soc 108 5527 1986.]

Penta-1,4-diene \([591-93-5]\) M 68.1, b 25.8-26.2°/756mm, d 0.645, n 1.3890. Distd from NaBH\textsubscript{4}. Purified by preparative gas chromatography. [Reimann et al. J Am Chem Soc 108 5527 1986.]

Pentaerythritol \([115-77-5]\) M 136.2, m 260.5°. Refluxed with an equal volume of MeOH, then cooled and the ppt dried at 90°. Cryst from dil aq HCl. Sublimed under vacuum at 200°.

Pentaerythritol tetraacetate \([597-71-7]\) M 304.3, m 78-79°. Crystd from hot water, then leached with cold water until the odour of acetic acid was no longer detectable.

Pentaerythrityl laurate \([13057-50-6]\) M 864.6, m 50°. Crystd from pet ether.
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Pentaerythritol tetranitrate. [78-11-5] M 316.2, m 140.1°. Cryst from acetone or aceton/EtOH. EXPLOSIVE.

Pentaethylenehexamine [4067-16-7] M 232.4, d 0.950, n_d 1.524, m 140.1°. Crystd from acetone or aceton/EtOH. 2,3,4,5,6-Pentafluorobenzoic acid [602-94-8] M 212.1, m 101-103°, 103-104°, 104-105°, 106-107°, n_4 1.75. Dissolve in Et_2O, treat with charcoal, filter, dry (CaSO_4), filter, evaporate and recrystallise residue from pet ether (b 90-100°) after adding a little toluene to give large colourless plates. 2,3,4,5,6-Pentafluorobenzoic acid has m 187° after recrystn from H_2O. [McBee and Rapkin J Am Chem Soc 73 1366 1951; Nield et al. J Chem Soc 166, 170 1959.]

O-(2,3,4,5,6-Pentafluorobenzyl)hydroxylamine hydrochloride (PFBHA) [57981-02-9] M 249.6, m 215°, 215-216°, p_Ka ~1.1. Recrystd from EtOH to form colourless leaflets. Drying the compound at high vacuum and elevated temperature will result in losses by sublimation. [Youngdale J Pharm Sci 65 625 1976; Wehner and Handke J Chromatogr 177 237 1979; Nambara et al. give incorrect m as 115-116° J Chromatogr 114 81 1975.]

2,2,3,3,3-Pentafluoropropan-1-ol [422-05-9] M 150.1, b 80°, d 1.507, n 1.288, p_K_2 12.74. Shaken with alumina for 24h, dried with anhydrous K_2CO_3, and distd, collecting the middle fraction (b 80-81°) and redistilling.

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Pentamethylbenzene [700-12-9] M 148.3, m 53.5-55.1º. Successively crystd from absolute EtOH, toluene and MeOH, and dried under vacuum. [Rader and Smith J Am Chem Soc 84 1443 1962.] It has also been crystd from *benzene or aqueous EtOH, and sublimed.

\( n \)-Pentane [109-66-0] M 72.2, b 36.1º, d 0.626, \( n^2 \) 1.35472. Stirred with successive portions of conc H_2SO_4 until there was no further coloration during 12h, then with 0.5N KMnO_4 in 3M H_2SO_4 for 12h, washed with water and aqueous NaHCO_3. Dried with MgSO_4 or Na_2SO_4, then P_2O_5 and fractionally distd through a column packed with glass helices. It was also purified by passage through a column of silica gel, followed by distn and storage with sodium hydride. An alternative purification is by azeotropic distn with MeOH, which is subsequently washed out from the distillate (using water), followed by drying and distn. For removal of carbonyl-containing impurities, see \( n \)-heptane. Also purified by fractional freezing (ca 40%) on a copper coil through which cold air was passed, then washed with conc H_2SO_4 and fractionally distd.

Pentane-1-thiol [110-66-7] M 104.2, m -76º, b 122.9º/697.5mm, \( d^2 \) 0.8375, \( pK_{\text{est}} \) -10.1. Dissolved in aqueous 20% NaOH, then extracted with a small amount of diethyl ether. The soln was acidified slightly with 15% H_2SO_4, and the thiol was distd out, dried with CaSO_4 or CaCl_2, and fractionally distd under nitrogen. [Ellis and Reid J Am Chem Soc 54 1674 1932.]

Pentan-2-ol [6032-29-7] M 88.2, b 119.9º, d 0.810, \( n \) 1.41787, \( n^2 \) 1.4052. Refluxed with CaO, distd, refluxed with magnesium and again fractionally distd.

Pentan-3-ol [584-02-1] M 88.2, b 116.2º, d 0.819, \( n^2 \) 1.4072. Refluxed with CaO, distd, refluxed with magnesium and again fractionally distd.

Pentan-3-one (diethyl ketone) [96-22-0] M 86.1, b 102.1º, d 0.8099, \( n \) 1.392. See diethyl ketone on p. 204.

Pentaquine monophosphate [5428-64-8] M 395.6, m 189-190º, \( pK^{70} \) 8.22. Crystd from 95% EtOH.

Pent-2-ene (mixed isomers) [109-68-2] M 70.1, b 36.4º, d 0.650, \( n \) 1.38003, \( n^2 \) 1.3839. Refluxed with sodium wire, then fractionally distd twice through a Fenske (glass helices packing) column.

cis-Pent-2-ene [627-20-3] M 70.1, b 37.1º, d 0.657, \( n^2 \) 1.3798. Dried with sodium wire and fractionally distd, or purified by azeotropic distn with MeOH, followed by washing out the MeOH with water, drying and distilling. Also purified by chromatography through silica gel and alumina [Klassen and Ross J Phys Chem 91 3668 1987].

trans-Pent-2-ene [646-04-8] M 70.1, b 36.5º, d 0.648, \( n \) 1.3793. It was treated as above and washed with water, dried over anhydrous Na_2CO_3, and fractionally distd. The middle cut was purified by two passes of fractional melting.

Pentobarbital (5-ethyl-5-1'-methylbutyl barbituric acid, Nembutal) [76-74-4] M 226.4, m ~127º(dec), \( pK_{\text{est}(1)} \) -8.0, \( pK_{\text{est}(2)} \) -12.7. Soln of the sodium salt in 10% HCl was prepared and the acid was extracted by addition of ether. Then purified by repeated crystn from CHCl_3. [Bucket and Sando-fy J Phys Chem 88 3274 1984.]

Pentyl acetate (\( n \)-amyl acetate) [628-63-7] M 130.2, b 147-149º/atm, 149.55º, 149.2º/atm, \( d^2 \) 0.8753, \( n^2 \) 1.4028. Purified by repeated fractional distn through an efficient column or spinning band column. [Timmermann and Hennant-Roland J Chim Phys 52 223 1955; Mumford and Phillips J Chem Soc 75 1950; \(^1\)H NMR: Crawford and Foster Can J Phys 34 653 1956.]

Pent-2-yne [627-21-4] M 68.1, b 26º/2.4mm, d 0.710, \( n^2 \) 1.4005. Stood with, then distd at low pressure from, sodium or NaBH_4.

**EXPLOSIVE.**

Perchlorobutadiene \([87-68-3]\) M 260.8, b 144.1°/100mm, 210-212°/760mm, d 1.683, n\(_1^\lambda\) 1.295. Washed with four or five 1/10th volumes of MeOH (or until the yellow colour has been extracted), then stirred for 2h with H₂SO₄, washed with distilled water until neutral and filtered through a column of P₂O₅. Distd under reduced pressure through a packed column. [Rytner and Bauer *J Am Chem Soc* 82 298 1960.]

Perfluorobutyric acid M 214.0, m -175°, b 120°/735mm, d 1.651, n\(_1^\lambda\) 1.295, pK\(_{2^+}\) -0.17. Fractionally distd twice in an Oldershaw column with an automatic vapour-dividing head, the first distn in the presence of conc H₂SO₄ as a drying agent.

Perfluorocyclobutane \([375-22-4]\) M 200.0, m -40°, b -50, d\(_2^5\) 1.654, d\(_\infty\) 1.72. Purified by trap-to-trap distn, retaining the middle portion.

Perfluorocyclohexane \([355-68-0]\) M 300.1, m 51° (sublimes), b 52°. Extracted repeatedly with MeOH, then passed through a column of silica gel (previously activated by heating at 250°).

Perfluoro-1,3-dimethylcyclohexane \([335-27-3]\) M 400.1, b 101°, d 1.829, n 1.300. Fractionally distd, then 35mL was sealed with about 7g KOH pellets in a borosilicate glass ampoule and heated at 135° for 48h. The ampoule was cooled and opened, and the liquid was resealed with fresh KOH in another ampoule and heated as before. This process was continued until no further decomposition was observed. The substance was then washed with distilled water, dried (CaSO₄) and distd. [Grafstein *Anal Chem* 26 523 1954.]

Perfluoroheptane \([335-57-9]\) M 388.1, b 99-101°, d\(_2^5\) 1.7200. Purified for *perfluorodimethylhexane*. Other procedures include shaking with H₂SO₄, washing with water, drying with P₂O₅ for 48h and fractionally distilling. Alternatively, it has been refluxed for 24h with saturated acid KMnO₄ (to oxidise and remove hydrocarbons), then neutralised, steam distd, dried with P₂O₅, and passed slowly through a column of dry silica gel. It has been purified by fractional crystn, using partial freezing.

Perfluorononane \([375-96-2]\) M 488.1, b 126-127°, d 1.80, n 1.275. Purified as for *perfluorodimethylcyclohexane*.

Perfluoropropyl iodide \([754-34-7]\) M 295.9, m 41°, d 2.13, n 1.339. Purified by fractional distn.

Perfluorotributylamine (heptacosfluorotributylamine) \([311-89-7]\) M 671.1, b 177.6°/760mm, d 1.881, n 1.291, pK\(_{\text{est}}\) -5.0. Purified as for *perfluorodimethylcyclopropane*, see also *perfluorotripropylamine* [Hazeldine *J Chem Soc* 102 1951].

Perfluorotributylamine (heneicosfluorotributylamine) \([338-83-0]\) M 521.1, b 130°/atm, 129.5-130.5°/atm, d 1.822, n 1.279, pK\(_{\text{est}}\) -5.6. Purified as for *perfluorodimethylcyclopropane*. [Hazeldine *J Chem Soc* 102 1951, for azeotropes see Simons and Linevsky *J Am Chem Soc* 74 4750 1972.]

Pericyazine [10-(3-(4-hydroxy-1-piperidinyl)-propyl)-10H-phenothiazine-2-carbonitrile] \([2622-26-6]\) M 365.4, m 116-117°. Recrystd from a saturated soln in cyclohexane. Antipsychotic and is a reagent for Pd and Rh.

Petroleum ether [8032-32-4] b 35-60°, d 0.640, n 1.363. Shaken several times with conc H2SO4, then 10% H2SO4 and conc KMnO4 (to remove unsatd, including aromatic, hydrocarbons) until the permanganate colour persists. Washed with water, aqueous Na2CO3 and again with water. Dried with CaCl2 or Na2SO4, and distd. It can be dried further using CaH2 or sodium wire. Passage through a column of activated alumina, or treatment with CaH2 or sodium, removes peroxides. For the elimination of carbonyl-containing impurities without using permanganate, see n-heptane. These procedures could be used for all fractions of pet ethers.

Rapid purification: Pass through an alumina column and fractionally distilling, collecting the desired boiling fraction.

R(-)-a-Phellandrene (p-menta-1,5-diene) [4221-98-1] M 136.2, b 61°/11mm, 175-176°/760mm, d 0.838, n 1.471. Purified by gas chromatography on an Apiezon column.


Phenanthrene [85-01-8] M 178.2, m 98°. Likely contaminants include, anthracene, carbazole, fluorene and other polycyclic hydrocarbons. Purified by distn from sodium, boiling with maleic anhydride in xylene, crystn from acetic acid, sublimation and zone melting. Has also been recrystd repeatedly from EtOH, *benzene or pet ether (b 60-70°), with subsequent drying under vacuum over P2O5 in an Abderhalden pistol. Feldman, Pantages and Orchin [J Am Chem Soc 73 4341 1951] separated from most of the anthracene impurity by refluxing phenanthrene (671g) with maleic anhydride (194g) in xylene (1.25L) under nitrogen for 22h, then filtered. The filtrate was extracted with aqueous 10% NaOH, the organic phase was separated, and the solvent was evaporated. The residue, after stirring for 2h with 7g of sodium, was vacuum distd, then recrystd twice from 30% *benzene in EtOH, then distilled in hot glacial acetic acid (2.2mL/g), slowly adding an aqueous soln of CrO3 (60g in 72mL H2O added to 2.2L of acetic acid), followed by slow addition of conc H2SO4 (30mL). The mixture was refluxed for 15min, diluted with an equal volume of water and cooled. The ppte was filtered off, washed with water, dried and distd, then recrystd twice from EtOH. Further purification is possible by chromatography from CHCl3 soln on activated alumina, with *benzene as eluent, and by zone refining.


9,10-Phenanthrenequinone [84-11-7] M 208.2, m 208°, pK -7.1 (aq H2SO4). Crystd from dioxane or 95% EtOH and dried under vacuum.

Phenanthridine [229-87-8] M 179.2, m 106.5°, 108-109°, b 350°, pK26 4.61 (4.48). Purified via the HgCl2 addition compound formed when phenanthridine (20g) in 1:1 HCl (100mL) was added to aq HgCl2 (60g in 3L), and the mixture was heated to boiling. Conc HCl was then added until all of the solid had dissolved. The compound separated on cooling, and was dec with aq NaOH (ca 5M). Phenanthridine was extracted with Et2O and crystd from pet ether (b 80-100°) or EtOAc. [Cumper et al. J Chem Soc 45218 1962.] Also purified by zone melting: sublimes in vac. [Slough and Ubbelohde J Chem Soc 911 1957.] See p. 124.

1,10-Phenanthroline (o-phenanthroline) [66-71-7 (anhydr); 5144-89-8 (H2O)] M 198.2, m 98-101°, 108-110° (hydr), 118° (anhydr), b >300°, pK12 0.7 (aq HClO4), pK23 4.86 (4.96). Crystd as its picrate (m 191°) from EtOH, then the free base was liberated, dried at 78°/8mm over P2O5 and crystd from pet ether (b 80-100°). [Cumper, Ginman and Vogel J Chem Soc 1188 1962.] It can be purified by zone melting. Also crystd from hexane, *benzene/pet ether (b 40-60°) or sodium-dried *benzene, dried and stored over H2SO4. The monohydrate is obtained by crystn from aqueous EtOH or ethyl acetate. It has been crystd from H2O (300 parts) to give the monohydrate m 102-103° and sublimes at 10°/3mm [Fielding and LeFevre J
The anhydrous compound has m 118° (after drying at high vacuum at 80°), also after recrystn from pet ether or *C₆H₅ (70 parts) and drying at 78°/8mm. [UV: Badger et al. J Chem Soc 3199 1951.]

It has a pKa in H₂O of 4.857 (25°) or 5.02 (20°) and 4.27 in 50% aq EtOH (20°) [Albert et al. J Chem Soc 2240 1948].

1,10-phananthroline hydrochloride (α-phananthroline hydrochloride) [3829-86-5] M 243.7, m 212-219°. It crystallises from 95% EtOH, m 212-219° as the monohydrate, the half hydrate has m 217°. The 3HCl has m 143-145° (sinters at 128°) [Thevenet et al. Acta Cryst Sect B 33 2526 1977].

4,7-Phenanthroline-5,6-dione [84-12-8] M 210.2, m 295°(dec). Cryst from MeOH.

Phenazine [92-82-0] M 180.2, m 171°, pKₐ 1.21. Cryst from EtOH, CHCl₃ or ethyl acetate, after pre-treatment with activated charcoal. It can be sublimed in vacuo, and zone refined.


Phenethylamine [64-04-0] M 121.2, b 87°/13mm, d 0.962, n 1.535, pKₐ 9.88. Dist from CaH₂, under reduced pressure, just before use.

Phenethyl bromide [103-63-9] M 185.1, b 92°/11mm, d 1.368, n 1.557. Washed with conc H₂SO₄, water, aq 10% Na₂CO₃ and water again, then dried with CaCl₂ and fractionally dist under reduced pressure.


Phenetole [103-73-1] M 122.2, b 60°/9mm, 77.5°/31mm, 170.°/760mm, d 0.967, n 1.50735, n₂5 1.50485. Small quantities of phenol can be removed by shaking with NaOH, but this is not a very likely contaminant of commercial material. Fractional distn from sodium, at low pressures, probably gives adequate purification. It can be dissolved in diethyl ether and washed with 10% NaOH (to remove phenols), then water. The ethereal soln was evaporated and the phenetole fractionally dist under vacuum.


Phenol [108-95-2] M 94.1, m 40.9°, b 85.5-86.0°/20mm, 180.8°/760mm, d 1.06, n 1.54178, n₂5 1.53957, pKₐ 9.86 (10.02). Steam was passed through a boiling soln containing 1mole of phenol and 1.5-2.0mole of NaOH in 5L of H₂O until all non-acidic material had distd. The residue was cooled, acidified with 20% (v/v) H₂SO₄, and the phenol was separated, dried with CaSO₄ and fractionally dist under reduced pressure. It was then fractionally crystallized several times from its melt [Andon et al. J Chem Soc 5246 1960]. Purification via the benzoate has been used by Berliner, Berliner and Nelidow [J Am Chem Soc 76 507 1954]. The benzoate was cryst from 95% EtOH, then hydrolysed to the free phenol by refluxing with two equivalents of KOH in aq EtOH until the soln became homogeneous. It was acidified with HCl and extracted with diethyl ether. The ether layer was freed from benzoic acid by thorough extraction with aqueous NaHCO₃ and, after drying and removing the ether, the phenol was distd. Phenol has also been crystd from a 75% w/w soln in water by cooling to 11° and seeding with a crystal of the hydrate. The crystals were centrifuged off, rinsed with cold water (0-2°) satd with phenol, and dried. It can be cryst from pet ether [Benasconi and Paschalis J Am Chem Soc 108 2969 1986].

Draper and Pollard [Science 109 448 1949] added 12% water, 0.1% aluminium (can also use zinc), and 0.05% NaHCO₃ to phenol, and distd at atmospheric pressure until the azo trope was removed. The phenol was then distd at 25mm. Phenol has also been dried by distn from the *benzen soln to remove the water. *benzene azo trope and the excess *benzene, followed by dist of the phenol at reduced pressure under nitrogen. Processes such as this are probably adequate for analytical grade phenol which has as its main impurity water. Phenol has also been crystd from pet ether/*benzene or pet ether (b 40-60°). Purified material is stored in a vacuum desiccator over P₂O₅ or CaSO₄.
Phenol-2,4-disulfonic acid [96-77-5] M 254.2, pK$_1$ <1, pK$_2$ <1, pK$_3$ ~8.3. Crystd from EtOH/diethyl ether.

Phenolphthalein [77-09-8] M 319.2, m 263°, pK$_{Est(1)}$ ~4.2, pK$_{Est(2)}$ ~9.8. Dissolved in EtOH (7mL/g), then diluted with eight volumes of cold water. Filtered. Heated on a water-bath to remove most of the alcohol and the pptd phenolphthalein was filtered off and dried under vacuum.


Phenosafranine (3,7-diamino-5-phenylphenazinium chloride) [81-93-6] M 322.8, m >300°, $\lambda_{max}$ 530nm (H$_2$O). Crystd from dilute HCl.

Phenothiazine [92-84-2] M 199.3, m 184-185°. Crystd from benzene or toluene (charcoal) after boiling for 10min under reflux. Filtered on a suction filter. Dried in an oven at 100°, then in a vacuum desiccator over paraffin chips. Also twice recrystd from water and dried in an oven at 100° for 8-10h.

Phenoxazine [135-67-1] M 199.2, m 156°, 156-158°, 158-159°, b 215°/4mm. Crystd from EtOH and sublimed in vacuo. If too impure then extract in a Soxhlet using toluene. evaporate the solvent and dissolve residue (ca 100g) in *C$_6$H$_6$ (1L) CARCINOGEN, use an efficient fume cupboard) and chromatograph through an A$_{120}$ column (50 x 450 mm). The eluent (ca 3L) is evaporated to ca 150mL and cooled when ca 103g of phenoxazine m 149-153° is obtained. Sublimation yields platelets m 158-159°. It forms a green picrate m 141.5-142°. [Gilman and Moore J Am Chem Soc 79 3485 1957; Muller et al. J Org Chem 24 37 1959.]


Phenoxyacetyl chloride [701-99-5] M 170.6, b 112°/10mm, 102°/16mm, 225-226°/atm, d'' 1.235, n'' 1.534. If it has no OH band in the IR then distil in a vacuum, taking precautions for the moisture-sensitive compound. If it contains free acid (due to hydrolysis, OH bands in the IR) then add an equal volume of redistilled SOCl$_2$, reflux for 2-3h, evaporate and distil the residue in a vacuum as before. The amide has m 101°. [McElvain and Carney J Am Chem Soc 68 2592 1946.]

4-Phenoxyaniline [139-59-3] M 185.2, m 95°, pK$_Z$ 4.44 (50% aq EtOH). Crystd from water.

Phenoxybenzamine [N-(2-chloroethyl)-N-(1-methyl-2-phenoxyethyl)benzylamine] [59-96-1] M 303.5, m 38-40°, hydrochloride [63-92-3] M 340.0, m 137.5-140°, pK$_{Est}$ ~4.2. The free base is crystd from pet ether and the HCl is crystd from EtOH/diethyl ether.

2-Phenoxybenzoic acid [2243-42-7] M 214.2, m 113°, b 355°/760mm, pK$_{15}$ 3.53. Crystd from aqueous EtOH.


Phenoxybutyric acid (lactic acid 0-phenylether) [940-31-8] M 180.2, m 64°, 65-66°, 82-83°, 99°, b 180-185°/12mm, pK 3.17. It has been purified by recrystn from pet ether, *C$_6$H$_6$, Et$_2$O-pet ether, EtOH and from H$_2$O. It can be steam distd or distd in a good vac. [UV: Ramart-Lucas and Hoch Bull Soc Chim Fr [4] 51 824 1932; Dann and Arndt Justus Liebigs Ann Chem 587 38 1954.] The acid chloride has b 154-156°/20mm [Hamford and Adams J Am Chem Soc 57 921 1935]; and the amide crystallises from *C$_6$H$_6$ as needles m 113°.

2-Phenoxypropionic acid (lactic acid O-phenylether) [940-31-8] M 166.2, m 115-116°, b 105-106°/5mm, 265-266°/758mm, pK 3.11. Crystd from water.

Phensuximide (N-methyl-2-phenylsuccinimide) [86-34-0] M 189.2, m 71-73°. Crystd from hot 95% EtOH.
Phenylacetamide [103-81-1] M 135.2, m 158.5°. Crystd repeatedly from absolute EtOH. Dried under vacuum over P₂O₅.

Phenyl acetate [122-79-2] M 136.2, b 78°/10mm, d 1.079, n₂2 1.5039. Freed from phenol and acetic acid by washing (either directly or as a soln in pentane) with aqueous 5% Na₂CO₃, then with saturated aqueous CaCl₂, drying with CaSO₄ or Na₂SO₄, and fractional distn at reduced pressure.

Phenylacetic acid [103-82-2] M 136.2, m 76-77°, b 140-150°/20mm, pK₁ -7.59 (aq H₂SO₄), pK₂ 4.31. Crystd from pet ether (b 40-60°), isopropyl alcohol, aq 50% EtOH or hot water. Dried under vac. It can be distd under reduced pressure.

Phenylacetone (1-phenylpropan-2-one) [103-79-9] M 134.2, b 69-71°/3mm, d 1.00, n₁ 1.516. Converted to the semicarbazone and crystd three times from EtOH (m 186-187°). The semicarbazone was hydrolysed with 10% phosphoric acid and the ketone was distd. [Kumler, Strait and Alpen J Am Chem Soc 72 1463 1950.]

4'-Phenylacetophenone [92-91-1] M 196.3, m 162O, pK₁ 5 2.58, pK₂ 9.24. Crystd from water and L-Phenylalanine [63-91-2] M 165.2, m 280°(dec), [α]D 25 -34.0° (c 2, H₂O). Likely impurities are leucine, valine, methionine and tyrosine. Crystd from water by adding 4 volumes of EtOH. Dried under vac over P₂O₅. Also crystd from satd refluxing aq solns at neutral pH, or 1:1 (vlv) EtOWater soln, or conc HCl. Phenylalaninol (2-amino-3-phenylpropan-1-ol) [R-(+)- 5267-64-1; S-(-)- 3182-95-4] M 151.2, m 91-92°, 91.5°, 92-94°, b 80°/11mm (Kügelrohr), [α]D 25 (+) and (-) 23-28.7° (c 1-5, EtOH), pKₑ₄ -9.3. It can be recrystd from Et₂O, *CsH₅-pet ether (40-60°) or toluene and distd in a vacuum. Has been purified by dissolving in Et₂O, drying over K₂CO₃, filtering, evaporating to a small volume, cooling in ice and collecting the plates. Store in the presence of KOH (i.e. CO₂-free atm). [Karrer and Ehrhardt Helv Chim Acta 34 3203 1951; Oeda Bull Chem Soc Jpn 13 465 1938.] The pivate has m 141-141.5° (from EtOH-pet ether). The hydrogen oxalate has m 177°, 161-162° [Hunt and McHale J Chem Soc 2073 1957]. The racemate has m 87-88° from *C₂H₅-pet ether (75-77° from Et₂O), and the hydrochloride has m 139-141° [Fodor et al. J Chem Soc 1858 1951].

3-Phenylallyl chloride (cinnamyl chloride) [E: 18685-01-3; Z: 39199-93-4] M 152.6, b 92-93°/3mm. Distd under vacuum three times from K₂CO₃.

Pheny 4-aminosalicylate [133-11-9] M 229.2, m 153°, pKₑ₄(1) -2.0 (NH₂), pKₑ₄(2) -9.7 (OH). Crystd from isopropanol.


9-Phenylanthracene [602-55-1] M 254.3, m 153-154°, b 417°. Crystd from water and *benzene and crystd from acetic acid.

N-Phenylantranilic acid [57-93-5] M 213.2, m 182-183°, pK₁ 1.28 (aq H₂SO₄), pK₂ 3.86 (CO₂H). Crystd from EtOH (5mL/g) or acetic acid (2mL/g) by adding hot water (1mL/g).
2-Phenyl-1-azaindolizine [56983-95-0] \( M \) 194.2, \( m \) 140°, \( pK_{\text{EtOH}} \approx 1.9 \). Crystd from EtOH or *benzene/pet ether.

\( p \)-Phenylnazobenzoyl chloride [104-24-5] \( M \) 244.7, \( m \) 93°. Crystd from pet ether (b 60-80°).

4-Phenylazo-1-naphthylamine [131-22-6] \( M \) 247.3, \( m \) 125-125.5°. Crystd from cyclohexane or aq EtOH. [Brode et al. J Am Chem Soc 74 4641 1952.1]

1-Phenylazo-2-naphthylamine [85-84-7] \( M \) 247.3, \( m \) 102-104°. See 1-benzeneazo-2-naphthylamine on p. 120.

4-Phenylazophenacyl bromide [62625-24-5] \( M \) 317.3, \( m \) 103-104°. Purified on a column of silica gel, using pet ether/diethyl ether (9:1 v/v) as solvent.

4-Phenylazophenol (4-hydroxyazobenzene) [1689-82-3] \( M \) 198.2, \( m \) 155°, \( pK_a^1 \approx 0.93 \), \( pK_a^2 \approx 8.2 \). Crystd from *benzene or 95% EtOH.

Phenyl benzenethiosulfonate (diphenyldisulfoxide) [121-20-8] \( M \) 250.3, \( m \) 36-37°, 45-46°, 45-47°. Recrystd from EtOH or MeOH. Also purified from phenylsulfide impurities by dissolving in CHCl₃, washing with aq satd NaHCO₃, drying (Na₂SO₄) evaporating and the residual oil was passed through a silica gel column (600g) and eluted with *C₆H₆ (1L, 4:1, eluting PhSSPh) then *C₆H₆ (1L) which elutes PhSSO₂Ph. [Trost and Massiot J Am Chem Soc 99 4405 1977; Knoevenagel and Romer Chem Ber 56 215 1923.1]

Phenyl benzoate [93-99-2] \( M \) 198.2, \( m \) 69.5°, b 198-199°. Crystd from EtOH using ca twice the volume needed for complete soln at 69°.

Phenyl-1,4-benzoquinone [363-03-1] \( M \) 184.2, \( m \) 114-115°. Crystd from heptane or pet ether (b 60-70°) and sublimed in vacuo. [Carlson and Miller J Am Chem Soc 107 479 1985.1]

1-Phenylbiguanide [102-02-3] \( M \) 177.2, \( m \) 144-146°, \( pK_1^{15} \approx 2.16 \), \( pK_2^{15} \approx 10.74 \). Crystd from water or toluene.

1-Phenylbutanol [22135-49-5] \( M \) 150.2, \( m \) 46-47°, 46-48°, 49°, b 90-92°/2mm. \([\alpha]_D^{20} -51.4° \) (c 5, CHCl₃), -44.7° (c 5.13, *C₆H₆). Purified by distn and crystallises on cooling. The hydrochloride has \([\alpha]_D^{20} +45.1° \) (c 4.8, *C₆H₆). The (-)-hydroperoxide has b 58°/0.005mm, \( n_\text{D}^{18} 1.5123 \), \( [\alpha]_D^{18} -2.14° \), \( (l = 0.5dcm, neat) \). [Holding and Ross J Chem Soc 145 1954; Davies and Feld J Chem Soc 4637 1958.] The (z)-racemate has b 73°/0.05mm, and its 4-nitrophenyldrazone has \( m \) 58°. [Prelog and Scherrer Helv Chim Acta 42 2227 1959; Levene and Marker J Biol Chem 93 761 1932, 100 685 1933; Cram J Am Chem Soc 74 2137 1952.1]

2-Phenylbutyramide [90-26-6] \( M \) 163.2, \( m \) 86°. Crystd from water.

2-Phenylbutyric acid [R-(-) 938-79-4; S-(+) 4286-15-1] \( M \) 164.2, b 102-104°/atm, \( d_1^{10} 1.056 \), \( n_\text{D}^{10} 1.521 \), \( [\alpha]_D^{10} (+) (+) 96° \) (c 2.5, *C₆H₆), \( [\alpha]_D^{25} (+) (+) 5.8° \) (neat), \( pK_{\text{EtOH}} \approx 4.3 \). Purified by distn at atmospheric pressure using an efficient column. The acid chlorides have b 106-107°/20mm, \( [\alpha]_D^{15} (+) (+) 108° \) (c 2. *C₆H₆). [Levene et al. J Biol Chem 100 589 1933, Gold and Aubert Helv Chim Acta 41 1512 1958; ORD in heptane: Rothen and Levene J Chem Phys 7 975 1939.1]

3-Phenylbutyric acid [R-(-)- 772-14-5; S-(+) 772-15-6] \( M \) 164.2, b 94-95°/3mm, 134°/4mm, \( d_1^{26} 1.066 \), \( n_\text{D}^{26} 1.5167 \), \( [\alpha]_D^{26} (+) (+) 57° \) (c 1, *C₆H₆), \( pK_1^{25} 4.40 \). Purified as the 2-isomer above, i.e. by distn, but under a good vacuum. [Prelog and Scherrer Helv Chim Acta 42 2227 1959; Levene and Marker J Biol Chem 93 761 1932, 100 685 1933; Cram J Am Chem Soc 74 2137 1952.1] The R-amide
crystallises from H₂O, m 101.5-102°, [α]₀²⁰ -16.5° (c 1.2, EtOH). The racemic acid has m 39-40°, b 134-136°/6mm. 158°/12mm [Marvel et al. J Am Chem Soc 62 3499 1940].

4-Phenylbutyric acid [1821-12-1] M 164.2, m 50°, pK₂ 4.76. Crystd from pet ether (b 40-60°).

o-(Phenylcarbamoyl)-1-scopolamine methobromide [138-10-3] M 518.4, m 200.5-201.5° (dec). Crystd from 95% EtOH.


O-Phenyl chlorothionoformate [1005-56-7] M 172.6, b 81-83°/6mm, 91°/10mm, d₂⁰ 1.276, n₂⁰ 1.585. Purified by dissolving in CHCl₃, washing with H₂O, drying (CaCl₂), filtering, evaporating and distilling twice under vacuum to give a clear yellow liquid. It is reactive and POISONOUS - work in a fume cupboard. Store in sealed ampoules under N₂. Possible impurity is O,O'-diphenyl thiocarbonate which has m 106° which remains behind in the distilling flask. [Bögemann et al. in Methoden Der Organischen Chemie (Houben-Weyl) 4th edn (E. Müller Ed.) Vol 9 Schwefel-Selen-Tellur Verbindungen pp. 807-808 1955; Rivier and Schalch Helv Chim Acta 20,612 1932; Kalson Chem Ber 20, 2384 1987; Rivier and Richard Helv Chim Acta 8 490 1925; Schönberg and Varga Justus Liebigs Ann Chem 483 176 1930; Chem Ber 64 1390 1931.]

Phenyl cinnamate [2757-04-2] M 224.3, m 75-76°, b 205-207°/15mm. Crystd from EtOH (2mL/g). It can also be distd under reduced pressure.

α-Phenylcinnamic acid [91-48-5] M 224.3, m 174°(cis), m 138-139°(trans), pK 4.8 (60% aq EtOH). Crystd from ether/pet ether.

o-Phenylendiamine [95-54-5] M 108.1, m 100-101°, pK₂ 0.67 (aq H₂SO₄), pK₂ 4.47 (4.85). Crystd from aqueous 1% sodium hydrosulphite (charcoal), washed with ice-water and dried in a vacuum desiccator, or sublimed in vacuo. It has been purified by recrystn from toluene and zone refined [Anson et al. J Am Chem Soc 108 6593 1986]. Purification by refluxing a CH₂Cl₂ solution containing charcoal was also carried out followed by evaporation and recrystn [Koola and Kochi J Org Chem 52 4545 1987], protect from light.


o-Phenylendiamine dihydrochloride [615-28-1] M 181.1, m 180°. Crystd from dilute HCl (60mL conc HCl, 40mL water, with 2g stannous chloride), after treatment of the hot soln with charcoal by adding an equal volume of conc HCl and cooling in an ice-salt mixture. The crystals were washed with a small amount of conc HCl and dried in a vacuum desiccator over NaOH.

2-Phenyl-1,3-diazahexahydroazulene [2161-31-1] M 212.3. Recrystd three times from de-aerated cyclohexane in the dark.
Purification of Organic Chemicals

1,4-Phenylene diisothiocyanate (bitoscanate) [4044-65-9] M 192.3, m 129-131°, 130-131°, 132°. Purified by recrystn from AcOH, pet ether (b 40-60°), Me2CO or aq Me2CO. [van der Kerk et al. Rec Trav Chim Pays-Bas 74 1262 1955; Leiber and Slutkin J Org Chem 27 2214 1962.]


l-Phenyl-1,2-ethanediol [13323-81-4] M 122.2, b 60.5-61.0°/3mm, 106-107°/22-23mm, d 1.01, n25m5 1.5254. Purified via its hydrogen phthalate. [See Houssa and Kenyon J Chem Soc 2260 1930.]

Shaken with a soln of ferrous sulfate, and the alcohol layer was washed with distilled H2O, dried (MgSO4) and fractionally distd.

2-Phenylethanol [60-12-8] M 122.2, b 215-217°, d 1.020. Purified by shaking with a soln of ferrous sulfate, and the alcohol layer was washed with distd water and fractionally distd.

Phenyl ether (diphenyl ether) [101-84-8] M 170.2, m 27.0°, d 1.074, n30m7 1.57596. Crystd from 90% EtOH. Melted, washed with 3M NaOH and water, dried with CaCl2 and fractionally distd under reduced pressure. Fractionally crystd from its melt and stored over P2O5.

1-Phenylethyl isocyanate (α-methylphenyl isocyanate) [R-(+)- 33375-06-3; S(-) 14649-03-7] M 147.2, b 82-83°/12-14mm, d20 1.045, n20 1.513, [α]D24 (+) and (-) 29° (c 3.5, *C6H6), (+) and (-) 10.5° (neat). Purified by fractional distn under vacuum. With ammonia it gives the ureido derivative which crystallises from H2O, m 121-122°, [α]D25 (+) and (-) 48.8°. [Cairns J Am Chem Soc 63 870 1941.]

The racemate has b 90-94°/3mm, 96°/18mm [Seifan Justus Liebigs Ann Chem 562 75 1949.]


5-(α-Phenylethyl)semioxamazide [93-95-8] M 207.1, m 167-168° (l-), 157° (dL-). Crystd from EtOH.

9-Phenyl-3-fluorone [975-17-7] M 320.3, m >300°(dec), λmax 462nm (ε 4.06 x 104, in 1M HCl aq EtOH). Recrystd from warm, acidified EtOH by addition of ammonia. The crude material (1g) can be extracted with EtOH (50mL) in a Soxhlet apparatus for 10h to remove impurities. Impurities can be detected by paper electrophoresis. [Petrova et al. Anal Lett 5 695 1972.]


Phenyldrazine [100-63-0] M 108.1, m 23°, b 137-138°/18mm, 241-242°/760mm, d 1.10, n 1.607, pK10 -5.2 (aq H2SO4), pK15 5.27. Purified by chromatography, then crystd from pet ether (b 60-80°)*benzene. [Shaw and Stratton J Chem Soc 5004 1962.]

Phenyldrazine hydrochloride [59-88-1] M 144.5, m 244°. One litre of boiling EtOH was added to 100g of phenyldrazine hydrochloride dissolved during 1-3h (without heating) in 200mL of warm water (60-70°). The soln was filtered off, while still hot, through Whatman No 2 filter paper and cooled in a refrigerator. The ppe was collected on a medium sintered-glass filter and recrystd twice this way, then washed with cold EtOH, dried thoroughly and stored in a stoppered brown bottle. [Peterson, Karrer and Guerra Anal Chem 29 144 1957.] Hough, Powell and Woods [J Chem Soc 4799 1956] boiled the hydrochloride with three times its weight of water, filtered hot (charcoal), added one-third volume of conc HCl and cooled to 0°. The crystals were washed with acetone, and dried over P2O5 under vacuum. The salt has also been crystd from 95% EtOH.
Phenylhydroxylamine (N-hydroxyaniline) \([100-65-2]\) M 109.1, m 82°, pK 3.2. Impure base deteriorates rapidly. Crystd from H₂O, *C₆H₆ or *C₆H₅pet ether (40-60°). Picrate has m 186°.

2-Phenyl-1,3-indandione \([83-12-5]\) M 222.2, m 149-151°, pK 4.12 (1% aq MeOH). Crystd from EtOH.

2-Phenylindolizine \([25379-20-8]\) M 119.1, b 45-47°/10mm, d 1.093, n 1.536. Distd under reduced pressure from P₂O₅.

Phenylisothiocyanate (phenyl mustard oil) \([103-72-0]\) M 135.2, m -21°, b 95°/12mm, 117.1°/33mm, 221°/760mm, d 1.128, n 1.64918. It is insol in H₂O, but sol in Et₂O and EtOH. If impure (due to formation of thiourea) then steam dist into a receiver containing 5-10mL of N H₂SO₄. Separate the oil, dry over CaCl₂ and distil under vacuum. [Dahs et al. Org Synth Coll Vol I 447 1941.]

8-Phenylmenthol \([1R,2S,SR-(-)- 65253-04-5; lS,2R,5S-(+)- 57707-91-2]\) M 232.4, [α] D (-) and (+) 26° (c 2, EtOH). Dissolve in toluene, dry (Na₂SO₄), evap and chromatograph on a silica gel column and eluting with 5% Et₂O in pet ether to give an oil with the desired rotation. IR has v 3420cm⁻¹ (OH) with consistent IH NMR [Corey and Ensley J Org Chem 43 1610 1978; Whitesell et al. Tetrahedron 42 2993 1986; Bednarski and Danishefsky J Am Chem Soc 108 7060 1986.]


Phenyl methanesulfonate \([16156-59-5]\) M 172.1, m 61-62°. Crystd from MeOH.

2-Phenylpropanal \([93-53-8]\) M 134.2, b 206°/760mm, d 1.001, n 1.5183. May contain up to 15% of acetophenone. Purified via the bisulfite addition compound [Lodge and Heathcock J Am Chem Soc 109 3353 1987 and see Chapter 2 for prepn, and decompn, of bisulfite adduct.

Phenylpropiolic acid [637-44-5] M 146.2, m 137.8-138.4°, pK 2.23. Crystd from *benzene, CCl₄ or aqueous EtOH.

RS-2-Phenylpropionic acid \([492-37-5]\) M 150.2, m 16-16.5°, b 153-155°/20 mm, 189°/48mm, 260-262°/atm, d 1.10, n 1.522, pK 4.3. Fractionally distd, or recrystd from pet ether (b 40-60°) strong cooling (see references below).

2-Phenylpropionic acid \([R-(-)- 7782-26-5; S-(+)- 7782-24-3]\) M 150.2, m 30.3-31°, 30-32°, b 115°/1-2mm, 142°/12mm, [α] D (-) and (+) 99.7° (l = 1 dcm, neat), (-) and (+) 89.1° (c
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1.7, EtOH), (-) and (+) 75° (c 1.6, CHCl3). Purified by vacuum distn and by recrystn from pet ether. The S-anilide has m 103-104° (from H2O or CHCl3/*C6H6), [α]D25 +47° (c 9, Me2CO) [Argus and Kenyon J Chem Soc 916 1939; Campbell and Kenyon J Chem Soc 25 1946; Levene et al. J Biol Chem 88 27, 34 1930; Beilstein 9, 3rd Suppl p 2417].

3-PHENYLPROPIONIC ACID (HYDROCINNAMIC ACID) M 150.2, m 48-48.5°, pK25 4.56. Crystd from *benzene, CHCl3 or pet ether (b 40-60°). Dried in a vacuum.

3-PHENYLPROPYL BROMIDE M 199.1, b 110°/12mm, 128-129°/29mm, d 1.31. Washed successively with conc H2SO4, water, 10% aqueous Na2CO3 and again with water, then dried with CaCl2 and fractionally distd just before use.

PHENYL 2-PYRIDYL KETOXIME M 198.2, m 110.5-111.5°, pK25 -5.2. Crystd from EtOH (charcoal).

2-PHENYLQUINOLINE-4-CARBOXYLIC ACID (CINCHOPHEN) M 249.3, m 215°, pK25 -0.5 (CO2H), pK25 -11.0 (OH). Dissolved in ca 1 equivalent of saturated aqueous Na2CO3, filtered and ppted by adding 0.8 equivalents of M HCl. Crystd from ethylene dichloride (charcoal), and sublimed at 0.1mm. [Brooks, Eglington and Norman J Chem Soc 66 1 1961].

1-PHENYL-5-SULFANILAMIDOPYRAZOLE M 314.3, m 179-183°. Crystd from EtOH.

4-PHENYLTHIOSEMICARBAZIDE M 537-47-3. Crystd from water and dried in vac over KOH.

PHENYLSEMICARBAZIDE M 151.2, m 172°. Crystd from water and dried in vac over KOH.

1-PHENYL-2-THIOUREA [103-85-5] M 152.1, m 154°. Crystd from water and dried at 100° in air.

1-PHENYL-5-SULFANILAMIDOPYRAZOLE [526-08-9] M 314.3, m 179-183°. Crystd from EtOH.


1-PHENYL-2-THIOUREA [103-85-5] M 152.1, m 154°. Crystd from water and dried at 100° in air.

1-PHENYL-2-Thioure a [103-85-5] M 152.1, m 154°. Crystd from water and dried at 100° in air.

PHENYLSEMICARBAZIDE [537-47-3] M 151.2, m 172°. Crystd from water and dried in vac over KOH.

3-PHENYLPROPIONIC ACID (HYDROCINNAMIC ACID) M 150.2, m 48-48.5°, pK25 4.56. Crystd from *benzene, CHCl3 or pet ether (b 40-60°). Dried in a vacuum.
Phenyl 4-toluenesulfonate [640-60-8] M 248.2, m 94.5-95.5°. Crystd from MeOH or glacial acetic acid.


4-Phenyl-1,2,4-triazole-3,5-diol (4-phenylurazole) [15988-11-1] M 175.2, m 207-209°. Crystd from water.

4-Phenyl-1,2,4-triazoline-3,5-dione (PTAD) [4233-33-4] M 175.2, m 165-170°(dec), 170-177°(dec). Carmin red needles obtained by sublimation (ice cold finger) at 100°/0.1mm, and/or by recrystn from EtOH. IR: v 1760, 1780 cm⁻¹. [Cookson et al. Org Synth 51 121 1971; Moore et al. J Org Chem 39 3700 1974.]


Phenylurea [64-10-8] M 136.2, m 148°, pKₓₓ (aq H₂SO₄). Crystd from boiling water (10mL/g). Dried in a steam oven at 100°.

9-Phenyl-9-xanthenol (hydroxypixyl) [596-38-3] M 274.3, m 158-161°, 158.5-159°, 159°. Dissolve in AcOH and add H₂O whereby it separates as colourless prisms. It is slightly soluble in CHCl₃, soluble in *C₆H₆ but insoluble in pet ether. It sublimes on heating. UV in H₂SO₄: δmax 450nm (E 5620) and 375nm (E 24,900) and the HClO₄ salt in CHCl₃ has δmax 450 (E 404) and 375nm (E 2420). [Shar J Chem Soc 2558 1958; Bünzly and Decker Chem Ber 37 2983 1904; Chattopadhyaya and Reece J Chem Soc, Chem Commun 639 1978; Gomberg and Cone Justus Liebigs Ann Chem 370 142 1909.]

Phloridzin (2H₂O) [phloretin 2'-O-P-D-glucoside] [60-81-11 M 472.5, m 110°, [α]⁺₂₀ 546 -62° (c 3.2, EtOH). Crystd from aqueous EtOH.

Phlorizin (2H₂O) [phloretin 2'-O-β-D-glucoside] [60-81-1] M 472.5, m 110°, [α]⁺₂₀ 346 -62° (c 3.2, EtOH). Crystd as dihydrate from water.

Phloroacetophenone (2H₂O) (2',4',6'-trihydroxyacetophenone) [480-66-0] M 186.2, m 218-219°, pKₓₓ(1)-7.9, pKₓₓ(2)-12.0. Crystd from hot water (35mL/g).

Phloroglucinol (2H₂O) (benzene-1,3,5-triol) [6099-90-7 (2H₂O); 108-73-6 (anhydr)] M 126.1, m 217-219°, 117° (anhydrous), pKₓₓ 7.74 (HClO₄), pK₂ₓₓ 7.97, pK₃ₓₓ 9.23. Crystd from water, and stored in the dark under nitrogen.

Phorone (2,6-dimethylhepta-2,5-dien-4-one) [504-20-1] M 138.2, m 28°, b 197°/743mm. Crystd repeatedly from EtOH.

"Phosphine" [dye CI 793, Chrysaniline mononitrate, 3-amino-9-(4-aminophenyl)-acridinium mononitrate] [10181-37-0] M 348.4, m >250°(dec), pKₓₓ -8.0. Crystd from benzene/EtOH.

Phthalaldehyde [643-79-8] M 134.1, m 54-56°, 55.5-56°, 58°, b 83-84°/0.8mm. Purified by steam distillation better by using super heated steam (at 175-180°) and efficient cooling. The distillate is saturated with Na₂SO₄ extracted exhaustively with EtOAc, dried (Na₂SO₄), filtered and evaporated. The residue
is recrystd from pet ether (b 90-100°) [Beill and Tarbell Org Synth Coll Vol IV 808 1963]. It can be distd under vacuum. The bis-2,4-dinitrophenylhydrazone has m 278-280° [Hatt and Stephenson J Chem Soc 199 1952].

Phthalazine [253-52-1] M 130.2, m 90-91°, pK2 3.47. Crystd from diethyl ether or *benzene, and sublimed under vacuum.


 o-Phthalic acid [88-99-3] M 166.1, m 211-211.5°, pK1 2.76 (3.05), pK2 5 4.92 (4.73). Crystd from water.

Phthalic anhydride [85-44-9] M 148.1, m 132°, b 295°. Distd under reduced pressure. Purified from the acid by extracting with hot CHCl3, filtering and evaporating. The residue was crystd from CHCl3, CCl4 or *benzene, or sublimed. Fractionally crystd from its melt. Dried under vacuum at 100°. [Saltiel J Am Chem Soc 108 2674 1986]
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Picein (p-acetylphenyl-β-D-glucopyranoside) [530-14-3] M 298.3, m 195-196°, [α]D20 -88° (c 1, H2O). Crystd from MeOH or (as monohydrate) from water.


3-Picoline-N-oxide (3-methylpyridine-1-oxide) [1003-73-2] M 109.1, m 37-39°, 37-38° (evac capillary), 84-85°/0.3 mm, 101-103°/0.7-0.8 mm, 114-115°/1.5 mm, 118°/2 mm, pK2 1.08. Purified by careful fractionation in vacuo. The distillate remains supercooled for several days before solidifying. It is a slightly hygroscopic solid which could melt in the hand. The picrate has m 149-151° (from EtOH). [Taylor and Corvetti Org Synth Coll Vol IV 654 1963; IR: Katritzky et al. J Chem Soc 3680 1959; Jaffé and Doak J Am Chem Soc 77 4441, 4481 1955; Boekelheide and Linn J Am Chem Soc 76 1286 1954].


Picolinic acid (pyridine-2-carboxylic acid) [98-98-6] M 123.1, m 138°, pK' 1.03 (1.36), pK2 5.30 (5.80). Crystd from water or *benzene.

α-Picolinium chloride [14401-91-3] M 129.6, m 200°. 1:1 Mixture of α-picoline and HCl, distd at 275°. Then vacuum sublimed at 91-95.1°.


Pieric acid [88-89-1] M 229.1, m 122-123°, pK2 0.33 (0.37). Crystd first from acetic acid then acetone, toluene, CHCl3, aqueous 30% EtOH, 95% EtOH, MeOH or H2O. Dried in a vacuum oven at 80° for 2h. Alternatively, dried over Mg(ClO4)2 or fused and allowed to freeze under vacuum three times. Because it is EXPLOSIVE, picric acid should be stored moistened with H2O, and only small portions should be dried at any one time. The dried acid should NOT be heated.

Picrolonic acid (3-methyl-4-nitro-1-(4-nitrophenyl)-2-pyrazolin-5-one, picrolonic acid) [550-74-3] M 264.2, m 120°(dec),116.5° (dec at 125°) 125°. Crystd from water or EtOH (Solubility is 0.123% at 15° and 1.203 at 100° in H2O; and 1.107 at 0° and 11.68% at 81° in EtOH). It forms Ca, Cu Hg, Mg, Na, Sr, and Pb complexes [Maquestian et al Bull Soc Chim Belg 82 233 1973; Isaki et al. Chem Ber 74 1420 1941].

PicROTOXIN [124-87-8] M 602.6, m 203°, [α]D20 40° (c 1, EtOH). Crystd from water.

Picryl chloride [88-88-0] M 226.3, m 83°. Crystd from CHCl3 or EtOH.


Pimelic acid (heptane-1,7-dioic acid) [111-16-0] M 160.2, m 105-106°, pK2 4.46, pK2 5.58. Crystd from water or from *benzene containing 5% diethyl ether.
Pinacol (hexahydrate) \([6091-58-3 (6H_2O); 76-09-5 (anhyd)]\) M 194.3, m 46.5°, b 59°/4mm. Distd then crystd repeatedly from water.

Pinacol (anhydrous) \([76-09-5]\) M 118.1, m 41.1°, b 172°. The hydrate is rendered anhydrous by azeotropic distn of water with *benzene. Recrystd from *benzene or toluene/pet ether, absolute EtOH or dry diethyl ether. Recrystn from water gives the hexahydrate.

Pinacolone oxime \([2475-93-6]\) M 115.2, m 78°. Crystd from aqueous EtOH.

Pinacyanol chloride \([2768-90-3]\) M 388.9, m 270°(dec). Crystd from EtOWdiethyl ether.

*R*-Pinene \([7785-70-8]\) M 136.2, b 61°/30mm, 156.2°/760mm, d 0.858, n 1.4634, n 1.4658, \([\alpha]_D^{25} +47.3°\). Isomerised by heat, acids and certain solvents. Should be distd under reduced pressure under nitrogen and stored in the dark. Purified via the nitrosochloride [Waterman et al. *Recl Trav Chim Pays-Bas* 48 1191 1929]. For purification of optically active forms see Lynn [J Am Chem Soc 91 361 1919]. Small quantities (0.5mL) have been purified by GLC using helium as carrier gas and a column at 90° packed with 20 wt% of polypropylene sebacate on a Chromosorb support. Larger quantities were fractionally distd under reduced pressure in a column packed with stainless steel gauze spirals. Material could be dried with CaH₂ or sodium, and stored in a refrigerator: CaSO₄ and silica gel were not satisfactory because they induced spontaneous isomerisation. [Bates, Best and Williams J Chem Soc 1521 1962.]

*S*-Pinene \([7785-26-4]\) M 136.2, b 155-156°/760mm, d 0.858, n 1.4634, \([\alpha]_D^{20} +47.2°\]. Purification as for *R*-Pinene above.

dl-Piperic acid (piperidine-2-carboxylic acid) \([4043-87-2]\) M 129.1, m 264°, pKᵢ 5 2.29, pKᵢ 5 10.77. Crystd from water.

Piperazine \([110-85-0]\) M 86.1, m 110-112°, 44° (hexahydrate 142-63-2) b 125-130°/760mm, pKᵢ 5 5.33, pKᵢ 5 9.73. Crystd from EtOH or anhydrous *benzene, and dried at 0.01mm. It can be sublimed under vacuum and purified by zone melting. § Piperazine on polystyrene support is commercially available.

Piperazine-N,N'-bis(2-ethanesulfonic acid) (PIPES) \([5625-37-6]\) M 302.4, pKᵢ 5 3, pKᵢ 5 6.82 (7.82). Crystd from boiling water (maximum solubility is about 1gL) or as described for ADA [N-(2-acetamido)iminodiacetic acid, see above].

Piperazine dihydrochloride (H₂O) \([142-64-3 (2HCl); 6094-40-2 (xHCl)]\) M 177.1, m 82.5-83.5°. Crystd from aqueous EtOH. Dried at 110°.

Piperazine phosphate (H₂O) \([18534-18-4]\) M 197.6. Crystd twice from water, air-dried and stored for several days over Drierite. The salt dehydrates slowly if heated at 70°.

Piperic acid \([trans,trans-5-(3,4-methylenedioxyphenyl)-2,4-pentadieneoic acid]\) \([136-72-1]\) M 218.2, m 217°, pKᵢ 5 -4.7. Crystd from EtOH. Turns yellow in light. Sublimes with partial dec.

Piperidine \([110-89-4]\) M 85.2, f -9°, b 35.4°/40mm, 106°/760mm, d 0.862, n 1.4535, n 1.4500, pKᵢ 5 11.20. Dried with BaO, KOH, CaH₂, or sodium, and fractionally distd (optionally from sodium, CaH₂, or P₂O₅). Purified from pyridine by zone melting. § Piperidine on polystyrene support is commercially available.

Piperidinium chloride \([6091-44-7]\) M 121.6, m 244-245°. Crystd from EtOH/diethyl ether in the presence of a small amount of HCl.

Piperidinium nitrate \([6091-45-8]\) M 145.2, m 110°. Crystd from acetone/ethyl acetate.

Piperonal [120-57-0] M 150.1, m 37°, b 140°/15mm, 263°/760mm. Crystd from aqueous 70% EtOH or EtOH/water.

Piperonylic acid [94-53-1] M 166.1, m 229°, pK2 4.50. Crystd from EtOH or water.

Pivalic acid (trimethylacetic acid) [75-98-9] M 102.1, m 35.4°, b 71-73°/0.1mm, pK2 5.03. Fractionally distd under reduced pressure, then fractionally crystd from its melt. Recrystd from *benzene.

Pivaloyl chloride (trimethylacetyl chloride) [3282-30-2] M 120.6, b 57.6°/150mm, 70.5-71/250mm, 104°/754mm, 104-105°/atm, dD2 1.003, nD2 1.4142. First check the IR to see if OH bands are present. If absent, or present in small amounts, then redistil under moderate vac. If present in large amounts then treat with oxalyl chloride or thionyl chloride and reflux for 2-3h, evap and distil residue. Strongly LACHRYMATORY - work in a fumecupboard. Store in sealed ampoules under N2. [Traynham and Battiste J Org Chem 22 1551 1957; Grignard reactns: Whitmore et al. J Am Chem Soc 63 647 1941.]

Plumbagin (5-hydroxy-2-methyl-1,4-naphthaquinone) [481-42-5] M 188.1, m 78-79°, pKEm(1) -9.5, pKEm(2) -11.0. Crystd from aqueous EtOH and sublimed in a vac. Steam distils.

Polyacrylonitrile [25014-41-9]. Ppted from dimethylformamide by addition of MeOH.

Poly(diallyldimethylammonium) chloride [26062-79-3]. Ppted from water in acetone, and dried in vacuum for 24h. [Hardy and Shriner J Am Chem Soc 107 3822 1985.]

Polyethylene [9002-88-4]. Crystd from thiophen-free *benzene and dried over P2O5 under vacuum.

Polymethyl acrylate [9003-21-8]. Ppted from a 2% soln in acetone by addition of water.


Polyvinyl acetate [9002-81-2]. Ppted from cyclohexanone by addition of MeOH.

Poly(N-vinylcarbazole) [25067-59-8]. Ppted seven times from tetrahydrofuran with MeOH, with a final freeze-drying from *benzene. Dried under vacuum.

Polyvinyl chloride [9002-81-2]. Ppted from cyclohexanone by addition of MeOH.

Poly(4-vinylpyridine) [25232-41-1] M (105.1)n. Purified by repeated pptn from solns in EtOH and dioxane, and then EtOH and ethyl acetate. Finally, freeze-dried from tert-butanol.

Poly(N-vinylpyrrolidone) [9003-39-8] M (111.1)n. crosslinked [25249-54-1] M >300°. Purified by dialysis, and freeze-dried. Also by pptn from CHCl3 soln by pouring into ether. Dried in a vacuum over P2O5. For the crosslinked polymer purification is by boiling for 10min in 10% HCl and then washing with glass-distilled water until free from Cl ions. Final Cl ions were removed more readily by neutralising with KOH and continued washing.

Prednisone [53-03-2] M 358.5, m 238°(dec), [α]D20 +168° (c 1, dioxane), λmax 238nm (log ε 4.18) in MeOH. Crystd from acetone/hexane.

5β-Pregnane-3α,20α-diol [80-92-2]  M 320.5, m 243-244°, [α]_D^{20} +31° (c 1, EtOH). Crystd from acetone.

5β-Pregnane-3α,20β-diol [80-91-1]  M 320.5, m 244-246°, [α]_D^{20} +22° (c 1, EtOH). Crystd from EtOH.

Procaine [4-(2-diethylaminomethoxy carbonyl) aniline] [59-46-1]  M 236.3, m 51° (dihydrate), 61° (anhydrous), pK_1^{15} 2.45, pK_2^{15} 8.91. Crystd as the dihydrate from aqueous EtOH and as anhydrous material from pet ether or diethyl ether. The latter is hygroscopic.

Proclavine (3,6-diaminoacridine) [92-62-6]  M 209.2, m 284-286°, pK_2^{25} 9.60. Crystd from aqueous MeOH. For proflavin see 3.6-diaminoacridine hydrochloride.

Progestrone [57-83-0]  M 314.5, m 128.5°, [α]_D^{20} +220° (c 2, dioxane). Crystd from EtOH.

L-Proline [147-85-3]  M 115.1, m 215-220°(dec)(D-isomer), 220-222°(dec) (L-form), 205°(dec)(DL-isomer), [α]_D^{25} (H_2O, L-isomer), pK_1^{15} 1.95, pK_2^{15} 10.64. Likely impurity are hydroxyproline. Purified via its picrate which was crystd twice from water, then decomposed with 40% H_2SO_4. The picric acid was extracted with diethyl ether, the H_2SO_4 was pptd with Ba(OH)_2, and the filtrate evapd. The residue was crystd from hot absolute EtOH [Mellan and Hoover J Am Chem Soc 73 3879 1951] or EtOH/ether. Hygroscopic. Stored in a desiccator.


L-Prolylglycine [2578-57-6]  M 172.2, m 236°, [α]_D^{20} +21.1° (c 4, H_2O), pK_1^{25} 3.19, pK_2^{25} 8.97. Crystd from water at 50-60° by addition of EtOH.

Proline-1,2-diamine (propylene diamine) [78-90-0]  M 74.1, b -189.7, d -42.1°/760mm, d 0.5005, n 1.2898. Purified by bromination of the olefinic contaminants. Propane was treated with bromine for 30min at 0°. Unreacted bromine was quenched, and the propane was distd through two -78° traps and collected at -196° [Skell et al. J Am Chem Soc 108 6300 1986].

Propan-1,2-diol (propylene glycol) [57-55-6]  M 76.1, b 104°/32mm, d 1.040, n 1.433. Dried with Na_2SO_4, decanted and distd under reduced pressure.

Propane-1,3-diol [504-63-2]  M 76.1, b 110-122°/12mm, d 1.053, n 1.4398. Dried with K_2CO_3 and distd under reduced pressure. More extensive purification involved conversion with benzaldehyde to 2-phenyl-1,3-dioxane (m 47-48°) which was subsequently decomposed by shaking with 0.5M HCl (3mL/g) for 15min and standing overnight at room temperature. After neutralisation with K_2CO_3, the benzaldehyde was removed by distn and the diol was recovered from the remaining aqueous soln by continuous extraction with CHCl_3 for 1day. The extract was dried with K_2CO_3, the CHCl_3 was evaporated and the diol was distd. [Foster, Haines and Stacey Tetrahedron 6 177 1961.]
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Propane-1-thiol \([107-03-9]\)  M 76.1, b 65.3°/702mm, \(d^25\) 0.83598, \(n^25\) 1.43511, \(pK^{10}\) 10.82. Purified by soln in aqueous 20% NaOH, extraction with a small amount of benzene and steam distn until clear. After cooling, the soln was acidified slightly with 15% \(H_2SO_4\), and the thiol was distd out, dried with anhydrous \(CaSO_4\) or \(CaCl_2\), and fractionally distd under nitrogen. [Mathias and Filho J Phys Chem 62 1427 1958.] Also purified by liberation of the mercaptan by adding dilute HCl to the residue remaining after steam distn. After direct distn from the flask, and separation of the water, the mercaptan was dried (\(Na_2SO_4\)) and distd under nitrogen.

Propane-2-thiol (Isopropyl mercaptan) \([75-33-2]\)  M 76.1, b 49.8°/696mm, \(d^25\) 0.80895, \(n^25\) 1.42154, \(pK^{15}\) 10.86. Purified as for propane-1-thiol above.

Propargyl alcohol (2-propyn-1-ol) \([107-19-7]\)  M 56.1, b 54°/57mm, 113.6°/760mm, d 0.947, \(n\) 1.432. Commercial material contains a stabiliser. An aqueous soln of propargyl alcohol can be concentrated by azetotropic distn with butanol or butyl acetate. Dried with \(K_2CO_3\) and distd under reduced pressure, in the presence of about 1% succinic acid, through a glass helices-packed column.

Propargyl chloride (3-chloropropyne) \([624-65-7]\)  M 74.5, b 58°/760mm, 65°/760mm, d 1.03, \(n\) 1.435. Purified by fractional distn at atm press. Note that a possible impurity propargyl alcohol has b 114-115°/atm. [Henry Chem Ber 8 398 1875] HIGHLY TOXIC and FLAMMABLE.

Propene \([115-07-1]\)  M 42.1, m -185.2°, b -47.8°/750mm, d 0.519, \(n^71\) 1.357. Purified by freeze-pump-thaw cycles and trap-to-trap distn.

\(p\)-(1-Propeny1)phenol \([cis/trans \, 6380-21-8; \, 539-12-8]\)  M 134.2, m 93-94°, \(pK_{\text{est}}\) -0.9 (H, scale, aq HSO\(_4\)). Crystd from water.

\(\beta\)-Propiolactone \([57-57-8]\)  M 72.1, b 83°/45mm, d 1.150, \(n^25\) 1.4117. Fractionally distd under reduced pressure, from sodium. CARCINOGEN.

Propionaldehyde \([123-38-6]\)  M 58.1, b 48.5-48.7°, d 0.804, \(n\) 1.3733, \(n^25\) 1.37115. Dried with \(CaSO_4\) or \(CaCl_2\), and fractionally distd under nitrogen or in the presence of a trace of hydroquinone (to retard oxidation). Blacet and Pitts [J Am Chem Soc 74 3382 1952] repeatedly vacuum distd the middle fraction until no longer gave a solid polymer when cooled to -80°. It was stored with \(CaSO_4\).

Propionamide \([79-05-0]\)  M 73.1, m 79.8-80.8°, \(pK^{24}\) -0.9 (H\(_o\) scale, aq H\(_2\)SO\(_4\)). Crystd from acetone, benzene, CHCl\(_3\), water or acetone/water, then dried in a vacuum desiccator over \(P_2O_5\) or conc H\(_2\)SO\(_4\).

Propionic acid \([79-09-4]\)  M 74.1, b 141°, d 0.992, \(n\) 1.3865, \(n^25\) 1.3843, \(pK^25\) -6.8 (H\(_o\) scale, aq H\(_2\)SO\(_4\)), \(pK^25\) 4.88. Dried with \(Na_2SO_4\) or by fractional distn, then redistd after refluxing with a few crystals of KMnO\(_4\). An alternative purification uses the conversion to the ethyl ester, fractional distn and hydrolysis. [Bradbury J Am Chem Soc 74 2709 1952.] Propionic acid can also be heated for 0.5h with an amount of benzoic anhydride equivalent to the amount of water present (in the presence of \(CrO_3\) as catalyst), followed by fractional distn. [Cham and Israel J Chem Soc 196 1960.]

Propionic anhydride \([123-62-6]\)  M 130.2, b 67°/18mm, 168°/780mm, d 1.407, \(n\) 1.012. Shaken with \(P_2O_5\) for several minutes, then distd.

Propionitrile \([107-12-0]\)  M 55.1, b 97.2°, d 1.407, \(n^15\) 1.36812, \(n^30\) 1.36132. Shaken with dil HCl (20%), or with conc HCl until the odour of isonitrile has gone, then washed with water, and aqueous \(K_2CO_3\). After a preliminary drying with silica gel or Linde type 4A molecular sieves, it is stirred with \(CaH_2\) until hydrogen evolution ceases, then decanted and distd from \(P_2O_5\) (not more than 5g/L, to minimise gel formation). Finally, it is refluxed with, and slowly distd from \(CaH_2\) (5g/L), taking precautions to exclude moisture.
n-Propyl acetate  [109-60-4]  M 102.1, b 101.5°, d 0.887, n 1.38442, pK25 -7.18 (H2, scale, aq H2SO4). Washed with satd aqueous NaHCO3 until neutral, then with satd aqueous NaCl. Dried with MgSO4 and fractionally distd.

n-Propyl alcohol (1-propanol)  [71-23-8]  M 60.1, b 97.2°, d25 0.79995, n 1.385, pK25 16.1. The main impurities in n-propyl alcohol are usually water and 2-propen-1-ol, reflecting the commercial production by hydration of propene. Water can be removed by azeotropic distn either directly (azeotrope contains 28% water) or by using a ternary system, e.g. by adding benzene. Alternatively, for gross amounts of water, refluxing over CaO for several hours is suitable, followed by distn and a further drying. To obtain more nearly anhydrous alcohol, suitable drying agents are firstly NaOH, CaSO4 or K2CO3, then CaH2, aluminium amalgam, magnesium activated with iodine, or a small amount of sodium. Alternatively, the alcohol can be refluxed with n-propylsuccinate or phthalate in a method similar to the one described under EtOH. Allyl alcohol is removed by adding bromine (15mL/L) and then fractionally distilling from a small amount of K2CO3.

Propionaldehyde, also formed in the bromination, is removed as the 2,4-dinitrophenylhydrazone. n-Propyl alcohol can be dried down to 2Oppm of water by passage through a column of pre-dried molecular sieves (type 3 or 4A, heated for 3h at 300°) in a current of nitrogen. Distn from sulfanilic or tartaric acids removes impurities. Albrecht [J Am Chem Soc 82 3813 1960] obtained spectroscopically pure material by heating with charcoal to 50-60°, filtering and adding 2,4-dinitrophenylhydrazine and a few drops of conc H2SO4. After standing for several hours, the mixture was cooled to 0°, filtered and vac distn.

Albrecht [J Am Chem Soc 82 3813 1960] obtained spectroscopically pure material by heating with charcoal to 50-60°, filtering and adding 2,4-dinitrophenylhydrazine and a few drops of conc H2SO4. After standing for several hours, the mixture was cooled to 0°, filtered and vac distn. Gold and Satchell [J Chem Soc 1938 1963] heated n-propyl alcohol with 3-nitrophthalic anhydride at 76-110° for 15h, then recrystd the resulting ester from H2O, *benzene/pet ether (b 100-120°)(3:1), and *benzene. The ester was hydrolysed under reflux with aq 7.5M NaOH for 45min under nitrogen, followed by distn (also under nitrogen). The fraction (b 87-92°) was dried with K2CO3 and stirred under reduced pressure in the dark over 2,4-dinitrophenylhydrazine, then freshly distilled. Also purified by adding 2g NaBH4 to 1.5L alcohol, gently bubbling with argon and refluxing for 1day at 50°. Then added 2g of freshly cut sodium (washed with propanol) and refluxed for one day. Distd, taking the middle fraction [Jou and Freeman J Phys Chem 81 909 1977].


n-Propyl bromide.  [106-94-5]  M 123.0, b 71.0°, d 1.354., n15 1.43695, n25 1.43123. Likely contaminants include n-propyl alcohol and isopropyl bromide. The simplest purification procedure uses drying with MgSO4 or CaC12 (with or without a preliminary washed of the bromide with aq NaHCO3, then water), followed by fractional distn away from bright light. Chien and Willard [J Am Chem Soc 79 4872 1957] bubbled a stream of oxygen containing 5% ozone through n-propyl bromide for 1h, then shook with 3% hydrogen peroxide soln, neutralised with aq Na2CO3, washed with distilled water and dried. Then followed vigorous stirring with 95% H2SO4 until fresh acid did not discolor within 12h. The propyl bromide was separated, neutralized, washed dried with MgSO4 and fractionally distd. The centre cut was stored in the dark. Instead of ozone, Schuler and McCauley [J Am Chem Soc 79 821 1957] added bromine and stored for 4 weeks, the bromine then being extracted with aq NaHSO3 before the sulfuric acid treatment was applied. Distd. Further purified by preparative gas chromatography on a column packed with 30% SE-30 (General Electric ethylsilicone rubber) on 42/60 Chromosorb P at 150° and 40psi, using helium. [Chu J Phys Chem 41 226 1964.]

n-Propyl chloride  [540-54-5]  M 78.5, b 46.6°, d 0.890, n 1.3880. Dried with MgSO4 and fractionally distd. More extensively purified using extraction with H2SO4 as for n-propyl bromide. Alternatively, Chien and Willard [J Am Chem Soc 75 6160 1953] passed a stream of oxygen containing about 5% ozone through the n-propyl chloride for three times as long as was needed to cause the first coloration of starch iodide paper by the exit gas. After washing with aqueous NaHCO3 to hydrolyse ozone and remove organic acids, the chloride was dried with MgSO4 and fractionally distd.

1-Propyl-3-(p-chlorobenzenesulfonyl) urea  [94-20-2]  M 260.7, m 127-129°. Crystd from aqueous EtOH.

Propylene carbonate  [108-32-7]  M 102.1, b 110°/0.5-1mm, 238-239°/760mm, d 1.204, n 1.423. Manufactured by reaction of 1,2-propylene oxide with CO2 in the presence of a catalyst (quaternary
ammonium halide. Contaminants include propylene oxide, carbon dioxide, 1,2- and 1,3-propanediols, allyl alcohol and ethylene carbonate. It can be purified by percolation through molecular sieves (Linde 5A, dried at 350° for 14h under a stream of argon), followed by distn under vac. [Jasinski and Kirkland Anal Chem 39 163 1967.] It can be stored over molecular sieves under an inert gas atmosphere. When purified in this way it contains less than 2ppm water. Activated alumina and dried CaO have been also used as drying agents prior to fractional distn under reduced pressure. It has been purified with 3A molecular sieves and distd under nitrogen in the presence of p-toluenesulphonic acid. Then redistilled and the middle fraction collected.

$\textit{dl-Propylene oxide} \ [75-56-9] \ M \ 58.1, \ b \ 34.5°, \ d \ 0.829, \ n \ 1.3664.$ Dried with Na$_2$SO$_4$ or CaH$_2$, and fractionally distilled through a packed column (glass helices), after refluxing with Na, CaH$_2$, or KOH pellets.

$n-$Propyl ether (dipropyl ether) \ [111-43-3] \ M \ 102.2, \ b \ 90.1°, \ d \ 0.740, \ n^{15} \ 1.38296, \ n \ 1.3803, \ pK \ -4.40 \ (aq \ H_2SO_4).$ Purified by drying with CaSO$_4$, by passage through an alumina column (to remove peroxides), and by fractional distn.

Propyl formate \ [110-74-7] \ M \ 88.1, \ b \ 81.3°, \ d \ 0.9058, \ n \ 1.3779.$ Distd, then washed with satd aq NaCl, and with satd aq NaHCO$_3$ in the presence of solid NaCl, dried with MgSO$_4$ and fractionally distd.

$n-$Propyl gallate \ [121-79-9] \ M \ 212.2, \ m \ 150°.$ Crystd from aqueous EtOH.

$n-$Propyl iodide (1-iodopropane) \ [107-08-4] \ M \ 170.0, \ b \ 1025°, \ d \ 1.745, \ n \ 1.5041.$ Should be distd at reduced pressure to avoid decomposition. Dried with MgSO$_4$ or silica gel and fractionally distd. Stored under nitrogen with mercury in a brown bottle. Prior to distn, free iodine can be removed by shaking with copper powder or by washing with aq Na$_2$S$_2$O$_3$ and drying. Alternatively, the $n$-propyl iodide can be treated with bromine, then washed with aq Na$_2$S$_2$O$_3$ and dried. See also $n$-butyl iodide.

$n-$Propyl propionate \ [106-36-5] \ M \ 120.2, \ b \ 122°, \ d \ 0.881, \ n \ 1.393.$ Treated with anhydrous CuSO$_4$, then distd under nitrogen.

6-Propyl-2-thiouracil (propacil, propyail) \ [51-52-5] \ M \ 170.2, \ m \ 218-220°, \ 218-220°, \ pK$^{21}$ \ -6.54 \ (aq H$_2$SO$_4$), \ pK$^2$ \ -4.22 \ (aq H$_2$SO$_4$), \ pK$^{21}$ \ 8.25 \ (4% aq EtOH).$ Purified by recrystn from H$_2$O (sol in 900 parts at 20°, and 100 parts at 100°). UV, MeOH: $\lambda$max 277nm. [Anderson et al. J Am Chem Soc 67 2197 1945; Vanderhaegue Bull Soc Chim Belg 59 689 1950.]

Propyne \ [74-99-7] \ M \ 40.1, \ m \ -101.5°, \ b \ -23.2°/760mm, \ d^{50} \ 0.7062, \ n^{40} \ 1.3863.$ Purified by preparative gas chromatography.

Protocatechualdehyde \ [139-85-5] \ M \ 138.1, \ m \ 153°.$ Crystd from water or toluene and dried in a vacuum desiccator over KOH pellets or shredded wax respectively.

Protopine [fumarine, macleyine, 4,6,7,14-tetrahydro-5-methyl-bis[1,3]-benzodioxolo[4,5-e:5',6'-g]azecine-13(5H)-one] \ [130-86-9] \ M \ 353.4, \ m \ 208°, \ pK \ 5.99.$ Crystd from EtOH/CHCl$_3$.

$JS,2S$-Pseudoephedrine (1-hydroxy-1-phenyl-2-methylaminopropane) \ [90-82-4] \ M \ 165.2, \ m \ 118-119°, \ [\alpha]^D_0 \ +53.0° \ (EtOH), \ +40.0° \ (H$_2$O), \ pK^{15} \ 9.71.$ Crystd from dry diethyl ether, or from water and dried in a vacuum desiccator.

$JS,2S$-Pseudoephedrine hydrochloride \ [345-78-8] \ M \ 210.7, \ m \ 181-182°, \ 185-188°, \ [\alpha]^D_0 \ +61° \ (c \ 1 \ H$_2$O).$ Crystd from EtOH.

Pteridine \ [91-18-9] \ M \ 132.2, \ m \ 139.5-140°, \ pK$^{20}$ \ 4.05 \ (equilibrium, hydrate), \ pK$^{20}$ \ 11.90 \ (OH of hydrate).$ Crystd from EtOH, *benzene, n-hexane, n-heptane or pet ether. It sublimes at 120-130°/20mm. Stored at 0°, in the dark; turns green in the presence of light and on long standing in the dark.
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2,4-(1H,3H)-Pteridinedione H₂O (lumazine) [487-21-8] M 182.1, m >350°, pK₁² <1.0, pK₂² 7.94. Crystd from water.

Pterin (2-aminopterin-4(3H)-one) [2236-60-4] M 163.1, m >300°, pK₁² 2.27 (basic), pK₂² 7.96 (acidic). It was dissolved in hot 1% aqueous ammonia, filtered, and an equal volume of hot 1M aqueous formic acid was added. The soln was allowed to cool at 0-2°C overnight. The solid was collected and washed with distilled water several times by centrifugation and dried in vacuo over P₂O₅ overnight, and then at 100°C overnight.

Pterocarpin [(6αR-cis)-6a,12a-dihydro-3-methoxy-6H-[1,3]dioxolo[5,6]benzofuro[3,2c][1]-benzopyran] [524-97-0] M 298.3, m 165°, [α]₅₄₆ 20° -215° (c 0.5, CHCl₃). Crystd from EtOH, or pet ether.

Pteroic acid (2-amino-6-p-carboxyanilinomethylpteridin-4(3H)-one) [119-24-4] M 312.3, m >300° (dec), pK₁ 2.3 (basic, N₁), 2.6 (basic, CH₂NH), pK₂ 4.5 (COOH), pK₃ 7.9 (acidic 4-OH). Crystd from dilute HCl. Hygroscopic IRRITANT


Purine [120-73-0] M 120.1, m 216-217°, pK₁² 2.30, pK₂² 9.86. Crystd from toluene or EtOH.

Purpurin (1,2,4-trihydroxy-5,10-anthraquinone) [81-54-9] M 256.2, m 253-256°, pK₁(E₄H₁)~ 2.3 (basic, N₁), pK₂(E₄H₂)~ 2.6 (basic, CH₂NH), pK₃(E₄H₃)~ 4.5 (COOH), pK₄(E₄OH) ~ 7.9 (acidic 4-OH). Crystd from dilute HCl. Hygroscopic IRRITANT

Pyocyanine (1-hydroxy-5-methylphenazinium zwitterion) [85-66-5] M 210.2, m 133° (sublimes and dec on further heating). Crystd from H₂O as dark blue needles. Picare has m 190° dec.


Pyrazinecarboxamide [98-96-4] M 123.1, m 189-191° (sublimes slowly at 159°), pK ~ 0.5. Cryst from water or EtOH.


Pyrazine-2,3-dicarboxylic acid [89-01-0] M 168.1, m 183-185° (dec), pK₁ < 2.0, pK₂ 0.9, pK₃ 2.77 (2.20). Cryst from water. Dried at 100°.


Pyrazole-3,5-dicarboxylic acid [3112-31-0] M 174.1, m 287-289° (dec), pK₁(E₄H₁) ~ 1.2 (CO₂H), pK₂(E₄H₂)~ 3.7 (CO₂H), pK₃(E₄OH) ~ 12 (NH). Cryst from water or EtOH.

Pyrene [129-00-0] M 202.3, m 149-150°. Cryst from EtOH, glacial acetic acid, *benzene or toluene. Purified by chromatography of CCl₄ solns on alumina, with *benzene or n-hexane as eluent. [Backer and Whitten J Phys Chem 91 865 1987.] Also zone refined, and purified by sublimation. Marvel and Anderson [J Am Chem Soc 76 5434 1954] refluxed pyrene (35g) in toluene (400mL) with maleic anhydride (5g) for 4days, then added 150mL of aqueous 5% KOH and refluxed for 5h with occasional shaking. The toluene layer was separated, washed thoroughly with H₂O, concentrated to about 100mL and allowed to cool. Crystalline pyrene was filtered off and recrystd three times from EtOH or acetonitrile. [Chu and Thomas J Am Chem Soc 108]
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1-Pyrenecarboxylic acid [19694-02-1] M 230.3, m 126-127°, pK<sub>est</sub> ~3.2. Crystd from C<sub>6</sub>H<sub>6</sub> or 95% EtOH.

1-Pyrenesulfonic acid [26651-23-0] M 222.2, m >350°, pK<sub>est</sub> <0. Crystd from EtOH/water. The tetra-Na salt cryst from H<sub>2</sub>O and the sulfonyl chloride has m 120°(dec). [Vollmann et al. *Justus Liebigs Ann Chem* 531 32 1937 and *Justus Liebigs Ann Chem* 540 189 1939.]

1,3,6,8-Pyrenetetrasulfonic acid [6528-53-6] M 522.2, m >400°, pK<sub>est</sub> <0. Crystd from water [Tietz and Bayer *Justus Liebigs Ann Chem* 540 189 1939.]

Pyridine [110-86-1] M 79.1, f -41.8°, b 115.6°, d 0.9831, n<sub>1.5102</sub>, pK<sub>25</sub> 5.23. Likely impurities are H<sub>2</sub>O and amines such as the picolines and lutidines. Pyridine is hygroscopic and is miscible with H<sub>2</sub>O and organic solvents. It can be dried with solid KOH, NaOH, CaO, BaO or sodium, followed by fractional distn. Other methods of drying include standing with Linde type 4A molecular sieves, CaH<sub>2</sub> or LiAlH<sub>4</sub>, azeotropic distn of the H<sub>2</sub>O with toluene or benzene, or treated with phenylmagnesium bromide in ether, followed by evaporation of the ether and distn of the pyridine. A recommended [Lindauer and Mukherjee Pure Appl Chem 27 267 1971] method dries pyridine over solid KOH (20g/Kg) for 2weeks, and fractionally distils the supernatant over Linde type 5A molecular sieves and solid KOH. The product is stored under CO<sub>2</sub>-free nitrogen. Pyridine can be stored in contact with BaO, CaH<sub>2</sub> or molecular sieves. Non-basic materials can be removed by steam distilling a soln containing 1.2 equivalents of 20% H<sub>2</sub>SO<sub>4</sub> or 17% HCl until about 10% of the base has been carried over along with the non-basic impurities. The residue is then made alkaline, and the base is separated, dried with NaOH and fractionally distd.

Alternatively, pyridine can be treated with oxidising agents. Thus pyridine (800mL) has been stirred for 24h with a mixture of ceric sulfate (20g) and anhydrous K<sub>2</sub>CO<sub>3</sub> (15g), then filtered and fractionally distd. Hurd and Simon [J Am Chem Soc 84 4519 1962] stirred pyridine (135mL), water (2.5L) and KMnO<sub>4</sub> (90g) for 2h at 100°, then stood for 3h before filtering off the ppted manganese oxides. Addition of solid KOH (ca 500g) caused pyridine to separate. It was decanted, refluxed with CaO for 3h and distd.

Separation of pyridine from some of its homologues can be achieved by crystn of the oxalates. Pyridine is ppted as its oxalate by adding it to the stirred soln of oxalic acid in acetone. The ppt is filtered, washed with cold acetone, and pyridine is regenerated and isolated. Other methods are based on complex formation with ZnCl<sub>2</sub> or HgCl<sub>2</sub>. Heap, Jones and Speakman [J Am Chem Soc 43 1936 1921] added crude pyridine (1L) to a soln of ZnCl<sub>2</sub> (848g) in 730mL of water, 346mL of conc HCl and 690mL of 95% EtOH. The crystalline ppt of ZnCl<sub>2</sub>·(pyridine) was filtered off, recrystd twice from absolute EtOH, then treated with a conc NaOH soln, using 26.7g of solid NaOH to 100g of the complex. The ppt was filtered off, and the pyridine was dried with NaOH pellets and distd. Similarly, Kyte, Jeffery and Vogel [J Chem Soc 4454 1960] added pyridine (60mL) in 300mL of 10% (v/v) HCl to a soln of HgCl<sub>2</sub> (405g) in hot water (2.3L). On cooling, crystals of pyridine-HgCl<sub>2</sub> (1:1) complex separated and were filtered off, crystd from 1% HCl (to m 178.5-179°), washed with a little EtOH and dried at 110°. The free base was liberated by addition of excess aq NaOH and separated by steam distn. The distillate was saturated with solid KOH, and the upper layer was removed, dried further with KOH, then BaO and distd. Another possible purification step is fractional crystn by partial freezing.

Small amounts of pyridine have been purified by vapour-phase chromatography, using a 180-cm column of polyethylene glycol-400 (Shell 5%) on Embacel (May and Baker) at 100°, with argon as carrier gas. The Karl Fischer titration can be used for determining water content. A colour test for pyrrole as a contaminant is described by Biddiscombe et al. [J Chem Soc 1957 1954].

§ Polystyrene supported pyridine is commercially available.
Pyridine-2-aldehyde  [1121-60-4]  M 107.1, b 81.5⁰/25mm, d 1.131, n 1.535, pKₐ 3.84, pKₐ 12.68. Sulfur dioxide was bubbled into a soln of 50g in 250mL of boiled water, under nitrogen, at 0⁰, until pptn was complete. The addition compound was filtered off rapidly and, after washing with a little water, it was refluxed in 17% HCl (200mL) under nitrogen until a clear soln was obtained. Neutralisation with NaHCO₃ and extraction with ether separated the aldehyde which was recovered by drying the extract, then distilling twice, under nitrogen. [Kyte, Jeffery and Vogel J Chem Soc 4454 1960.]


Pyridine-4-aldoxime  [696-54-8]  M 122.1, m 129⁰, pKₐ 4.73, pKₐ 10.03. Crystd from water.


Pyridine-3,4-dicarboxylic acid  [490-11-9]  M 167.1, m 256⁰, pKₐ 2.43, pKₐ 4.78. Crystd from dilute aqueous HCl.

Pyridine hydrobromide perbromide (pyridinium bromide perbromide)  [39416-48-3]  M 319.9, m 130⁰ (dec), 132-134⁰ (dec). It is a very good brominating agent - liberating one mol. of Br₂. Purified by recrystn from glacial acetic acid (33g from 100mL of AcOH). [Fieser and Fieser Reagents for Organic Chemistry Vol 1 967 1967.]

Pyridine hydrochloride  [628-13-7]  M 115.6, m 144⁰, b 218⁰. Crystd from CHCl₃/ethyl acetate and washed with diethyl ether.


Pyridine 3-sulfonic acid  [636-73-7]  M 159.2, m 365-366⁰ (dec), 357⁰, pKₐ 2.89 (12% aq EtOH), 3.22 (H₂O)(protonation on N). Purified by recrystn from H₂O or aqueous EtOH as needles or plates. [pKa: Evans and Brown J Org Chem 27 3127 1962; IR: Arnett and Chawla J Am Chem Soc 100 214 1978.] UV in 50% aqueous EtOH: λmax at 208 and 262nm. The ammonium salt has m 243⁰ (from aqueous EtOH), the hydrochloride has m > 300⁰ (dec), and the N-methyl betaine has m 130⁰ (from H₂O). [Gastel and Wibaut Recl Trav Chim Pays Bas 53 1031 1934; McIlvain and Goese J Am Chem Soc 65 2233 1943; Machek Monatsh Chem 72 77 1938.]

2-Pyridinethiol (2-mercaptopyridine)  [2637-34-5]  M 111.2, m 127.4⁰, 127-130⁰, 130-132⁰, pKₐ 1.07, pKₐ 9.97. If impure, dissolve in CHCl₃, wash with dil AcOH, H₂O, dry (MgSO₄), evaporate under reduced press and recryst residue from CHCl₃ or H₂O. 2-Methylmercaptopyridine (b 100-104⁰/33mm) was
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formed by treatment with MeI/NaOH. [Albert and Barlin J Chem Soc 2394 1959; Phillips and Shapiro J Chem Soc 584 1942.]

Pyridoxal hydrochloride, pyridoxamine hydrochloride and pyridoxine hydrochloride (vitamin B₆) see entries in Chapter 6.

1-(2-Pyridylazo)-2-naphthol (PAN) [SS-SS-S] M 249.3, m 140-142°, pK₃P-36 2.9, pK 30-36 11.2. Purified by repeated crystn from MeOH. It can also be purified by sublimation under vacuum. Purity can be checked by TLC using a mixed solvent (pet ether, diethyl ether, EtOH; 10:10:1) on a silica gel plate.

4-(2-Pyridylazo)resorcinol (PAR) [I 141-59-9] M 215.2, m >195°(dec), λ₅₅₅ 415nm, ε 2.59 x 10⁴ (pH 6-12), pKᵢ'2.69, pKᵢ'5.50. Purified as the sodium salt by recrystn from 1:1 EtOH/water. Purity can be checked by TLC using a silica gel plate and a mixed solvent (n-BuOH:EtOH:2M NH₃; 6:2:2).


1-(4-pyridyl)ethanol [R-(+) -27854-88-2; S-(-) -54656-96-3] M 129.1, m 156-158°, [α]²⁺⁺ 110° (c 0.5, H₂O). Crystd from EtOH/pet ether.

S-Pyroglutamic acid (5-oxo-L-proline) [98-79-3] M 129.1, m 156-158°, 162-164°, [cr]g6 -11O (c 5, H₂O), pK 12.7 (by electron spin resonance). Crystd from EtOH by addition of pet ether. NH₄ salt has m 184-186° (from EtOH).

Pyromellitic acid (benzene-1,2,4,5-tetracarboxylic acid) [89-05-4] M 254.2, m 276°, 281-284°, pK₁ 1.87, pK₂ 2.72, pK₃ 4.30, pK₄ 5.52. Dissolved in 5.7 parts of hot dimethylformamide, decolorised and filtered. The ppte obtained on cooling was separated and air dried, the solvent being removed by heating in an oven at 150-170° for several hours. Crystd from water.


γ-Pyrene (4H-pyran-4-one) [108-97-4] M 96.1, m 32.5-32.6°, 33°, 32-34°, b 88.5°/7mm, 91-91.5°/9mm, 95-97°/13mm, 105°/23mm, 215°/atm, pK¹ 0.10. Purified by vacuum distn, the distillate crystallises and is hygroscopic. It is non-steam volatile. The hydrochloride has m 139° (from EtOH), and the picrate has m 130.2-130.3° (from EtOH or H₂O). [Mayer Chem Ber 90 2362 1957; IR: Jones et al. Can J Chem 57 2007 1959; Neelakatan J Org Chem 22 1584 1957.]
Pyronin Y [3,6-bis(dimethylamino)xanthylium chloride] M 302.8, m 250-260°, CI 45005, λmax 522nm, pK_{est} -7.6. Commercial material contained a large quantity of zinc. Purified by dissolving 1 g in 50mL of hot water containing 5g NaEDTA. Cooled to 0°, filtered, evapd to dryness and the residue extracted with EtOH. The soln was evaporated to 5-10mL, filtered, and the dye pptd by addition of excess dry diethyl ether. It was centrifuged and the crystals were washed with dry ether. The procedure was repeated, then the product was dissolved in CHCl₃, filtered and evapd. The dye was stored in a vacuum.


Pyridine [123-75-1] M 71.1, b 87.5-88.5°, d 0.860, n 1.443, pK₂ 11.31. Dried with BaO or sodium, then fractionally distd, under N₂, through a Todd column packed with glass helices (see p. 174).

Pyridine-1-carboxylic acid ammonium salt [127-17-3] M 88.1, m 13°, b 65°/10mm, pK₂ 2.39 (2.60). Distd twice, then fractionally crystd by partial freezing.


Quercetin (2H₂O) (3,3',4',5,6-pentahydoxyflavone) [6151-25-3 (2H₂O); 117-39-3 (anhydr)] M 338.3, m ca 315°(dec), (phenolic pKs 7—10). Crystd from aq EtOH and dried at 100°.

Quercitrin (quercetin glycoside) [522-12-3] M 302.2, m 168°, 176-178°. Crystd from aq EtOH and dried at 150° to give the higher melting form.


Quinalizarin (1,2,5,8-tetrahydroxy-9,10-anthraquinone) [81-61-8] M 272.2, m 275°, pK_{Est(1)} 7.1 (1-OH), pK_{Est(2)} 9.9 (8-OH), pK_{Est(3)} 11.1 (5-OH), pK_{Est(4)} 11.8 (2-OH). Crystd from acetic acid or nitrobenezene. It can be sublimed in vacuo.

Quinazoline [253-82-7] M 130.2, m 48.0-48.5°, b 120-121°/17-18mm, pK₂ 2.3.1.5 (aq H₂SO₄, anhydrous dication), pK₂ 2.01 (anhydrous monocation), pK₂ 4.3 (equilibrium with 3,4-hydrated species), pK₂ 7.2.1 (hydrated anion). Purified by passage through an activated alumina column in *benzene or pet ether (b 40-60°). Distd under reduced pressure, sublimed under vacuum and crystd from pet ether.

Quinhydrone [106-34-3] M 218.2, m 168°. Crystd from H₂O at 65°, then dried in a vac desiccator.

1R,3R,4R,5R-Quinic acid (1,3,4,5-tetrahydroxy-cyclohexane-carboxylic acid) [77-95-2] M 192.3, m 172°(dec), [α]₂ 20° -51° (c 20, H₂O), pK₂ 3.58. Crystd from water.

Quinidine [56-54-2] M 324.4, m 171°, [α]₂ 20° +301.1° (CHCl₃ contg 2.5% (v/v) EtOH), pK₂ 4.13, pK₂ 8.77. Crystd from *benzene or dry CHCl₃/pet ether (b 40-60°), discarding the initial, oily crop of crystals. Dried under vacuum at 100° over P₂O₅.
Quinine \([130-95-0]\) M 324.4, m 177°(dec), \([\alpha]_{D}^{20} +160^\circ\) (c 1, CHCl₃), pKₐ 4.13 (quinoline N), pKₐ 8.52 (piperidine N). Crystd from abs EtOH.

Quinine bisulfate \([6183-68-2\) (7H₂O); 549-56-4 (anhydr)] M 422.4, m 160° (anhydr). Crystd from 0.1M H₂SO₄, forms heptahydrate when crystd from water

Quinine sulfate (2H₂O) \([6119-70-6\) (H₂O); 804-63-7 (anhydr)] M 783.0, m 205°. Crystd from water, dried at 110°.


Quinoline \([91-22-5]\) M 129.2, m -16°, b 111.5°, 236°/758mm, d 1.093, n 1.625, pKₐ 4.80 (4.93). Dried with Na₂SO₄ and vac distd from zinc dust. Also dried by boiling with acetic anhydride, then fractionally distilling. Calvin and Wilmarth \([J Am Chem Soc 78 1301 1956]\) cooled redistd quinoline in ice and added enough HCl to form its hydrochloride. Diazotization removed aniline, the diazo compound being broken down by warming the soln to 60°. Non-basic impurities were removed by ether extraction. Quinoline was liberated by neutralising the hydrochloride with NaOH, then dried with KOH and fractionally distd at low pressure. Addition of cuprous acetate (7g/L of quinoline) and shaking under hydrogen for 12h at 100° removed impurities due to the nitrous acid treatment. Finally the hydrogen was pumped off and the quinoline was distd. Other purification procedures depend on conversion to the phosphate (m 159°, pptd from MeOH soin, filtered, washed with MeOH, then dried at 55°) or the picrate (m 201°) which, after crystn were reconverted to the amine. The method using the picrate \([Packer, Vaughan and Wong J Am Chem Soc 80 905 1958]\) is as follows: quinoline is added to picric acid dissolved in the minimum volume of 95% EtOH, giving yellow crystals which were washed with EtOH, air-dried and crystd from acetonitrile. These were dissolved in dimethyl sulfoxide (previously dried over 4A molecular sieves) and passed through basic alumina, on which the picric acid is adsorbed. The free base in the effluent is extracted with n-pentane and distd under vacuum. Traces of solvent can be removed by vapour-phase chromatography. \([Moonaw and Anton J Phys Chem 80 2243 1976.1\] The ZnCl₂ and dichromate complexes have also been used. \([Cumper, Redford and Vogel J Chem Soc 1176 1962.1\]


Quinoline ethiodide (1-ethylquinolinium iodide) \([634-35-5]\) M 285.1, m 158-159°. Crystd from aqueous EtOH.

Quinoxaline \([91-19-0]\) M 130.2, m 28° (anhydr), 37°(H₂O), b 108-110°/0.1mm, 140°/40mm, pKₐ 5.52 (-5.8, dication), pKₐ 2.08 (monocation). Crystd from pet ether. Crystallises as the monohydrate on addition of water to a pet ether soin.

Quinoxaline-2,3-dithiol \([1199-03-7]\) M 194.1, m 345°(dec), pKₐ 6.9, pKₐ 9.9. Purified by repeated dissolution in alkali and re-pptn by acetic acid.

p-Quinquephenyl \((p\text{-pentaphenyl})\) \([61537-20-0]\) M 382.5, m 388.5°. Recrystd from boiling dimethyl sulfoxide (b 189°, lowered to 110°). The solid obtained on cooling was filtered off and washed repeatedly with toluene, then with conc HCl. The final material was washed repeatedly with hot EtOH. It was also recrystd from pyridine, then sublimed in vacuo.

Quinuclidine \((1\text{-azabicyclo[2.2.2]octane})\) \([100-76-5]\) M 111.2, m 158°(sublimes), pKₐ 10.95. Crystd from diethyl ether.
D-Raffinose \((\text{5H}_2\text{O})\) \([17629-30-0 \ (\text{5H}_2\text{O}); \ 512-69-6 \ (\text{anhydr})]\) M 594.5, m 80°, \([\alpha]_{\text{D}}^{20}+124^\circ\) (c 10, \(\text{H}_2\text{O}\)). Crystd from aqueous EtOH.


Reductic acid (1,2-dihydroxycyclopent-1,2-en-3-one) [80-72-8] M 114.1, m 213°, pK\(^{20}\) 4.72. Crystd from ethyl acetate.

Rescinnamine [24815-24-5] M 634.7, m 238-239\(^o\)(vac), \([\alpha]_{\text{D}}^{20}+97^\circ\) (c 1, CHC\(_2\)), \(pK_{\text{H}(1)}\)~<0 (carbazole \(\text{N}\)), \(pK_{\text{H}(2)}\)~<0 (quinolizidine \(\text{N}\)). Crystd from *benzene or MeOH.

Reserpic acid [83-60-3] M 400.5, m 241-243\(^o\), \(pK_{\text{H}(1)}\)~<0 (carbazole \(\text{N}\)), \(pK_{\text{H}(2)}\)~<4.0 (CO\(_2\)H), \(pK_{\text{H}(3)}\)~<7.4 (quinolizidine \(\text{N}\)). Crystd from MeOH. The hydrochloride 0.5\(\text{H}_2\text{O}\) has m 257-259°, \([\alpha]_{\text{D}}^{20}+81^\circ\) (H\(_2\)O).

Reserpine [50-55-5] M 608.7, m 262-263\(^o\), \([\alpha]_{\text{D}}^{20}+148^\circ\) (c 1, CHC\(_2\)), \(pK_{\text{H}(1)}\)~<0 (carbazole \(\text{N}\)), \(pK_2\) 6.6 (7.4)(quinolizidine \(\text{N}\)). Crystd from aq acetone.

Resorcinal [108-46-3] M 110.1, m 111.2-111.6\(^o\), \(pK_1^{25}\) 9.23, \(pK_2^{25}\) 13.05. Crystd from *benzene, toluene or *benzene/diethyl ether.

Retene [483-65-8] M 234.3, m 99°. Crystd from EtOH.

Retinal (vitamin A aldehyde), Retinoic acid (vitamin A acid), Retinol (vitamin A alcohol) see entries in Chapter 6.

Retinyl acetate [127-47-9] M 328.5, m 57°. Separated from retinol by column chromatography, then crystd from MeOH. See Kofler and Rubin [Vitamins and Hormones (NY) 18 315 1960] for review of purification methods. Stored in the dark, under \(\text{N}_2\) or \(\text{Ar}\), at 0°. See Vitamin A acetate p. 574 in Chapter 6.

Retinyl palmitate [79-81-2] M 524.9, m 28-29\(^o\), \(\epsilon_{1\text{cm}}^{1\%}\) (all-trans) 1000 (325 nm) in EtOH. Separated from retinol by column chromatography on water-deactivated alumina with hexane containing a very small percentage of acetone. Also chromatographed on TLC silica gel G, using pet ether/isopropyl ether/acetic acid/water (180:20:2:5) or pet ether/acetonitrile/acetic acid/water (190:10:1:15) to develop the chromatogram. Then recrystd from propylene at low temperature.

Rhamnetin (3,3'-4',5-tetrahydroxy-7-methoxy flavone, 7-methyl quercitin) [90-19-7] M 316.3, m >300\(^o\)(dec), several phenolic \(pKs\) ~7-10.5. Crystd from EtOH.

L-\(\alpha\)-Rhamnose (\(\text{H}_2\text{O}\)) [10030-85-0 (\(\text{H}_2\text{O}); \ 3615-41-6 \ (\text{anhydr})] M 182.2, m 105°, \([\alpha]_{\text{D}}^{15}+9.1^\circ\) (c 5, \(\text{H}_2\text{O}\)). Crystd from water or EtOH.

Rhodamine B chloride [3,5-bis-(diethylamino)-9-(2-carboxyphenyl)xanthylum chloride] [81-88-9] M 479.0, m 210-211\(^o\)(dec), CI 45170, \(\lambda_{\max} 543\text{nm}, \ [\text{Free base} \ 509-34-2] \ CI 749), pK 5.53. Major impurities are partially dealkylated compounds not removed by crystn. Purified by chromatography, using ethyl acetate/isopropanol/ammonia (conc)(9:7:4, \(R_F\) 0.75 on Kieselgel G). Also crystd from conc soln in MeOH by slow addition of dry diethyl ether; or from EtOH containing a drop of conc HCl by slow addition of ten volumes of dry diethyl ether. The solid was washed with ether and air dried. The dried material has also been extracted with *benzene to remove oil-soluble material prior to recrystn. Store in the dark.

Rhodamine 6G [Basic Red 1, 3,5-bis-(ethylamino)-9-(2-ethoxycarbonylphenyl)-2,7-dimethylxanthylum chloride] [989-38-8] M 479.3, CI 45160, \(\lambda_{\max} 524\text{nm}, pK 5.58.\) Crystd from MeOH or EtOH, and dried in a vac oven.
Rhodanine (2-mercaptotiazolidin-4-one) \[141-84-4\] M 133.2, m 168.5° (capillary), pK\textsuperscript{20} 5.18. Crystd from glacial acetic acid or water.

Riboflavin, riboflavin-5'-phosphate (Na salt, 2H\textsubscript{2}O) and ribonucleic acid see entries in Chapter 6.

α-D-Ribose \[50-69-1\] M 150.1, m 90°, [α]\textsuperscript{20} +1°, -24° (after 24h, c 10, H\textsubscript{2}O), pK\textsuperscript{2} 12.22. Crystd from aqueous 80% EtOH, dried under vacuum at 60° over P\textsubscript{2}O\textsubscript{5} and stored in a vacuum desiccator.

Ricinoleic acid (dl-12-hydroxyoleic acid) \[141-22-0\] M 298.5, m 7-8° (α-form), 5.0° (γ-form), n \(\lambda\) 1.4717, pK\textsubscript{ESt} -4.5. Purified as methyl acetylricinoleate [Rider J Am Chem Soc 53 4 130 1931], fractionally distilling at 180-185°/0.3mm, then 87g of this ester was refluxed with KOH (56g), water (25mL), and MeOH (250mL) for 10min. The free acid was separated, crystd from acetone at -50°, and distd in small batches, b 180°/0.005mm. [Bailey et al. J Chem Soc 3027 1957.]

Rosaniline HCl (Magenta I, Fuschin) \[632-99-5\] M 337.9, m >200°(dec). Purified by dissolving in EtOH, filtering and adding H\textsubscript{2}O. Filter or centrifuge and wash the ppt with Et\textsubscript{2}O and dry in air. Could be crystd from H\textsubscript{2}O. Also recrystd from water and dried in vacuo at 40°. Crystals have a metallic green lustre. UV max in EtOH is at 543nm (E 93,000). Solubility in H\textsubscript{2}O is 0.26%. A carmine red colour is produced in EtOH. [Scalan J Am Chem Soc 57 887 1937.]

p-Rosolic acid (4-[bis-{4-hydroxyphenyl}methylene]-2,5-cyclohexadien-one, 4',4"-dihydroxy-fuschson, aurin, corallin) \[603-45-2\] M 290.3, m 292°, 295-300° (dec with liberation of phenol), 308-310° (dec), pK\textsubscript{1} 3.11, pK\textsubscript{2} 8.62. It forms green crystals with a metallic lustre but the colour depends on the solvent used. When recrystd from brine (sadt aqueous NaCl) acidified with HCl it forms red needles, but when recrystd from EtOH-AcOH the crystals have a beetle iridescent green colour. It has been recrystd from Me\textsubscript{2}CO (although it dissolves slowly), methyl ethyl ketone, 80-95% AcOH and from AcOH-*C\textsubscript{6}H\textsubscript{6}. An aq KOH soln is golden yellow and a 70% H\textsubscript{2}SO\textsubscript{4} soln is deep red in colour. An alternative purification is to dissolve this triphenylmethane dye in 1.5% of aq NH\textsubscript{3}, filter, and heat to 70-80°, then acidify with dilute AcOH by adding it slowly with vigorous stirring, whereby the aurin separates as a brick-red powder or as purplish crystals depending on the temperature and period of heating. Filter off the solid, wash with H\textsubscript{2}O and a little dilute AcOH then H\textsubscript{2}O again. Stir this solid with Et\textsubscript{2}O to remove any ketones and allow to stand overnight in the Et\textsubscript{2}O, then filter and dry in air then in a vacuum. [Gomberg and Snow J Am Chem Soc 47 202 1925; Baines and Driver J Chem Soc 123 1216 1923; UV: Burawoy Chem Ber 64 462 1941; Neuk and Schmid J Prakt Chem 2 23 549 1881.]

Rubijervine (slanid-5-ene-3β-12α-diol) \[79-58-3\] M 413.6, m 240-246°, [α]\textsuperscript{D}+19° (EtOH), pK\textsubscript{ESt} ~7.0. Crystd from EtOH. It has solvent of crystn.

Rubrene \[517-51-1\] M 532.7, m >315°. See 5,6,11,12-tetraphenylnaphthacene on p. 366.

(+)-Rutin (quercetin-3-rubinoside) \[153-18-4\] M 610.5, m 188-189, [α]\textsuperscript{20}+13° (c 5, EtOH) (polyphenolic flavone pKs 7—10). Crystd from MeOH or water/EtOH, air dried, then dried for several hours at 110°.

**Saccharic acid** (D-glucaric acid) \[87-73-0\] M 210.1, m 125-126°, [α]\textsuperscript{D}+6.9° → +20.6° (H\textsubscript{2}O), pK\textsubscript{1} 3.01, pK\textsubscript{2} 3.94 (D-isomer). Crystd from 95% EtOH.

Safranine O \[477-73-6\] M 350.9, λ\textsubscript{max} 530nm, pK\textsuperscript{25} 6.4. Crystd from *benzene/MeOH (1:1) or water. Dried under vacuum over H\textsubscript{2}SO\textsubscript{4}.
Purification of Organic Chemicals

Safrole (5-allyl-1,3-benzodioxole, 4-allyl-1,2-methylenedioxybenzene) [94-59-7] M 162.1, m~ 11°, b 69-70°/1.5mm, 104-105°/6mm, 231.5-232°/atm, 235-237°/atm, d 1.099, n 1.53738. It has been purified by fractional distn, although it has also been recrystd from low boiling pet ether at low temperatures. [IR: Briggs et al. Anal Chem 29 904 1957; UV: Patterson and Hibbert J Am Chem Soc 65 1962 1943.] The maleic anhydride adduct forms yellow crystals from toluene m 257° [Hickey J Org Chem 13 443 1948], and the picare forms orange-red crystals from CHCl₃ [Baril and Magrdichian J Am Chem Soc 58 1936].

D(-)-Salicin [138-52-3] M 286.3, m 204-208°, [α]D⁻²⁵ -63.5° (c ca 3, H₂O). Crystd from EtOH.

Salicylaldehyde (α-hydroxybenzaldehyde) [90-02-8] M 122.1, b 93°/25mm, 195-197°/760mm, d 1.167, n 1.574, pK 8.37. Ppted as the bisulfite addition compound by pouring the aldehyde slowly and with stirring into a 25% soln of NaHSO₃ in 30% EtOH, then standing for 30min. The ppte, after filtering at the pump, and washing with EtOH, was decomposed with aq 10% NaHCO₃, and the aldehyde was extracted into diethyl ether, dried with Na₂SO₄ or MgSO₄, and distd, under reduced pressure. Alternatively, salicylaldehyde can be pptd as its copper complex by adding it to warm, satd soln of copper acetate, shaking and then standing in ice. The ppte was filtered off, washed thoroughly with EtOH, then with diethyl ether, and decomposed with 10% H₂SO₄, the aldehyde was extracted into diethyl ether, dried and distd. It has also been purified by repeated vacuum distn, and by dry column chromatography on Kieselgel G [Nishiya et al. J Am Chem Soc 108 3880 1986]. The acetyl derivative has m 38-39° (from pet ether or EtOH) and b 142°/18mm, 253°/atm.


Salicylic acid (2-hydroxybenzoic acid) [69-72-7] M 138.1, m 157-159°, 158-160°, 159.5°, 159-160°, 162°, b 211°/20mm, pK 3.01, pK 13.43 (13.01). It has been purified by steam distn, by recrystn from H₂O (solubility is 0.22% at room temp and 6.7% at 100°), absolute MeOH, or cyclohexane and by sublimation in a vacuum at 76°. The acid chloride (needles) has m 19-19°, b 92°/15mm, amide m 133° (yellow needles from H₂O), and anilide (prisms from H₂O) m 135°. The O-acetyl derivative has m 135° (rapid heating and the liquid resolidifies at 118°) and the o-benzoyl derivative has m 132° (aq EtOH). [IR: Hales et al. J Chem Soc 3145 1954; UV: Bergmann et al. J Chem Soc 2351 1950].


Scopoletin (7-hydroxy-6-methoxycoumarin) [92-61-5] M 192.2, m 206°, 208-209°, pK 8.96 (70%aq EtOH). Crystd from water, acetic acid or °C₆H₆/MeOH.

Sebacic acid [111-20-6] M 202.3, m 134.5°, pK 4.58, pK 5.54. Purified via the disodium salt which, after crystn from boiling water (charcoal), was again converted to the free acid. The free acid was cryst repeatedly from hot distd water or from Me₂CO+pet ether and dried under vacuum.

Sebacic acid monomethyl ester [818-88-2] M 216.3, m 42-43°, b 169-171°/4mm. Recrystd from Me₂CO+pet ether or pet ether at low temperature and distd in a vacuum.

Sebaconitrile (decanedinitrile) [1871-96-1] M 164.3, m 8°, b 199-200°. Mix with P₂O₅ (10% by wt) and distilled from it, then redistilled.
Secobarbital (5-allyl-5-methylbutylbarbituric acid) [76-73-3] M 260.3, m 100°, pK_{Em}(1)=3.5, pK_{Em}(2)=12.0. A soln of the salt in 10% HCl was ppted and the acid form was extracted by the addition of ether. Then purified by repeated cryst from CHC13. [Buchet and Sandorfy J Phys Chem 88 3274 1984.]


Sennoside A [81-27-6] M 862.7, m 220-240°(dec), [α]^{20}_D -147° (c 5, Me_{2}CO/H_{2}O 7:1). Cryst from aq acetone or large vols of H_{2}O.

Sennoside B [128-57-4] M 962.7, m 182-190°(dec), [α]^{20}_D -100° (c 2, Me_{2}CO/H_{2}O 7:3). Cryst from aq acetone or large vols of H_{2}O.


Serotonin creatinine sulfate (H_{2}O) [971-74-4] M 405.4, m 220°(dec), pK_{1} 10.1, pK_{2} 11.1, pK_{3} 18.25 (NH) for serotonin, pK 4.9 for creatinine. Crystd (as monohydrate) from water.

Shikimic acid [138-59-0] M 174.2, m 183-184.5°, 190°, [α]^{20}_{546} -210° (c 2, H_{2}O), pK^{14}_{D} 4.15. Cryst from water or MeOH/AcOEt and sublimes in a vac.

Sinomenine hydrochloride (7,8-didehydro-4-hydroxy-3,7-dimethoxy-17-methyl-9α,13α,14α-morphan-6-one HCl) [6080-33-7] M 365.9, m 231°, [α]^{17}_{D} -83° (c 4, H_{2}O), pK_{Em}(1)=10.0 (N), pK_{Em}(2)=10.4 (OH). Cryst from water.


Skellysolve A is essentially n-pentane, b 28-30°.
Skellysolve A is essentially n-hexane, b 60-68°.
Skellysolve C is essentially n-heptane, b 90-100°.
Skellysolve D is mixed heptanes, b 75-115°.
Skellysolve E is mixed octanes, b 100-140°.
Skellysolve F is pet ether, b 30-60°.
Skellysolve G is pet ether, b 40-75°.
Skellysolve H is hexanes and heptanes, b 69-96°.
Skellysolve L is essentially octanes, b 95-127°. For methods of purification, see petroleum ether.

Smilagenin [126-18-1] M 416.6, m 185°, [α]^{25}_{D} -69° (c 0.5, CHCl_{3}). Cryst from acetone.

Solanidine [80-78-4] M 397.6, m 218-219°, [α]^{20}_{D} -29° (c 0.5, CHCl_{3}), pK^{15}_{D} 6.66. Cryst from CHCl_{3}/MeOH.

α-Solanine [20562-02-1] M 868.1, m 286°(dec), [α]^{20}_{D} -58° (c 0.8, pyridine), pK^{15}_{D} 6.66.
See α-solanine on p. 566 in Chapter 6.
Solanone \([S(+)-\text{trans}-2\text{-methyl}-5\text{-isopropyl}-1,3\text{-nonan-8-one}]\) [1937-54-8] \(M \) 194.3, \(b \) 60°/1mm, \([\alpha]_D^{20} +14^\circ \) (neat). Purified by high vacuum distillation and stored in sealed ampules [Kohda and Sato J Chem Soc, Chem Commun 951 1981]. It has UV (hexane) at \(\lambda_{\text{max}} \) 230nm \((E \text{ 11,800})\).

Solasodine \([126-17-0]\) \(M \) 413.6, \(m \) 202°, \([\alpha]_D^{25} -100^\circ \) \((c 2, \text{MeOH})\), \(pK \) 7.7. Crystd \((\text{as monohydrate})\) from \(\text{MeOH}\) or \(\text{aq 80% EtOH}\), and sublimes in a vac.

Solasodine (solasodine-3-\(\alpha\)-mannoglucoside) \([19121-58-5]\) \(M \) 884.0, \(m \) 279°, \(-75^\circ \) \((c 0.5, \text{MeOH})\), \(pK_{\text{Est}} \) -7.7. Crystd from \(\text{aq 80% dioxane}\) or \(\text{MeOH}\).

Solochrome Violet R \([4\text{-hydroxy-3-(2-hydroxynaphthyl-1-ylazo)benzenesulfonic acid}]\) \([2092-55-9]\) \(M \) 367.3, \(CI \) 15670, \(h_{\text{max}} \) 501nm, \(pK_2' 7.22 \) (OH), \(pK_1' 13.39 \) (OH). Converted to the monosodium salt by pptn with \(\text{NaOAc/MeOH buffer of pH 4}\), then purified by pptn of the free acid from \(\text{aq solution} \) with conc HCl, washing and extracting with \(\text{EtOH} \) in a Soxhlet extractor. The acid ppted on evaporating the \(\text{EtOH}\) and was reconverted to the sodium salt as described for Chlorazole Sky Blue FF. Dried at 110°. It is hygroscopic. [Coates and Rigg Trans Faraday Soc 57 1088 1961].

Sorbic acid (2,4-hexadienoic acid) \([110-44-1]\) \(M \) 112.1, \(m \) 134°, \(pK_{\text{25}} 4.76\). Crystd from water.

Sorbitol \([50-70-4]\) \(M \) 182.2, \(m \) 89-93° \((\text{hemihydrate})\), 110-110° \((\text{anhydrous})\), \([\alpha]_D^{20} -1.8^\circ \) \((c 10, \text{H}_{2} \text{O})\), \(pK_6' 13.00\). Crystd \((\text{as hemihydrate})\) several times from \(\text{EtOH/water} \) \((1:1)\), then dried by fusing and storing over \(\text{MgSO}_4\).

\((-\)-Sparteine sulfate pentahydrate \([6160-12-9]\) \(M \) 422.5, \(m \) loses \(\text{H}_2\text{O}\) at 100° and turns brown at 136° \((\text{dec})\), \([\alpha]_D^{10} -22^\circ \) \((c 5, \text{H}_2\text{O})\), \([\alpha]_D^{25} -1.6^\circ \) \((c 10, \text{EtOH for free base})\), \(pK_1^{20} 2.24\), \(pK_2^{25} 9.46\). Recrystd from \(\text{aq EtOH}\) or \(\text{H}_2\text{O}\) although the solubility in the latter is high. The free \((-\)-base) has \(b \) 173°/8mm and is steam volatile but resinifies in air. The dipicrate forms yellow needles from \(\text{EtOH}-\text{Me}_2\text{CO} \), \(m \) 205-206° \([\text{Clemo et al. J Chem Soc 429 1931}]; \text{see also Bolmman and Schuman The Alkaloids (Ed Manske) Vol 9 175 1967}]. The free \((\pm)-\)base has \(m \) 71-72.5° \([\text{van Tamelen and Foltz J Am Chem Soc 82 2400 1960}].

Spermidine \([\text{N-(3-aminopropyl)-1,4-diaminobutane}]\) \([124-20-9]\) \(M \) 145.3, \(m \) 23-25°, \(b \) 128-131°/15mm, \(d \) 0.918, \(n \) 1.482, \(pK_{\text{15}}' 8.25\), \(pK_{\text{564}}' 9.64\), \(pK_{\text{25}}' 10.43\). It is a strong base with an alkylamine odour and absorbs \(\text{CO}_2\) from the atmosphere. It is purified by shaking with solid \(\text{K}_2\text{CO}_3\) or \(\text{NaOH}\), decanting and distilling from \(\text{K}_2\text{CO}_3\) in a vacuum. Store in the dark under \(\text{N}_2\).

Spermine 4\(\text{HCl}\) \((\text{N,N-bis(3-aminopropyl)-1,4-butanediamine} \cdot 4\text{HCl})\) \([306-67-2]\) \(M \) 348.2, \(m \) 313-315°. The \(pK\)s are similar to spermidine above. Purification as for spermidine trihydrochloride above.

Squalene (all-trans- \(2,6,10,15,19,23\text{-hexamethyltetracosahe}x\text{a-2,6,10,14,18,22-ene, spinacen}) \([111-02-4]\) \(M \) 410.7, \(m \) \(-75^\circ\), \(b \) 203°/0.15mm. See squalene on p. 567 in Chapter 6.

Squaric acid (3,4-dihydroxy-3-cyclobutene-1,2-dione) \([2892-51-5]\) \(M \) 114.1, \(m \) 293° \((\text{dec})\), 294° \((\text{dec})\), >300°, \(pK_2' 1.50\), \(pK_1' 2.93\). Purified by recryst from \(\text{H}_2\text{O} \) — this is quite simple because the acid is ~7% soluble in boiling \(\text{H}_2\text{O}\) and only 2% at room temperature. It is not soluble in \(\text{Me}_2\text{CO}\) or \(\text{EtO} \) hence it can be rinsed with these solvents and dried in air or a vacuum. It is not hygroscopic and gives an intense purple colour with \(\text{FeCl}_3\). It has IR v at 1820 (C=O) and 1640 (C=C) cm\(^{-1}\); and UV \(\lambda_{\text{max}}\) at 269.5nm \((c 37K \text{ M}^{-1}\text{cm}^{-1})\). [Cohn et al. J Am Chem Soc 81 3480 1959; Park et al. J Am Chem Soc 84 2919 1962] See also \(pK_a\) values of 0.59 ±0.09 and 3.48 ±0.023 [Schwartz and Howard J Phys Chem 74 4374 1970].

Starch \([9005-84-9]\) \(M \) (162.1)n. See entry on p. 567 in Chapter 6.
Stearic acid (octadecanoic acid)  [57-11-4]  M 284.5, m 71.4°, 72°, b 144-145°/27 mm, 383.9/760 mm, d 0.911, n 1.428, pK<sub>E</sub> -5.0. Crystd from acetone, acetonitrile, EtOH (5 times), aq MeOH, ethyl methyl ketone or pet ether (b 60-90°), or by fractional pptn by dissolving in hot 95% EtOH and pouring into distd water, with stirring. The ppt, after washing with distd water, was dried under vacuum over P<sub>2</sub>O<sub>5</sub>. It has also been purified by zone melting and partial freezing. [Tamai et al. *J Phys Chem* 91 541 1987.]

Stigmasterol  [83-48-7]  M 412.7, m 170°, [α]<sub>2</sub> -51° (CHCl<sub>3</sub>), [α]<sub>2</sub> -59° (c 2, CHCl<sub>3</sub>). Crystd from hot EtOH. Dried in vacuum over P<sub>2</sub>O<sub>5</sub> for 3h at 90°. Purity was checked by NMR.


(-)-Strychnine  [57-24-9]  M 334.4, m 268°, [α]<sub>2</sub> -139° (c 1, CHCl<sub>3</sub>), pK<sub>1</sub> 2.50, pK<sub>2</sub> 8.2. Crystd as the hydrochloride from water, then neutralised with ammonia.

Styphnic acid (2,4,6-trinitroresorcinol)  [82-71-3]  M 245.1, m 177-178°, 179-180°, pK<sub>1</sub> 0.06 (1.74), pK<sub>2</sub> 4.23 (4.86). Crystd from ethyl acetate or water containing HCl [EXPLODES violently on rapid heating.]

Styrene  [100-42-5]  M 104.2, b 41-42°/18 mm, 145.2°/760 mm, d 0.907, n 1.5469, n<sub>2</sub> 1.5441. Styrene is difficult to purify and keep pure. Usually contains added inhibitors (such as a trace of hydroquinone). Washed with aqueous NaOH to remove inhibitors (e.g. tert-butanol), then with water, dried for several hours with MgSO<sub>4</sub> and distd at 25° under reduced pressure in the presence of an inhibitor (such as 0.005% p-tert-butylcatechol). It can be stored at -78°. It can also be stored and kept anhydrous with Linde type 5A molecular sieves, CaH<sub>2</sub>, CaSO<sub>4</sub>, BaO or sodium, being fractionally distd, and distd in a vacuum line just before use. Alternatively styrene (and its deuterated derivative) were passed through a neutral alumina column before use [Woon et al. *J Am Chem Soc* 108 7990 1986; Collman *J Am Chem Soc* 108 2588 1986].


Styrene oxide  [96-09-3]  M 120.2, b 84-86°/18 mm, 145.2°/760 mm, d 0.907, n 1.5469, n<sub>2</sub> 1.5441. Styrene oxide is treated with hydrogen under 3 atmospheres pressure in the presence of platinum oxide. The aldehyde, but not the oxide, is reduced to <b>1</b>-phenylethanol) and separation is now readily achieved by fractional distn. [Schenck and Kaizermann *J Am Chem Soc* 75 1636 1953.]

Suberic acid (hexane-1,6-dicarboxylic acid)  [505-48-6]  M 174.2, m 141-142°, pK<sub>1</sub> 4.12, pK<sub>2</sub> 5.40. Crystd from acetone and sublimes at 300° without dec.

Succinamic acid (succinic acid amide)  [1638-32-4]  M 117.1, m 155°, 156-157°, pK<sub>1</sub> 4.54. Crystd from Me<sub>2</sub>C<sub>0</sub> or H<sub>2</sub>O and dried in vac. Not v sol in MeOH. Converted to succinimide above 200°.


Succinic acid  [110-15-6]  M 118.1, m 185-185.5°, pK<sub>1</sub> 4.21, pK<sub>2</sub> 5.72. Washed with diethyl ether. Crystd from aceton, distd water, or tert-butanol. Dried under vacuum over P<sub>2</sub>O<sub>5</sub> or conc H<sub>2</sub>SO<sub>4</sub>. Also
purified by conversion to the disodium salt which, after crystn from boiling water (charcoal), is treated with mineral acid to regenerate the succinic acid. The acid is then recrystd and vacuum dried.

**Succinic anhydride** [108-30-5] M 100.1, m 119-120°. Crystd from redist acetic anhydride or CHCl₃, then filtered, washed with diethyl ether and dried under vacuum.

**Succinimide** [123-56-8] M 99.1, m 124-125°, pK² 9.62. Crystd from EtOH (1mL/g) or water.

**Succinonitrile** [110-61-2] M 80.1, m 57.9°, b 108°/1mm, 267°/760mm. Purified by vacuum sublimation, also crystd from acetone.

D(+)−Sucrose (β-D-fructofuranosyl-α-D-glucopyranoside) [57-50-1] M 342.3, m 160-186°, 186-188°, [α]ᵣ⁵₄₆ +78° (c 10, H₂O), [α]ᵣ²⁶ + 66° (c 26, H₂O), pK 12.62. Crystd from water (solubility: 1g in 0.5mL H₂O at 20°, 1g in 0.2mL in boiling H₂O). Sol in EtOH (0.6%) and MeOH (1%). Sucrose diacetate hexaisobutyrate is purified by melting and, while molten, treated with NaHCO₃ and charcoal, then filtered.

**D-Sucrose octaacetate** [82-12-7] M 678.6, m 83-85°, [α]ᵣ²⁰ +70° (c 1, CHCl₃). Crystd from EtOH.

**Sudan I** (Solvent Yellow 14, 1-phenylazo-2-naphthol) [824-07-9] M 248.3, m 135°, CI 12055, λmax 476nm, pKₑₛₜ −9.0. Crystd from EtOH.

**Sudan III** [Solvent Red 23, 1-(p-phenylazo-phenylazo)-2-naphthol] [85-86-9] M 352.4, m 199°(dec), CI 26100, λmax 354, 508 nm, pKₑₛₜ −9.0. Crystd from EtOH, EtOH/water or *benzene/abs EtOH (1:1).

**Sudan IV** [Solvent Red 24, 1-(4-o-tolylazo-o-tolylazo)-2-naphthol] [85-83-6] M 380.5, m ~184°(dec), CI 26105, λmax 520nm, pKₑₛₜ −9.0. Crystd from EtOH/water or acetone/water.

**Sulfaguanidine** [57-67-0] M 214.2, m 189-190°, pK₁ 0.48, pK₂ 2.75. Crystd from hot water (7mL/g).

**Sulfamethazine** [57-68-1] M 278.3, m 198-200°, pK₁ 2.65, pK₂ 7.4. Crystd from dioxane.

**Sulfanilamide** (p-aminobenzenesulfonamide) [63-74-1] M 172.2, m 166°, pK¹₂⁰ 2.30, pK²₂⁰ 10.26. Crystd from water or EtOH.

**Sulfanilic acid** (4-aminobenzenesulfonic acid) [121-57-3] M 173.2, pK₁²⁵ <1, pK₂²⁵ 3.23, Crystd (as dihydrate) from boiling water. Dried at 105° for 2-3h, then over 90% H₂SO₄ in a vacuum desiccator.

**Sulfapyridine** [144-83-2] M 349.2, m 193°, pK² 8.64. Crystd from 90% acetone and dried at 90°.

**o-Sulfobenzoic acid** (H₂O) [123333-68-6 (H₂O); 632-25-7] M 202.2, m 68-69°, pKₑₛₜ(1)<1, pKₑₛₜ(2)−3.1 (CO₂H). Crystd from water.

**o-Sulfobenzoic acid** (monoammonium salt) [6939-89-5] M 219.5. Crystd from water.

**o-Sulfobenzoic anhydride** [81-08-3] M 184.2, m 128°, b 184-186°/18mm. See also 2,1-benzoazathiol-3-one-1,1-dioxide on p. 126.

**Sulfone (tetramethylenesulfone)** [126-33-0] M 120.2, m 28.5°, b 153-154°/18mm, 285°/760mm, d 1.263, n₀ 1.4820. Prepared commercially by Diels-Alder reaction of 1,3-butadiene and sulfur dioxide, followed by Raney nickel hydrogenation. The principle impurities are water, 3-sulfolene, 2-sulfolene and 2-isopropyl sulfolanyl ether. It is dried by passage through a column of molecular sieves. Distd

Also, it was stirred at 50° and small portions of solid KMnO₄ were added until the colour persisted during 1h. Dropwise addition of MeOH then destroyed the excess KMnO₄, the soln was filtered, freed from potassium ions by passage through an ion-exchange column and dried under vacuum. It has also been vacuum distd from KOH pellets. It is hygroscopic. [See Sacco et al. J Phys Chem 80 749 1976; J Chem Soc, Faraday Trans 1 73 1936 1977; 74 2070 1978; Trans Faraday Soc 62 2738 1966.]

Coetzee has reviewed the methods of purification of sulfolane, and also the removal of impurities. [Coetzee in Recommended Methods of Purification of Solvents and Tests for Impurities, Coetzee Ed. Pergamon Press, 1982.]

5-Sulfosalicylic acid [5965-83-3] M 254.2, m 108-110°, pK⁺⁵ <0, pK⁻⁵ 2.67, pK⁻³ 11.67. Crystd from water. Alternatively, it was converted to the monosodium salt which was crystd from water and washed with a little water, EtOH and then diethyl ether. The free acid was recovered by acidification.


The methyl ester has m 107° (from MeOH), the 4-acetyl derivative has m 190° and the 4-benzoyl derivative has m 229-232°. [Hahn and Wassmuth Chem Ber 67 2050 1934; UV: Lemon J Am Chem Soc 69 2998 1947 and Pearl and Beyer J Am Chem Soc 72 1743 1950.]

D(-)-Tagatose [87-81-0] M 180.2, m 134-135°, [α]₅₄₆ ~6.5° (c 1, H₂O). Crystd from aqueous EtOH.

d- Tartaric acid [147-71-7] M 150.1, m 169.5-170° (2S,3S-form, natural) [α]₅₄₆ ~15° (c 10, H₂O); m 208° (2RS,3RS-form), pK⁺⁵ 3.03, pK⁻⁵ 4.46, pK⁺³ 14.4. Crystd from distilled H₂O or *benzene/diethyl ether containing 5% of pet ether (b 60-80°) (1:1). Soxhlet extraction with diethyl ether has been used to remove an impurity absorbing at 265nm. It has also been crystd from absolute EtOH/hexane, and dried in a vacuum for 18h [Kornblum and Wade J Org Chem 52 5301 1987].

meso-Tartaric acid [147-73-9] M 150.1, m 139-141°, pK⁺⁵ 3.17, pK⁻⁵ 4.91. Crystd from water, washed with cold MeOH and dried at 60° under vacuum.

Taurocholic acid [81-24-3] M 515.6, m 125°(dec), [α]₀ +38.8 (c 2, EtOH), pK 1.4. Crystd from EtOH/diethyl ether.


Terephthalic acid (benzene-1,4-dicarboxylic acid) [100-21-0] M 166.1, m sublimes >300° without melting, pK⁺¹ 3.4, pK⁻¹ 4.34. Purified via the sodium salt which, after crystn from water, was reconverted to the acid by acidification with mineral acid.

Terephthaloyl chloride [100-20-9] M 203.0, m 80-82°. Crystd from dry hexane.

o-Terphenyl [84-15-1] M 230.3, m 57-58°. Crystd from EtOH. Purified by chromatography of CCl₄ solns on alumina, with pet ether as eluent, followed by crystn from pet ether (b 40-60°) or pet ether/*benzene. They can also be distd under vacuum.

p-Terphenyl [92-94-4] M 230.3, m 212.7°. Crystd from nitrobenzene or trichlorobenzene. It was purified by chromatography on alumina in a darkened room, using pet ether, and then crystallizing from pet ether (b 40-60°) or pet ether*benzene.

Terpin hydrate [2451-01-6] M 190.3, m 105.5° (cis), 156-158° (trans). Crystd from H2O or EtOH.

2,2′:6′,2″-Terpyridyl (2,2′:6′,2″-terpyridyl) [1148-79-4] M 233.3, m 91-92°, pK 2.6, pK 3 4.33. Crystd from diethyl ether, toluene or from pet ether, then aqueous MeOH, followed by vacuum sublimation at 90°.

Terreic acid (2-hydroxy-3-methyl-1,4-benzoquinone-5,6-epoxide) [121-40-4] M 154.1, m 127-127.5°, [α] D +74° (pH 4, phosphate buffer), -17° (CHCl3), pK 4.5. Crystd from *benzene or hexane. Sublimed in vacuo.

Terthiophene (2,5-di[thienyl]thiophene; α-terthienyl) [1081-34-1] M 248.4, m 94-95.5°, 94-96°. Possible impurities are bithienyl and polythienyls. Suspend in H2O and steam distil to remove bithienyl. The residue is cooled and extracted with CHCl3, dried (MgSO4), filtered, evaporated and the residue chromatographed on Al2O3 using pet ether-3% Me2CO as eluant. The terphenyl zone is then eluted from the Al2O3 with Et2O, the extract is evaporated and the residue is recrystd from MeOH (40mL per g). The platelets are washed with cold MeOH and dried in air. [UV: Sease and Zechmeister J Am Chem Soc 69 270 1947; Uhlenbroek and Bijloo Recl Trav Chim Pays-Bas 79 1181 1960.] See also entry on p. 568 in Chapter 6.


Testosterone propionate [57-85-2] M 344.5, m 118-122°, [α] 20 130° (c 1, dioxane). Crystd from aqueous EtOH.


Tetra-n-amylamnonium iodide [2498-20-6] M 425.5, m 135-137°. Crystd from EtOH and dried at 35° under vac. Also purified by dissolving in acetone and pptd by adding diethyl ether; and dried at 50° for 2 days.

1,4,8,11-Tetraazacyclotetradecane [295-37-4] M 200.33, m 173° (closed capillary and sublimes at 125°), 183-185°, 185°, pK 2.8, pK 3 6.0, pK 4 9.0, pK 5 9.6. Purified by recrystn from dioxane (white needles) and sublimes above 120°. It has been distilled, b 132-140°/4-8mm. It forms complexes with metals and gives a sparingly soluble nitrate salt, m 205° (dec), which crystallises from H2O and is dried at 150°. [UV: Bosnich et al. Inorg Chem 4 1102 1963, van Alphen Recl Trav Chim Pays-Bas 56 343 1937.]

Tetrabenazine (2-oxo-3-isobutyl-9,10-dimethoxy-1,2,3,4,6,7-hexahydro-11bH-benzo[a]quinolizine) [58-46-8] M 317.4, m 127-128°, pK 8. Crystd from MeOH. The hydrochloride has m 208-210° and the oxime has m 158° (from EtOH).

1,1,2,2,-Tetramethylethane [79-27-6] M 345.7, f 0.0°, b 243.5°, d 2.965, n 1.63533. Washed successively with conc H2SO4 (three times) and H2O (three times), dried with K2CO3 and CaSO4 and distd.
Purification of Organic Chemicals

3′,3″,5′,5″-Tetrabromophenolphthalein ethyl ester [1176-74-5] M 662.0, m 212-214°. Crystd from benzene, dried at 120° and kept under vacuum.

Tetra-n-butylammonium bromide [1643-19-2] M 322.4, m 119.6°. Crystd from benzene (5mL/g) at 80° by adding hot n-hexane (three volumes) and allowing to cool. Dried over P2O5 or Mg(ClO4)2, under vacuum. The salt is very hygroscopic. It can also be crystd from ethyl acetate or dry acetone by adding diethyl ether and dried in vacuo at 60° for 2 days. It has been crystd from acetone by addition of diethyl ether. So hygroscopic that all manipulations should be carried out in a dry-box. Purified by precipitation of a saturated solution in dry CC14 by addition of cyclohexane or by recrystallisation from ethyl acetate, then heating in vacuum to 75° in the presence of P2O5. [Symons et al. J Chem Soc, Faraday Trans I 76 2251 1908.] Also recrystallised from CH2Cl2/diethyl ether and dried in a vacuum desiccator over P2O5. [Blau and Espenson J Am Chem Soc 108 1962 1986.]

Tetra-n-butylammonium chloride [1112-67-0] M 277.9, m 15.7°. Crystd from acetone by addition of diethyl ether. Very hygroscopic and forms crystals with 34H2O.


Tetra-n-butylammonium iodide [311-28-4] M 369.4, m 146°. Crystd from toluene/pet ether (see entry for the corresponding bromide), acetone, ethyl acetate, EtOH/diethyl ether, nitromethane, aq EtOH or water. Dried at room temperature under vac. It has also been dissolved in MeOH/acetone (1:3, 10mL/g), filtered and allowed to stand at room temperature to evaporate to ca half its original volume. Distilled water (1mL/g) was then added, and the ppt was filtered off and dried. It was also dissolved in acetone, ppted by adding ether and dried in vac at 90° for 2 days. It has also been recrystallised from CH2Cl2/pet ether or hexane, or anhydrous methanol and stored in a vacuum desiccator over H2SO4. [Chau and Espenson J Am Chem Soc 108 1962 1986.]

Tetra-n-butylammonium nitrate [1941-27-1] M 304.5, m 119°. Crystd from benzene (7mL/g) or EtOH, dried in a vacuum over P2O5 at 60° for 2 days.


Tetra-n-butylammonium picrate [914-45-4] M 490.6, m 89°. Crystd from EtOH. Dried in a vacuum desiccator over P2O5.

Tetra-n-butylammonium tetrabutylborate (Bu4N° Bu4B−) [23231-91-6] M 481.7, m 109.5°. Dissolved in MeOH or acetone, and crystd by adding dist water. Dried in vac at 70°. It has also been successively recrystd from isopropyl ether, isopropyl ether/acetone (50:1) and isopropyl ether/EtOH (50:1) for 10h, then isopropyl ether/acetone for 1h, and dried at 65° under reduced pressure for 1 week. [Kondo et al. J Chem Soc, Faraday Trans I 76 812 1980.]
Purification of Organic Chemicals

2,3,4,5-Tetrachloroaniline [634-83-3] M 230.9, m 119-120°, pK_{ESt} ~-0.26. Crystd from EtOH.

2,3,5,6-Tetrachloroaniline [3481-20-7] M 230.9, m 107-108°, pK_{ESt} ~-1.8. Crystd from EtOH.

1,2,3,4-Tetrachlorobenzene [634-66-2] M 215.9, m 45-46°, b 254°/760mm. Crystd from EtOH.

1,2,3,5-Tetrachlorobenzene [634-90-2] M 215.9, m 51°, b 246°/760mm. Crystd from EtOH.

1,2,4,5-Tetrachlorobenzene [95-94-3] M 215.9, m 139.5-140.5°, b 240°/760mm. Crystd from EtOH, ether, *benzene, *benzene/EtOH or carbon disulfide.

3,4,5,6-Tetrachloro-1,2-benzoquinone [2435-53-2] M 245.9, m 130°. Crystd from AcOH. Dry in vacuum desiccator over KOH.

1,1,2,2-Tetrachloro-1,2-difluoroethane [72-12-0] M 203.8, f 26.0°, b 92.8°/760mm. Purified as for trichlorotrifluoroethane.

sym-Tetrachloroethane [79-34-5] M 167.9, b 62°/100mm, 146.2°/atm, d 1.588, n \textsuperscript{1.5} 1.49678. Stirred, on a steam-bath, with conc H\textsubscript{2}SO\textsubscript{4} until a fresh portion of acid remained colourless. The organic phase was then separated, dist in steam, dried (CaCl\textsubscript{2} or K\textsubscript{2}CO\textsubscript{3}), and fractionally distd in a vac.

Tetrachloroethylene [127-18-4] M 165.8, b 62°/80mm, 121.2°, d \textsubscript{1.5} 1.63109, d \textsubscript{1.6} 1.623, n \textsubscript{1.5} 1.50759, n \textsubscript{1.6} 1.50566 It decomposes under similar conditions to CHCl\textsubscript{3}, to give phosgene and trichloroacetic acid. Inhibitors of this reaction include EtOH, diethyl ether and thymol (effective at 2-5ppm). Tetrachloroethylene should be distd under a vac (to avoid phosgene formation), and stored in the dark out of contact with air. It can be purified by washing with 2M HCl until the aq phase no longer becomes coloured, then with water, drying with Na\textsubscript{2}CO\textsubscript{3}, Na\textsubscript{2}SO\textsubscript{4}, CaCl\textsubscript{2} or P\textsubscript{2}O\textsubscript{5}, and fractionally distilling just before use. 1,1,2-Trichloroethane and 1,1,1,2-tetrachloroethane can be removed by counter-current extraction with EtOH/water.

Tetrachloro-N-methylphthalimide [14737-80-5] M 298.9, m 209.7°. Crystd from absolute EtOH.

2,3,4,6-Tetrachloronitrobenzene [879-39-0] M 260.9, m 42°. Crystd from aqueous EtOH.

2,3,5,6-Tetrachloronitrobenzene [117-18-0] M 260.9, m 99-100°. Crystd from aqueous EtOH.

2,3,4,5-Tetrachlorophenol [4901-51-3] M 231.9, m 116-117°, pK_{ESt} ~-6.2. Crystd from pet ether.

2,3,4,6-Tetrachlorophenol [58-90-2] M 231.9, m 70°, b 150°/15mm, pK_{ESt} ~-5.4. Crystd from pet ether.

2,3,5,6-Tetrachlorophenol [935-55-5] M 231.9, m 115°, pK_{ESt} ~-5.0. Crystd from pet ethers.

Tetrachlorophthalic anhydride [117-08-8] M 285.9, m 255-257°. Crystd from chloroform or *benzene, then sublimed.

2,3,4,6-Tetrachloropyridine [14121-36-9] M 216.9, m 74-75°, b 130-135°/16-20mm, pK_{ESt} ~-5.7. Crystd from 50% EtOH.

Tetracosane [646-31-7] M 338.7, m 54°, b 243-244°/15mm. Crystd from diethyl ether.

Tetracosanoic (lignoceric) acid [557-59-5] M 368.7, m 84°, 87.5-88°, pK_{ESt} ~-5.0. Crystd from acetic acid, Me\textsubscript{2}CO, toluene, pet ether/Me\textsubscript{2}CO, *C\textsubscript{6}H\textsubscript{6}/Me\textsubscript{2}CO.
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7,7,8,8-Tetracyanoquinodimethane [1518-16-7] M 204.2, m 287-290°(dec). Recrystd from distd, dried, acetonitrile.

1-Tetradecanol [112-72-1] M 214.4, m 39-395°, b 160°/10mm, 170-173°/20mm. Crystd from aq EtOH. Purified by zone melting.

Tetradecyl ether (di-tetradecyl ether) [5412-98-6] M 410.7. Distd under vac and then crystd repeatedly from MeOH/*benzene.

Tetradecyltrimethylammonium bromide [119-97-7] M 336.4, m 244-249°. Crystd from acetone or a mixture of acetone and >5% MeOH. Washed with diethyl ether and dried in a vacuum oven at 60°. [Dearden and Wooley J Phys Chem 91 2404 1987.]

Tetraethylammonium bromide [71-91-0] M 210.2, m 269°(dec), 284°(dec). Recrystd from EtOH, CHCl3 or diethyl ether, or, recrystd from acetonitrile, and dried over P2O5 under reduced pressure for several days. Also recrystd from EtOH/diethyl ether (1:2), EtOAc, water or boiling MeOH/acetone (1:3) or by adding equal volume of acetone and allowing to cool. Dried at 100° in vacuo for 12 days, and stored over P2O5. [Cox et al. J Am Chem Soc 106 5965 1984; Liu et al. J Am Chem Soc 108 1740 1986; White and Murray J Am Chem Soc 109 2576 1987.]


Tetraethylammonium iodide [68-05-3] M 257.2, m 302°, >300°(dec). Crystd from acetone/MeOH, EtOH/water, dimethylacetamide or ethyl acetate/EtOH (19:1). Dried under vacuum at 50° and stored over P2O5.


Tetraethylammonium picrate [741-03-7] M 342.1, m >300°(dec). Purified by successive crystns from water or 95% EtOH followed by drying in vacuum at 70°.

Tetraethylammonium tetrafluoroborate [429-06-1] M 217.1, m 235°, 275-277°, 289-291°. Recrystd three times from a mixture of ethyl acetate/hexane (5:1) or MeOH/pet ether, then stored at 95° for 48h

Dried in a vacuum oven at 60° for several days. *Similarity for the propyl and butyl homologues.*

**Tetraethyl 1,1,2,2-ethanetetracarboxylate** [632-56-4] M 318.3, m 73-74°. Twice recrystd from EtOH by cooling to 0°.

**Tetraethylene glycol dimethyl ether** [143-24-8] M 222.3, b 105°/1mm, d 1.010, n 1.435.
Stood with CaH₂, LiAlH₄ or sodium, and distd when required.

**Tetraethylene pentamine** [112-57-2] M 189.3, b 169-171°/0.05mm, d 0.999, n 1.506, pK₁ 2.98, pK₂ 4.72, pK₃ 8.08, pK₄ 9.10, pK₅ 9.68. Distd under vacuum. Purified via its pentachloride, nitrate or sulfate. Jonassen, Frey and Schaafsma (*J Phys Chem* 61 504 1957) cooled a soln of 150g of the base in 300mL of 95% EtOH, and added dropwise 180mL of conc HCl, keeping the temperature below 20°. The white ppte was filtered, crystd three times from EtOH/water, then washed with diethyl ether and dried by suction. Reilley and Holloway (*J Am Chem Soc* 80 2917 1958), starting with a similar soln cooled to 0°, added slowly (keeping the temperature below 10°) a soln of 4.5g-moles of HNO₃ in 600mL of aqueous 50% EtOH (also cooled to 0°). The ppte was filtered by suction, recrystd five times from aqueous 5% HNO₃, then washed with acetone and absolute EtOH and dried at 50°. [For purification via the sulfate see Reilley and Vavoulis (*Anal Chem* 25 243 1959), and for an additional purification step using the Schiff base with benzaldehyde see Jonassen et al. *J Am Chem Soc* 79 4279 1957.]

**Tetraethyl orthocarbonate** (ethyl orthocarbonate, tetraethoxy ethane) [78-09-1] M 192.3, b 59.6-60°/14mm, 158°/atm, 159°/atm, 160-161°/atm, d₄ 0.9186, n₂ 1.3932. Likely impurities are hydrolysis products. Shake with brine (sated NaCl; dilute with a little Et₂O if amount of material is small) and dry (MgSO₄). The organic layer is filtered off and evaporated, and the residue is distd through a helices packed fractionating column with a total reflux partial take-off head. All distns can be done at atmospheric pressure in an inert atmosphere (e.g. N₂). [Roberts and McMahon *Org Synth Coll Vol IV* 457 1963; Connolly and Dyson *J Chem Soc* 828 1937; Tieckelmann and Post *J Org Chem* 13 266 1948.]
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Tetra-\(n\)-hexylammonium bromide \([4328-13-6]\) \(M\) 434.6, \(m\) 99-100\(^\circ\). Washed with ether, and dried in a vacuum at room temperature for 3 days.

Tetra-\(n\)-hexylammonium chloride \([5922-92-9]\) \(M\) 390.1. Crystd from EtOH.

Tetra-\(n\)-hexylammonium iodide \([2138-24-1]\) \(M\) 481.6, \(m\) 99-101\(^\circ\). Washed with diethyl ether and dried at room temperature in vacuo for 3 days.

Tetrahexylammonium perchlorate \([4656-81-9]\) \(M\) 454.1, \(m\) 104-106\(^\circ\). Crystd from acetone and dried in vacuo at 80\(^\circ\) for 24h.

Tetrahydrofuran \([109-99-9]\) \(M\) 72.1, \(b\) 25\(^9\)/176mm, 66\(^9\)/760mm, \(d_4^{20}\) 0.889, \(n_D^{20}\) 1.4070, \(pK\) -2.48 (aq H\(_2\)SO\(_4\)). It is obtained commercially by catalytic hydrogenation of furan from pentosan-containing agricultural residues. It was purified by refluxing with, and distilling from LiAlH\(_4\) which removes water, peroxides, inhibitors and other impurities [Jaeger et al. J Am Chem Soc 101 717 1979]. Peroxides can also be removed by passage through a column of activated alumina, or by treatment with aq ferrous sulfate and sodium bisulfate, followed by solid KOH. In both cases, the solvent is then dried and fractionally distd from sodium. Lithium wire or vigorously stirred molten potassium have also been used for this purpose. CaH\(_2\) has also been used as a drying agent.

Several methods are available for obtaining the solvent almost anhydrous. Ware [J Am Chem Soc 83 1296 1961] dried vigorously with sodium-potassium alloy until a characteristic blue colour was evident in the solvent at Dry-ice/cellulosolve temperatures. The solvent was kept in contact with the alloy until distd for use. Worsfold and Bywater [J Chem Soc 5234 1960], after refluxing and distilling from P\(_2\)O\(_5\) and KOH, in turn, refluxed the solvent with sodium-potassium alloy and fluorenone until the green colour of the disodium salt of fluorenone was well established. [Alternatively, instead of fluorenone, benzophenone, which forms a blue ketyl, can be used.] The tetrahydrofuran was then fractionally distd, degassed and stored above CaH\(_2\). p-Cresol or hydroquinone inhibit peroxide formation. The method described by Coetzee and Chang [Pure Appl Chem 57 633 1985] for 1,4-dioxane also applies here. Distns should always be done in the presence of a reducing agent, e.g. FeSO\(_4\). It irritates the skin, eyes and mucous membranes and the vapour should never be inhaled. It is HIGHLY FLAMMABLE and the necessary precautions should be taken.

Rapid purification: Purification as for diethyl ether.

\(l\)-Tetrahydropalmatine (2\(_2\),3\(_9\),9\(_{-}\),10-tetramethoxy-6H-dibenzo[a,g]quinolizidine) \([10097-84-4]\) \(M\) 355.4, \(m\) 148-149\(^9\), \([\alpha]_D^{20}\) -291\(^9\) (EtOH). Crystd from MeOH by addition of water [see J Chem Soc (C) 530 1967].

Tetrahydrofuran \([142-68-7]\) \(M\) 86.1, \(b\) 88.0\(^9\), \(n\) 1.4202, \(d\) 0.885, \(pK\) -2.79 (aq H\(_2\)SO\(_4\)). Dried with CaH\(_2\), then passed through a column of silica gel to remove olefinic impurities and fractionally distd. Freed from peroxides and moisture by refluxing with sodium, then distilling from LiAlH\(_4\). Alternatively, peroxides can be removed by treatment with aqueous ferrous sulfate and sodium bisulfate, followed by solid KOH, and fractional distn from sodium.

Tetrahydrothiophene \([110-01-0]\) \(M\) 88.2, \(m\) -96\(^9\), \(b\) 14.5\(^9\)/10mm, 120.9\(^9\)/760mm, \(d\) 0.997, \(n\) 1.5289. Crude material was purified by crystn of the mercuric chloride complex to a constant melting point. It was then regenerated, washed, dried, and fractionally distd. [Whitehead et al. J Am Chem Soc 73 3632 1951]. It has been dried over Na\(_2\)SO\(_4\) and distd in a vacuum [Roberts and Friend J Am Chem Soc 108 7204 1986].


Tetrakis(dimethylamino)ethylene [996-70-3] M 300.2, b 60°/1mm, d 0.861, n 1.4817, pK(0) 0.0, pK(1) -1.5, pK(2) 5.1. Impurities include tetramethylurea, dimethylamine, tetramethylethanediamine and tetramethyloxamide. It was washed with water while being flushed with nitrogen to remove dimethylamine, then distilled under reduced pressure from sodium or BaO. Degassed on a vacuum line by distillation from a trap at 50° to one at -70°.

Tetralin (1,2,3,4-tetrahydronaphthalene) [119-64-2] M 132.2, b 65-66°/5mm, 207.6°/1760mm, d 0.968, n 1.5413. It was washed with successive portions of conc H2SO4 until the acid layer no longer became coloured, then washed with aq 10% Na2CO3, and then distill water. Dried (CaSO4 or Na2SO4), filtered, refluxed and fractionally distill at under reduced pressure from sodium or BaO. It can also be purified by repeated fractional freezing. Bass [J Chem Soc 3498 1964] freed tetralin, purified as above, from naphthalene and other impurities by conversion to ammonium tetralin-6-sulfonate. Conc H2SO4 (150mL) was added slowly to stirred tetralin (272mL) which was then heated on a water bath for about 2h to give complete soln. The warm mixture, when poured into aq NH4Cl soln (120g in 400mL water), gave a white ppte which, after filtering off, was crystd from boiling water, washed with 50% aq EtOH and dried at 100°. Evapn of its boiling aq soln on a steam bath removed traces of naphthalene. The pure salt (229g) was mixed with conc H2SO4 (266mL) and steam distill from an oil bath at 165-170°. An ether extract of the distillate was washed with aq Na2SO4, and the ether was evapd, prior to distilling the tetralin from sodium. Tetralin has also been purified via barium tetralin-6-sulfonate, conversion to the sodium salt and decomposition in 60% H2SO4 using superheated steam.


α-Tetralone (1,2,3,4-tetrahydro-1-oxonaphthalene) [529-34-0] M 146.2, m 2-7°, 7.8-8.0°, b 75-85°/0.3mm, 89°/0.5mm, 94-95°/2mm, 132-134°/15mm, 143-145°/20mm, di 1.0695, nD 1.5665. Check the IR first. Purify by dissolving 20mL in Et2O (200mL), washing with H2O (100mL), 5% aq NaOH (100mL), H2O (100mL), 3% aq AcOH (100mL), 5% NaHCO3 (100mL) then H2O (100mL) and dry the ethereal layer over MgSO4. Filter, evap and fractionate the residue through a 6in Vigreux column under reduced pres to give a colourless oil (-17g) with b 90-91°/0.5-0.7mm. [Snyder and Werber Org Synth Coll Vol III 798 1955.] It has also been fractionated through a 0.5metre packed column with a heated jacket under reflux using a partial take-off head. [Olson and Bader Org Synth Coll Vol IV 898 1963.]

β-Tetralone (1,2,3,4-tetrahydro-2-oxonaphthalene) [530-93-8] M 146.2, m 17-18°, ~18°, b 93-95°/2mm, 104-105°/4mm, 114-115°/4-5mm, 140°/18mm, di 1.1000, nD 1.5598. If reasonably pure then fractionate through an efficient column. Otherwise purify via the bisulfite adduct. To a soln of NaHSO3 (32.5g, 0.31mol) in H2O (57mL) is added 95% EtOH (18mL) and set aside overnight. Any bisulfite-sulfate that separated is removed by filtration and the filtrate is added to the tetralone (14.6g, 0.1mol) and shaken vigorously. The adduct separates in a few minutes as a white ppte and kept on ice for ~3.5h with occasional shaking. The ppte is collected, washed with 95% EtOH (13mL), then with Et2O (4 x 15mL, by stirring the suspension in the solvent, filtering and repeating the process). The colourless product is dried in air and stored in air tight containers in which it is stable for extended periods (yield is ~17g). This bisulfite (5g) is suspended in H2O (25mL) and Na2CO3, H2O (7.5g) is added (pH of soln is ~10). The mixture is then extracted.
with Et₂O (5 x 10mL, i.e. until the aqueous phase does not test for tetralone --- see below). Wash the combined extracts with 10% aqueous HCl (10mL), H₂O (10mL, i.e. until the washings are neutral), dry (MgSO₄), filter, evaporate and distil the residual oil using a Claisen flask under reduced pressure and in a N₂ atm. The pure tetralone is a colourless liquid b 70-71/0.25mm (see also above). The yield is ~2 g. Tetralone test: Dissolve a few drops of the tetralone soln (ethereal or aqueous) in 95% EtOH in a test tube and add 10 drops of 25% NaOH down the side of the tube. A deep blue colour develops at the interface with air. [Soffer Org Synth Coll Vol IV 903 1963; Cornforth et al. J Chem Soc 689 1942; UV: Soffer et al. J Am Chem Soc 1556 1952.] The phenylhydrazone has m 108° [Crawley and Robinson J Chem Soc 2001 1938].

Tetramethylammonium bromide [64-20-0] M 154.1, sublimes with dec >230°. Crystd from EtOH, EtOH/diethyl ether, MeOH/acetonitrile, or from acetone/MeOH (4:1) by adding an equal volume of acetone. It was dried at 110° under reduced pressure or at 140° for 24h.

Tetramethylammonium chloride [75-57-0] M 109.6, m >230°(dec). Crystd from EtOH, EtOH/CHCl₃, EtOH/diethyl ether, acetone/EtOH (1:1), isopropanol or water. Traces of the free amine can be removed by washing with CHCl₃.

Tetramethylammonium hydroxide (5H₂O) [10424-65-4 (5H₂O); 75-59-2 (aq soln)] M 181.2, m 63°, 65-68°. Freed from chloride ions by passage through an ion-exchange column (Amberlite IRA-400, prepared in its OH⁻ form by passing 2M NaOH until the effluent was free from chloride ions, then washed with distilled H₂O until neutral). A modification, to obtain carbonate-free hydroxide, uses the method of Davies and Nancolls [Nature 165 237 1950].

Tetramethylammonium perchlorate [2537-36-2] M 173.6, m 300°(dec). Crystd from acetone and dried in vacuo at 60° for several days.

Tetramethylammonium tetraphenylborate [15525-13-0] M 393.3. Recrystd from acetone, acetone/CCl₄ and from acetone/1,2-dichloroethane. Dried over P₂O₅ in vacuo, or in a vacuum oven at 60° for several days.

1,2,3,4-Tetramethylbenzene (prehnitine) [488-23-3] M 134.2, m -6.3°, b 79.4°/10mm, 204-205°/760mm, d 0.905, n 1.5203. Dried over sodium and distd under reduced pressure.

1,2,3,5-Tetramethylbenzene (isodurene) [527-53-7] M 134.2, m -23.7°, b 74.4°/10mm, 198°/760mm, d 0.890, n 1.5130. Refluxed over sodium and distd under reduced pressure.


N,N,N',N'-Tetramethylbenzidine [366-29-0] M 240.4, m 195.4-195.6°, pKₑₐₙ(1) = 3.4, pKₑₐₙ(2) = 4.5. Crystd from EtOH or ether, then from ether/*benzene, and sublimed in a vacuum. [Guarr et al. J Am Chem Soc 107 5104 1985.] Dried under vac in an Abderhalden pistol, or carefully on a vacuum line.

2,2,4,4-Tetramethylcyclobutan-1,3-dione [933-52-8] M 140.2, m 114.5-114.9°. Crystd from *benzene and dried under vacuum over P₂O₅ in an Abderhalden pistol.

3,3,5,5-Tetramethylcyclohexanone [14376-79-5] M 154.3, m 11-12°, 13.2°, b 59-61°, 80-82°/13mm, 196°/760mm, 203.8-204.8°/760mm, d²0 0.8954, n²0 1.4515. Purified first through a
24in column packed with Raschig rings then a 40cm Vigreux column under reduced pressure (b 69-69.3°/7mm, see above). The oxime has m 144-145° (from 60% EtOH) and the semicarbazone has m 196-197°, 197-198° (214.5°, 217-218°) [Karasch and Tawney J Am Chem Soc 63 2308 1941; UV: Sandris and Ourisson Bull Soc Chim Fr 95 1956].

\[ p,p'-\text{Tetramethyldiaminodiphenylmethane [bis(p-dimethylaminophenyl)methane, Michler's base]} \] [101-61-1] M 254.4, m 89-90°, b 155-157°/0.1mm, \( pK_{\text{EtOH}} \approx 5.8 \), \( pK_{\text{EtOH}} \approx 5.1 \). Crystd from EtOH (2mL/g) or 95% EtOH (ea 12mL/g). It sublimes on heating.

Tetramethylene sulfoxide (tetrahydrothiophen 1-oxide) [1600-44-8] M 104.2, b 235-237°, d 1.175. Shaken with BaO for 4 days, then distd from CaH2 under reduced pressure.

N,N,N',N'-Tetramethylethylenediamine (TMEDA, TEMED) [110-18-9] M 116.2, b 122°, d 1.175, n\(_D\) 1.4153, \( pK_1 5.90 \), \( pK_2 9.14 \). Partially dried with molecular sieves (Linde type 4A), and distd in vacuum from butyl lithium. This treatment removes all traces of primary and secondary amines and water. [Hay, McCabe and Robb J Chem Soc, Faraday Trans 1 68 1 1972.] Or, dried with KOH pellets. Refluxed for 2h with one-sixth its weight of n-butyric anhydride (to remove primary and secondary amines) and fractionally distd. Refluxed with fresh KOH, and distd under nitrogen. [Cram and Wilson J Am Chem Soc 85 1245 1963.] Also distd from sodium.


1,1,3,3-Tetramethylguanidine [80-70-6] M 115.2, b 159-160°, d 0.917 n\(_D\) 1.470, \( pK_2 13.6 \). Refluxed over granulated BaO, then fractionally distd.

N,N,N',N'-Tetramethyl-1,8-naphthalenediamine [20734-58-1] M 214.3, m 45-48°, 47-48°, b 144-145°/4mm, \( pK_1 -10.5 \), \( pK_2 12.34 \) (monoprotonation). It is prepared by methylating 1,8-diaminonaphthalene and likely impurities are methylated products. The tetramethyl compound is a stronger base than the unmethylated, di and trimethylated derivatives. The \( pK_a \) values are: 1,8-(NH\(_2\))\(_2\) = 4.61, 1,8-(NHMe))\(_2\) = 5.61, 1-NHMe-8-NHMe\(_2\) = 6.43 and 1,8-(NMe\(_2\))\(_2\) = 12.34. The mixture is then treated H\(_2\)O at pH 8 (where all but the required base are protonated) and extracted with Et\(_2\)O or CHCl\(_3\). The dried extract (K\(_2\)CO\(_3\)) yields the tetramethyldiamine on evapn which can be distd. It is a strong base with weak nucelophilic properties, e.g. it could not be alkylated by refluxing with Et\(_2\) in MeCN for 4 days and on treatment with methyl fluorosulfonate only the fluorosulfonate salt of the base is obtained. [NMR: Adler et al. J Chem Soc, Chem Commun 723 1968; J Am Chem Soc 63 358 1941.] See Proton sponge p. 134.

Tetramethyloxyphenoxy (methyl orthocarbonate, tetramethoxy methane) [1850-14-2] M 136.2, m -5.6°, -5°, -2°, b 113.5°/760mm, 113.5-114°/755mm, 112-114°/atm, \( d_4^0 \) 1.0202, \( n_7^0 \) 1.3860. Purified in the same way as for tetraethyl orthocarbonate. [Smith Acta Chem Scand 10 1006 1956; Tiekelman and Post J Org Chem 13 266 1948.]

N,N,N',N'-Tetramethyl-1,4-phenylenediamine [100-22-1] M 164.3, m 51°, b 260°/760mm, \( pK_1^{\text{EtOH}} 2.29 \), \( pK_2^{\text{EtOH}} 6.35 \). Crystd from pet ether or water. It can be sublimed or dried carefully in a vacuum line, and stored in the dark under nitrogen. Also recrystd from its melt.

N,N,N',N'-Tetramethyl-1,4-phenylenediamine dihydrochloride [637-01-4] M 237.2, m 222-224°. Crystd from isopropyl or n-butyl alcohols, satd with HCl. Treated with aq NaOH to give the free base which was filtered, dried and sublimed in a vacuum. [Guarr et al. J Am Chem Soc 107 5104 1985.]

2,2,6,6-Tetramethyl-4-piperidone hydrochloride (triacetoneamine) [33973-59-0] M 191.7, m 190° (dec), 198-199° (dec), pK<sub>Est</sub> 7.90. Purified by recrystn from EtOH/Et2O, MeCN or Me2CO/MeOH. The free base has m 37-39° (after sublimation), b 102-105°/18mm, and hydrate m 56-58° (wet Et2O); the hydrobromide has m 203° (from EtOH-Et2O) and the picrate has m 196° (from aq EtOH). [Sandris and Ourisson Bull Soc Chim Fr 345 1958.]

Tetramethylthiuram disulfide [bis-(dimethylthiocarbamyl)-disulfide] [137-26-8] M 240.4, m 146-148°, 155-156°. Crystd (three times) from boiling CHCl₃, then recrystd from boiling CHCl₃ by adding EtOH dropwise to initiate pptn, and allowed to cool. Finally it was ppted from cold CHCl₃ by adding EtOH (which retained the monosulfide in soln). [Ferington and Tobolsky J Am Chem Soc 77 4510 1955.]

1,1,3,3-Tetramethyl urea [632-22-4] M 116.2, f -1.2°, b 175.2°/760mm, d 0.969, n 1.453. Dried over BaO and distd under nitrogen.

Tetramethyl uric acid [2309-49-1] M 224.2, m 225°, 228°, pK<sub>Est</sub> <0. Crystd from H₂O or MeOH.

1,3,5,5-Tetranitrohexahydropyrimidine [81360-42-1] M 270.1, m 153-154°. Crystd from EtOH (5x), and sublimed (~65°/0.05mm) [J Org Chem 47 2474 1982; J Labelled Comp Radiopharm 29 1197 1991].

Tetranitromethane [509-14-8] M 196.0, m 14.2°, b 21-23°/23mm, 126°/760mm, d 1.640, n 1.438. Shaken with dilute NaOH, washed, steam distd, dried with Na₂SO₄ and fractionally crystd by partial freezing. The melted crystals were dried with MgSO₄ and fractionally distd under reduced pressure. Shaken with a large volume of dilute NaOH until no absorption attributable to the nitro anion (from mono-di- and tri-nitromethanes) is observable in the water. Then washed with distilled water, and distilled at room temperature by passing a stream of air or nitrogen through the liquid and condensing in a trap at -80°. It can be dried with MgSO₄ or Na₂SO₄, fractionally crystd from the melt, and fractionally distd under reduced pressure.


Tetraphenylethylene [632-51-9] M 332.4, m 223-224°, b 415-425°/760mm. Crystd from dioxane or from EtOH/*benzene. Sublimed under high vacuum.

Tetraphenylhydrazine [632-52-0] M 336.4, m 147°, pK<sub>Est</sub> ~0. Crystd from 1:1 CHCl₃/toluene or CHCl₃/EtOH. Stored in a refrigerator, in the dark.

trans-1,1,4,4-Tetraphenyl-2-methylbutadiene [20411-57-8] M 372.5. Crystd from EtOH.

1,2,3,4-Tetraphenylnaphthalene [751-38-2] M 432.6, m 199-201°, 204-204.5°. Crystd from MeOH or as EtOH. [Fieser and Haddadin Org Synth 46 107 1966.]
5,6,11,12-Tetraphenylnaphthacene (Rubrene) \([517-51-1]\) \(M\ 532.7, \ m>315^\circ, 322^\circ, \ d\ 1.255\) Orange crysts by sublimation at 250-260°/3-4mm [UV Badger and Pearce *Spectrochim Acta* 4 280 1950]. Also recrystd from *benzene under red light because it is chemiluminescent and light sensitive.

5,10,15,20-Tetraphenylporphyrin (TPP) \([917-23-7]\) \(M\ 614.7, \ \lambda_{\text{max}}\ 482\text{nm.} \) Purified by chromatography on neutral (Grade I) alumina, and recrystd from CH\(_2\)Cl\(_2\)/MeOH [Yamashita et al. *J Phys Chem* 91 3055 1987].

Tetra-n-propylammonium bromide \([1941-30-6]\) \(M\ 266.3, \ m>280^\circ\text{(dec)}. \) Crystd from ethyl acetate/MeOH (9:1), acetone or MeOH. Dried at 110° under reduced pressure.

Tetra-n-propylammonium iodide \([631-40-3]\) \(M\ 313.3, \ m>280^\circ\text{(dec).} \) Purified by crystn from EtOH, EtOH/diethyl ether (1:1), EtOH/water or aqueous acetone. Dried at 50° under vacuum. Stored over P\(_2\)O\(_5\) in a vacuum desiccator.

Tetra-n-propylammonium perchlorate \([15780-02-6]\) \(M\ 285.8, \ m\ 239-241^\circ. \) See tetrapropylammonium perchlorate on p. 483 in Chapter 5.

5,10,15,20-Tetra-4'-pyridinylporphyrin \([16834-13-2]\) \(M\ 618.7, \ m>300^\circ\text{(dec).} \) Purified by chromatography on alumina (neutral, Grade I), followed by recrystn from CH\(_2\)Cl\(_2\)/MeOH [Yamashita et al. *J Phys Chem* 91 3055 1987].

Tetrathiafulvalene \([31366-25-3]\) \(M\ 204.4, \ m\ 122-124^\circ. \) Recrystd from cyclohexane/hexane under an argon atmosphere [Kauzlarich et al. *J Am Chem Soc* 109 4561 1987].

1,2,3,4-Tetrazole \([288-94-8]\) \(M\ 70.1, \ m\ 156^\circ, \ pK_1 4.89\) (acidic). Crystd from EtOH, sublimed under high vacuum at ca 120° (care should be taken due to possible EXPLOSION).

Thebaine \([115-37-7]\) \(M\ 311.4, \ m\ 193^\circ, [\alpha]_D^{25} -219^\circ\text{ (EtOH)}, \ pK_1 8.15. \) Sublimed at 170-180°.

2-Thenoyltrifluoroacetone \([326-91-0]\) \(M\ 222.2, \ m\ 42-44^\circ, \ b\ 96-98°/9\text{mm.} \) Crystd from hexane or *benzene. (Aqueous solns slowly decompose).

2-Thenylamine (nitrogen), from BaO, through a column packed with glass helices. \([27757-85-3]\) \(M\ 113.1, \ b\ 78.5^\circ/15\text{mm}, \ pK_3 8.92. \) Distd under reduced pressure (nitrogen), from BaO, through a column packed with glass helices.

Theobromine \([83-67-0]\) \(M\ 180.2, \ m\ 337^\circ, \ pK_1^{10} -0.16, \ pK_2^{15} 9.96. \) Crystd from water.

Theophylline \([58-55-9]\) \(M\ 180.2, \ m\ 270-274^\circ, \ pK_1^{40} -0.24, \ pK_2 2.5, \ pK_3^{49} 8.79. \) Crystd from H\(_2\)O.

Thevetin \([11018-93-2]\) \(M\ 858.9, \ m\ softens at 194°, \ m\ 210^\circ. \) Crystd (as trihydrate) from isopropanol. Dried at 100°/10mm to give the hemihydrate (very hygroscopic).

Thianthrene \([92-85-3]\) \(M\ 216.3, \ m\ 158^\circ. \) Crystd from Me\(_2\)CO (charcoal), AcOH or EtOH. Sublimes in a vacuum.

\(\varepsilon\)-[2-(4-Thiazolidone)]hexanoic acid \([539-35-5]\) \(M\ 215.3, \ m\ 140^\circ, \ pK_{\text{est}} 4.7. \) Crystd from H\(_2\)O, Me\(_2\)CO or MeOH.

Thiazoline-2-thiol \([96-53-7]\) \(M\ 119.2, \ m\ 106-107°, 106-108°, \ pK_{\text{est}} 13.0. \) Purified by dissolution in alkali, pptn by addition of HCl and then recrystd from H\(_2\)O as needles. [IR: Flett *J Chem Soc* 347 1953 and Mecke et al. *Chem Ber* 90 975; Gabriel and Stelzner *Chem Ber* 28 2931 1895.]
4-(2-Thiazolylazo)resorcinol [2246-46-0] M 221.2, m 200-202°(dec), λmax 500 nm, pK1,2 1.25, pK2,5 6.53, pK2,5 10.76. Dissolved in alkali, extracted with diethyl ether, and re-ppted with dil HCl. The purity was checked by TLC on silica gel using pet ether/ethyl ether/EtOH (10:1:1) as the mobile phase.

Thietane (trimethylene sulfide) [287-27-4] M 74.1, m -64°, -73.2°, b 93.8-94.2°/752 mm, 95°/atm, d 1.0200, nD 1.5020. Purified by preparative gas chromatography on a dinonyl phthalate column. It has also been purified by drying over anhydrous K2CO3, and distd through a 25 cm glass helices packed column (for 14g of thietane), then dried over CaSO4 before sealing in a vac. [Haines et al. J Phys Chem 58 270 1954.] It is characterised as the dimethylsulfonium iodide m 97-98° [Bennett and Hock J Chem Soc 2496 1927]. The S-oxide has b 102°/25 mm, nD 1.5075 [Tamres and Searles J Am Chem Soc 81 2100 1959].

Thioacetamide [62-55-5] M 75.1, m 112-113°, pK2,5 13.4. Crystd from absolute diethyl ether or benzene. Dried at 70° in vacuum and stored over P2O5 at 0° under nitrogen. (Develops an obnoxious odour on storage, and absorption at 269 nm decreases, hence it should be freshly crystd before use).


Thiobarbituric acid [504-17-6] M 144.2, m 235°(dec), pK2,5 2.25, pK2,5 10.72 (2% aq ETOH). Crystd from water.


(1R)-(--)Thiocamphor (1R-borneane-2-thione, 1R-(--)-1,7,7-trimethylbicyclo[2.2.1]heptane-2-thione) [33402-10-1] M 168.3, m 136-138°, 146°, [α]D 22° -22° (c 3, EtOAc). Forms red prisms from ETOH and sublimes under vacuum. It possesses a sulfurous odour and is volatile as camphor. [Sen J Indian Chem Soc 12 647 1935; 18 76 1941.] The racemate crystallises from *C6H6 and has m 145° [138.6-139°, White and Bishop J Am Chem Soc 62 10 1940].


Thioflavine T [2390-54-7] M 318.9, pK2,5 2.7. Crystd from *benzene/EtOH (1:1).

Thioformamide [115-08-2] M 61.0, m 29°, pKest 12.4. Crystd from ethyl acetate or ether/pet ether.

Thioglycollic acid [68-11-1] M 92.1, b 95-96°/8mm, d 1.326, n 1.505, pK2,5 3.42, pK2,5 10.20. Mixed with an equal volume of *benzene, the *benzene is then distd to dehydrate the acid. After heating to 100° to remove most of the *benzene, the residue was dissd under vaccum and stored in sealed ampoules at 3°. [Eshelman et al. Anal Chem 22 844 1960.]

Thioguanosine (2-amino-6-mercaptop-9-β-D-ribofuranosylpurine) [85-31-4] M 299.3, m 230-231°(dec), [α]D 20 -64° (c 1.3, 0.1N NaOH), pK 8.33. Crystd (as hemihydrate) from water.
Thioindigo \([522-75-8]\) M 296.2, m >280°. Adsorbed on silica gel from \(\text{CCl}_4/\text{benzene}\) (3:1), eluted with \(\text{benzene}\), crystd from \(\text{CHCl}_3\) and dried at 60-65°. [Wyman and Brode *J Am Chem Soc* 73 1487 1951.] This paper also gives details of purification of other thioindigo dyes.

Thiomalic (mercaptosuccinic) acid \([70-49-5]\) M 150.2, m 153-154°, \(pK_a 3.64 (3.17), pK_a 4.64 (4.67), pK_a^+ 10.37 (10.52)\). Extracted from aqueous soln several times with diethyl ether, and the aqueous soln freeze-dried.

Thio-Michler's Ketone \([1226-46-6]\) M 284.6, \(\lambda_{\text{max}} 457\text{ nm } (\varepsilon 2.92 \times 10^4\text{ in } 30\% \text{aq } n-\text{propanol})\). Purified by recrysta from hot EtOH or by triturating with a small volume of \(\text{CHCl}_3\), followed by filtration and washing with hot EtOH [Terbell and Wystrade *J Phys Chem* 68 210 1964].

Thionanthone (thioxanthone) \([492-22-8]\) M 160.2, m 81°, 82°, b 153.5°/15mm, 286°/760mm, \(pK_a -6.1\). Crystd from EtOH.

Thionine \((3,7\text{-diaminophenothiazine})\) \([135-59-1; 581-64-6 (\text{HCl})]\) M 263.7, \(\varepsilon_{590} 6.2 \times 10^4\text{ M}^{-1}\text{cm}^{-1}, pK_a 6.9\). The standard biological stain is highly pure. It can be crystd from water or 50% EtOH, then chromatographed on alumina using \(\text{CHCl}_3\) as eluent [Shepp, Chaberek and McNeil *J Phys Chem* 66 2563 1962]. Dried overnight at 100° and stored in a vacuum. The hydrochloride can be crystd from 50% EtOH or dilute HCl and aqueous \(n\)-butanol. Purified also by column chromatography and washed with \(\text{CHCl}_3\) and acetone. Dried in vacuo at room temperature.

Thioxine hydrochloride (8-mercaptoquinoline hydrochloride) \([34006-16-1]\) M 197.7, m 170-175° (dec), \(pK_a^+ 2.16, pK_a^+ 8.38\). Crystallises from EtOH and the crystals are yellow in colour. It has \(pK_a\) values of 2.05 and 8.29 in H₂O. [UV: Albert and Barlin *J Chem Soc* 2384 1959.]

Thiophene (tetrahydrothiophene) \([110-01-0]\) M 88.2, b 40.3°/39.7mm. See tetrahydrothiophene on p. 361.

Thiophene \([110-02-1]\) M 84.1, f -38.5°, b 84.2°, d 1.525, n 1.52890, n\(^{30}\) 1.5223. The simplest purification procedure is to dry with solid KOH, or reflux with sodium, and fractionally distd through a glass-helices packed column. More extensive treatments include an initial wash with aq HCl, then water, drying with CaSO₄ or KOH, and passage through columns of activated silica gel or alumina. Fawcett and Rasmussen [*J Am Chem Soc* 67 1705 1945] washed thiophene successively with 7M HCl, 4M NaOH, and distd water, dried with CaCl₂ and fractionally distd. *Benzene was removed by fractional crystn by partial freezing, and the thiophene was degassed and sealed in Pyrex flasks. [Also a method is described for recovering the thiophene from the *benzene-enriched portion.]

Thiophene-2-acetic acid \([1918-77-0]\) M 142.2, m 76°, \(pK_a 3.89\). Crystd from ligroin.

Thiophene-3-acetic acid \([6964-21-2]\) M 142.2, m 79-80°, \(pK_a^- 3.1\). Crystd from ligroin.

2-Thiophenecarboxaldehyde \([98-03-3]\) M 112.2, b 106°/30mm, d 1.593, n 1.222. Washed with 50% HCl and distd under reduced pressure just before use.

Thiophene-2-carboxylic acid \([527-72-0]\) M 128.2, m 129-130°, \(pK_a 3.89\). Crystd from water.

Thiophene-3-carboxylic acid \([88-31-1]\) M 128.1, m 137-138°, \(pK_a 6.23\). Crystd from water.

Thiophenol (benzenethiol) \([110-98-5]\) M 110.2, f -14.9°, b 46.4°/10mm, 168.0°/760mm, d 1.073, n 1.5897, \(pK_a^- 6.62\). Dried with CaCl₂ or CaSO₄, and distd at 10mm pressure or at 100mm (b 103.5°) in a stream of nitrogen.
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Thiopyronine (2,7-dimethylaminothiaxanthane) [2412-14-8] M 318.9, λ_max 564 nm (ε 78,500) H_2O, pK_{Est} ~ 7. Purified as the hydrochloride by recrystn from hydrochloric acid. [Fanghanel et al. J Phys Chem 91 3700 1987.]

Thiosalicylic (2-mercaptobenzoic) acid [147-93-3] M 154.2, m 164-165°, pK_2^1 3.54, pK_2^2 8.80. Crystd from hot EtOH (4mL/g), after adding hot distd water (8mL/g) and boiling with charcoal. The hot soln was filtered, cooled, the solid collected and dried in vacuo (F_2O_3). Cryst from AcOH and sublimes in vacuo.


Thiothienoyltrifluoroacetone [4552-64-1] M 228.2, m 61-62°. Easily oxidised and has to be purified before use. This may be by recrystd from *benzene or by dissolution in pet ether, extraction into 1M NaOH soln, acidification of the aqueous phase with 1-6M HCl soln, back extraction into pet ether and final evapn of the solvent. The purity can be checked by TLC. It was stored in ampoules under nitrogen at 0° in the dark. [Muller and Rother Anal Chim Acta 66 49 1973.]

Thiourea [62-56-6] M 76.1, m 179°, pK_2^0 -1.19 (aq H_2SO_4). Crystd from absolute EtOH, MeOH, acetonitrile or water. Dried under vacuum over H_2SO_4 at room temperature.


Thymin [65-71-4] M 126.1, m 326°, pK_2^2 9.82. Crystd from ethyl acetate or water. Purified by preparative (2mm thick) TLC plates of silica gel, eluting with ethyl acetate/isopropanol/water (75:16:9, v/v; RF 0.75). Spot localised by uv lamp, cut from plate, placed in MeOH, shaken and filtered through a millipore filter, then rotary evapd. [Infante et al. J Chem Soc, Faraday Trans 1 68 1586 1973.]

Thymolphthalein complexone [1913-93-5] M 720.8, m 190° (dec), pK_2^1 7.35, pK_2^2 12.25. Purification as for phthalein complexone except that it was synthesised from thymolphthalein instead of cresolphthelein.

Tiglic acid [80-59-1] M 100.1, m 63.5-64°, b 198.5°, pK_2^1 4.96. Crystd from water.

Tinuvin P (2-[2H-benzotriazol-2-y1]-p-cresol) [50936-05-5] M 225.3, m 131-133°, pK_{Est(1)}^1 ~ 1.6 (N protonation), pK_{Est(2)}^1 ~ 8 (phenolic OH). Recrystd from n-heptane or Me_2CO/pentane. [Woessner et al. J Phys Chem 81 3629 1975.]

o-Tolidine (3,3'-dimethylbenzidine) [119-93-7] M 212.3, m 131-132°, pK_2^2 4.45. Dissolved in *benzene, percolated through a column of activated alumina and crystd from *benzene/pet ether.

p-Toluolaldehyde [104-87-0] M 120.2, b 83-85°/0.1mm, 199-200°/760mm, d 1.018, n 1.548. Steam distd, dried with CaSO_4 and fractionally distd.
o-Toluamide \[527-85-5\] M 135.2, m 141°. Crystd from hot water (10mL/g) and dried in air.

Toluene \[108-88-3\] M 92.1, b 110.6°, d\(^{10}\) 0.87615, d\(^{25}\) 0.86231, n \(1.49693\), n \(25\) 1.49413. Dried with CaCl\(_2\), CaH\(_2\) or CaSO\(_4\), and dried further by standing with sodium, P\(_2\)O\(_5\) or CaH\(_2\). It can be fractionally distd from sodium or P\(_2\)O\(_5\). Unless specially purified, toluene is likely to be contaminated with methyliothiophenes and other sulfur containing impurities. These can be removed by shaking with conc H\(_2\)SO\(_4\), but the temperature must be kept below 30° if sulfonation of toluene is to be avoided. A typical procedure consists of shaking toluene twice with cold conc H\(_2\)SO\(_4\) (100mL of acid per L), once with water, once with aqueous 5% NaHCO\(_3\) or NaOH, again with H\(_2\)O, then drying successively with CaSO\(_4\) and P\(_2\)O\(_5\), with final distn from P\(_2\)O\(_5\) or over LiAlH\(_4\) after refluxing for 30min. Alternatively, the treatment with NaHCO\(_3\) can be replaced by boiling under reflux with 1% sodium amalgam. Sulfur compounds can also be removed by prolonged shaking of the toluene with mercury, or by two distns from AlCl\(_3\), the distillate then being washed with water, dried with K\(_2\)CO\(_3\) and stored with sodium wire. Other purification procedures include refluxing and distn of sodium dried toluene from diphenylpicrylhydrazyl, and from SnCl\(_2\) (to ensure freedom from peroxides). It has also been co-distd with 10% by volume of ethyl methyl ketone, and again fractionally distd. [Brown and Pearsall \textit{J Am Chem Soc} 74 191 1952.] For removal of carbonyl impurities see \textit{benzene}. Toluene has been purified by distn under nitrogen in the presence of sodium benzophenone ketyl. Toluene has also been dried with MgSO\(_4\), after the sulfur impurities have been removed, and then fractionally distd from P\(_2\)O\(_5\) and stored in the dark [Tabushi et al. \textit{J Am Chem Soc} 107 4465 1985]. Toluene can be purified by passage through a tightly packed column of Fuller's earth.

Rapid purification: Alumina, CaH\(_2\) and 4A molecular sieves (3% w/v) may be used to dry toluene (6h stirring and standing). Then the toluene is distd, discarding the first 5% of distillate, and is stored over molecular sieves (3A, 4A) or Na wire.

Toluene-2,4-diamine \[95-80-7\] M 122.2, m 99°, b 148-150°/8mm, 292°/760mm, \(pK_{ESh}(-2.5), pK_{EH2}(-4.4)\). Recrystd from water containing a very small amount of sodium dithionite (to prevent air oxidation), and dried under vacuum. Also cryst from \textit{benzene}.

o-Toluenesulfonamide \[88-19-7\] M 171.2, m 155.5°. Crystd from hot water, then from EtOH or Et\(_2\)O-pet ether.

p-Toluenesulfonamide \[70-55-3\] M 171.2, m 137-137.5°, 138°. Crystd from hot water, then from EtOH or Et\(_2\)O-pet ether.

p-Toluenesulfonic acid \(6192-52-5\) M 190.2, m 38° (anhydrous), m 105-107° (monohydrate), \(pK 1.55\). Purified by pptn from a satd soln at 0° by introducing HCl gas. Also cryst from conc HCl, then cryst from dilute HCl (charcoal) to remove benzenesulfonic acid. It has been crystd from EtOH/water. Dried in a vacuum desiccator over solid KOH and CaCl\(_2\). p-Toluenesulfonic acid can be dehydrated by azotropic distn with \textit{benzene} or by heating at 100° for 4h under water-pump vacuum. The anhydrous acid can be crystd from \textit{benzene}, CHCl\(_3\), ethyl acetate, anhydrous MeOH, or from acetone by adding a large excess of \textit{benzene}. It can be dried under vacuum at 50°.

Toluenesulfonic acid hydrazide (tosylhydrazide) \[1576-35-8\] M 186.2, m 108-110°, 109-110°. Dissolve in hot MeOH (~1g/4mL), filter through Celite and ppte material by adding 2-2.5 vols of distd H\(_2\)O. Air or vac dry. [Fiedman et al. \textit{Org Synth Coll Vol V} 1055 1973.]

p-Toluenesulfonyl chloride (tosyl chloride) \[98-59-9\] M 190.7, m 66-69°, 67.5-68.5°, 69°, b 138-139°/9mm, 146°/15mm, 167°/36mm. Material that has been standing for a long time contains tosic acid and HCl and has m ca 65-68°. It is purified by dissolving (10g) in the minimum volume of CHCl\(_3\) (ca 25mL) filtered, and diluted with five volumes (i.e. 125mL) of pet ether (b 30-60°) to precipitate impurities. The soln is filtered, clarified with charcoal and concentrated to 40mL by evaporation. Further evaporation to a very small volume gave 7g of white crystals which were analytically pure, m 67.5-68.5°. (The insoluble material was largely tosic acid and had m 101-104°). [Pelletier \textit{Chem Ind (London)} 1034 1953.] Also cryst from toluene/pet ether in the cold, from pet ether (b 40-60°) or \textit{benzene}. Its soln in diethyl ether has been washed with aqueous 10% NaOH until colourless, then dried (Na\(_2\)SO\(_4\)) and cryst by cooling in
powdered Dry-ice. It has also been purified by dissolving in *benzene, washing with aqueous 5% NaOH, then dried with K₂CO₃ or MgSO₄, and distd under reduced pressure and can be sublimed at high vacuum [Ebel Chem Ber 60 20861927].

**p-Toluenethiol** [106-45-6]  M 124.2, m 43.5-44.0, pK₂ 6.82. Crystd from pet ether (b 40-70°).

**Toluhydroquinone (2-methylbenzene-1,4-diol)** [95-71-6]  M 124.1, m 128-129°, pK₁ 10.15, pK₂ 11.75. Crystd from EtOH.

**o-Toluic acid** [118-90-1]  M 136.2, m 102-103°, pK₂ 3.91. Crystd from *benzene (2.5mL/g) and dried in air.


**o-Toluidine (2-methylaniline)** [95-53-4]  M 107.2, f -16.3°, b 80.1°/10mm, 200.3°/760mm, d 0.999, n 1.57246, n₂5 1.56987, pK₂ 4.45. In general, methods similar to those for purifying aniline can be used, e.g. distn from zinc dust, at reduced pressure, under nitrogen. Berliner and May [J Am Chem Soc 49 1007 1927] purified via the oxalate. Twice-distd o-toluidine was dissolved in four times its volume of diethyl ether and the equivalent amount of oxalic acid needed to form the dioxalate was added as its soln in diethyl ether. (If p-toluidine is present, its oxalate pptes and can be removed by filtration.) Evapn of the ether soln gave crystals of o-toluidine dioxaalate. They were filtered off, recrystd five times from water containing a small amount of oxalic acid (to prevent hydrolysis), then treated with dilute aqueous Na₂CO₃ to liberate the amine which was separated, dried (CaCl₂) and distd under reduced pressure.

**m-Toluidine (3-methylaniline)** [108-44-1]  M 107.2, f -30.4°, b 82.3°/10mm, 203.4°/760mm, d 0.989, n 1.56811, n₂5 1.56570, pK₂ 4.71. It can be purified as for aniline. Twice-distd, m-toluidine was converted to the hydrochloride using a slight excess of HCl, and the salt was fractionally crystd from 25% EtOH (five times), and from distd water (twice), rejecting, in each case, the first material that crystd. The amine was regenerated and distd as for o-toluidine. [Berliner and May J Am Chem Soc 49 1007 1927.]

**p-Toluidine (4-methylaniline)** [106-49-0]  M 107.2, m 44.8°, b 79.6°/10mm, 200.5°/760mm, d 0.962, n 1.5636, n₂5 1.5534, pK₂ 5.08. In general, methods similar to those for purifying aniline can be used. It can be separated from the o- and m-isomers by fractional crystn from its melt. p-Toluidine has been crystd from hot water (charcoal), EtOH, *benzene, pet ether or EtOH/water (1:4), and dried in a vacuum desiccator. It can also be sublimed at 30° under vacuum. For further purification, use has been made of the oxalate, the sulfate and acetylation. The oxalate, formed as described for o-toluidine, was filtered, washed and recrystd three times from hot distd water. The base was regenerated with aq Na₂CO₃ and recrystd three times from distd water. [Berliner and May J Am Chem Soc 49 1007 1927.] Alternatively, p-toluidine was converted to its acetyl derivative which, after repeated crystn from EtOH, was hydrolysed by refluxing (50g) in a mixture of 500mL of water and 115mL of conc H₂SO₄ until a clear soln was obtained. The amine sulfate was isolated, suspended in water, and NaOH was added. The free base was distd twice from zinc dust under vacuum. The p-toluidine was then recrystd from pet ether and dried in a vacuum desiccator or in a vacuum for 6h at 40°. [Berliner and Berliner J Am Chem Soc 76 6179 1954; Moore et al. J Am Chem Soc 108 2257 1986.]

**Toluidine Blue O** [93-31-9]  M 305.8, Cl 52040, λmax 626nm, pK₂ 7.5. Crystd from hot water (18mL/g) by adding one and a half volumes of alcohol and chilling on ice. Dried at 100° in an oven for 8-10h.

**p-Toluidine hydrochloride** [540-23-8]  M 143.6, m 245.9-246.1°. Crystd from MeOH containing a few drops of conc HCl. Dried under vacuum over paraffin chips.
2-p-Toluidinyl naphthalene-6-sulfonic acid [7724-15-4] M 313.9, pK_{Eh} ~ 0. Crystd twice from 2% aqueous KOH and dried under high vacuum for 4h at room temperature. Crystd from water. Tested for purity by TLC on silica gel with isopropanol as solvent. The free acid was obtained by acidifying a satd aqueous soln.

o-Tolunitrile [529-19-1] M 117.2, b 205.2°, d 0.992, n 1.5279. Fractionally distd, washed with conc HCl or 50% H_{2}SO_{4} at 60° until the smell of isonitrile had gone (this also removed any amines), then washed with saturated NaHCO_{3} and dilute NaCl solns, then dried with K_{2}CO_{3} and redistd.

m-Tolunitrile [620-22-4] M 117.2, b 209.5-210°/773mm, d 0.986, n 1.5250. Dried with MgSO_{4}, fractionally distd, then washed with aqueous acid to remove possible traces of amines, dried and redistd.

p-Tolunitrile [104-85-8] M 117.2, m 29.5°, b 104-106°/20mm. Melted, dried with MgSO_{4}, fractionally crystd from its melt, then fractionally distd under reduced pressure in a 6-in spinning band column. [Brown J Am Chem Soc 81 3232 1959.] It can also be crystd from benzene/pet ether (b 40-60°).

4-Tolyl-2-benzoic acid (4'-methylbiphenyl-2-carboxylic acid) [7148-03-0] M 196.2, m 138-139°, pK_{2} 3.64. Crystd from toluene.


p-Tolyl carbinol (4-methylbenzyl alcohol) [589-18-4] M 122.2, m 61°, b 116-118°/20mm, 217°/760mm. Crystd from pet ether (b 80-100°, 1g/mL). It can also be distd under reduced pressure.

trans-Traumatic acid (2-dodecene-1,12-dioic acid) [6402-36-4] M 228.3, m 165-166°, 150-160°/0.001mm, pK_{a} 4.2, pK_{b} 4.6. Crystd from EtOH, acetone or glyme.

alpha,alpha'-Trehalose (2H_{2}O) [6138-23-4] M 378.3, m 96.5-97.5°, 203° (anhdyrous). Crystd (as the dihydrate) from aqueous EtOH. Dried at 130°.

1,2,3-Triaminopropane trihydrochloride [free base 21291-99-6] M 198.7, m 250°, pK_{1} 3.72, pK_{2} 7.95, pK_{3} 9.59. Cryst from EtOH.

trans-Traumatic acid (2-dodecene-1,12-dioic acid) [6402-36-4] M 228.3, m 165-166°, 150-160°/0.001mm, pK_{a} 4.2, pK_{b} 4.6. Crystd from EtOH, acetone or glyme.

alpha,alpha'-Trehalose (2H_{2}O) [6138-23-4] M 378.3, m 96.5-97.5°, 203° (anhdyrous). Crystd (as the dihydrate) from aqueous EtOH. Dried at 13°.

1,2,3-Triazabicyclo[4.4.0] dec-5-ene (TBD, 1,3,4,6,7,8-hexahydro-2H-pyrimido[1,2-a]-pyrimidine) [5807-14-7] M 139.2, m 125-130°, pK ~ 16 Cryst from Et_{2}O but readily forms white crystals of the carbonate. It is a strong base (see pK, i.e. about 100 times more basic than tetramethylguanidine. The picrate has m 220.5-222° (from EtOH). Forms the 5-nitro derivative m 145-160° that gives a 5-nitro nitrate salt m 100-101° (from EtOH-Et_{2}O) and a 5-nitro picrate m 144-145° (from H_{2}O). [McKay and Kreling Can J Chem 35 1438 1957; Schwesinger Chimia 39 369 1985; Hilpert et al. J Chem Soc, Chem Commun 1401 1983; Kamfen and Eschenmoser Helv Chim Acta 72 185 1989].

1,2,4-Triazole [288-88-0] M 69.1, m 121°, 260°, pK_{1} 2.27 (basic), pK_{2} 10.26 (acidic). Crystd from EtOH or water [Barszcz et al. J Chem Soc, Dalton Trans 2025 1986].
Purification of Organic Chemicals

Tribenzylamine \([620-40-6]\) M 287.4, m 93-94°, 230°/13 mm, \(pK_{\text{Est}} < 0\). Crystd from abs EtOH or pet ether. Dried in a vacuum over \(P_2O_5\) at room temperature. \(HCl\) has m 226-228° (from EtOH) and \(\text{picrate}\) has m 191° (from \(H_2O\) or aq EtOH).

2,4,6-Tribromoacetanilide \([607-93-2]\) M 451.8, m 232°. Crystd from EtOH.

2,4,6-Tribromoaniline \([147-82-0]\) M 329.8, m 120°, \(pK_{\text{Est}} \sim 0.5\) (aq \(H_2SO_4\)). Crystd from MeOH.

\textit{sym}-Tribromobenzene \([626-39-1]\) M 314.8, m 122°. Crystd from glacial acetic acid/water (4:1), then washed with chilled EtOH and dried in air.

Tribromochloromethane \([594-15-0]\) M 287.2, m 55°. Melted, washed with aqueous \(Na_2S_2O_3\), dried with \(BaO\) and fractionally crystd from its melt.

2,4,6-Tribromophenol M 330.8, m 94°, \(pK_{25} 6.00\). Crystd from EtOH or pet ether. Dried under vacuum over \(P_2O_5\) at room temperature.

\textit{Tri-\text{-}n\text{-}butylamine} \([102-82-9]\) M 185.4, b 68°/3 mm, 120°/44 mm, d 0.7788, n 1.4294, \(pK_{25} 9.93\). Purified by fractional distn from sodium under reduced pressure. Pegolotti and Young \(J Am\ Chem Soc\) \textit{83} 3251 1961 heated the amine overnight with an equal volume of acetic anhydride, in a steam bath. The amine layer was separated and heated with water for 2h on the steam bath (to hydrolyse any remaining acetic anhydride). The soln was cooled, solid \(K_2CO_3\) was added to neutralize any acetic acid that had been formed, and the amine was separated, dried (\(K_2CO_3\)) and distd at 44 mm pressure. Davis and Nakshbendi \(J Am\ Chem Soc\) \textit{84} 2085 1926 treated the amine with one-eighth of its weight of benzenesulfonyl chloride in aqueous 15% \(NaOH\) at 0-5°. The mixture was shaken intermittently and allowed to warm to room temperature. After a day, the amine layer was washed with aq \(NaOH\), then water and dried with \(KOH\). (This treatment removes primary and secondary amines.) It was further dried with \(CaH_2\) and distd under vacuum.

\textit{Tri-\text{-}n\text{-}butylammonium hydrobromide} \([37026-85-0]\) M 308.3, m 75.2-75.9°. Crystd from ethyl acetate.

\textit{Tri-\text{-}n\text{-}butylammonium nitrate} \([33850-87-2]\) M 304.5. Crystd from mixtures of \(n\)-hexane and acetone (95:5). Dried over \(P_2O_5\).

\textit{Tri-\text{-}n\text{-}butylammonium perchlorate} \([14999-66-7]\) M 285.5. Recrystd from \(n\)-hexane.

\textit{sym}-\textit{Tri-\text{-}tert\text{-}butylbenzene} \([11460-02-2]\) M 246.4, m 73.4-73.9°. Crystd from EtOH.

\textit{2,4,6\text{-}Tri-\text{-}tert\text{-}butylphenol} \([732-26-3]\) M 262.4, m 129-132°, 131°/1 mm, 147°/10 mm, 278°/760 mm, \(pK_{25} 12.19\). Crystd from \(n\)-hexane or several times from 95% EtOH until the EtOH soln was colourless [Balasubramanian and Bruice \textit{J Am Chem Soc}\ textit{108} 5495 1986]. It has also been purified by sublimation [Yuan and Bruice \textit{J Am Chem Soc}\ \textit{108} 1643 1986; Wong et al. \textit{J Am Chem Soc}\ \textit{109} 3428 1987]. Purification has been achieved by passage through a silica gel column followed by recrystn from \(n\)-hexane [Kajii et al. \textit{J Phys Chem}\ \textit{91} 2791 1987].

\textit{Tricarballylic acid (propane-1,2,3-tricarboxylic acid)} \([99-14-9]\) M 176.1, m 166°, \(pK_{25} 3.47\), \(pK_{10} 4.54\), \(pK_{25} 5.89\). Crystd from diethyl ether.

\textit{Trichloroacetamide} \([594-65-0]\) M 162.4, m 139-141°, b 238-240°. Its xylene soln was dried with \(P_2O_5\), then fractionally distd.

\textit{Trichloroacetanilide} \([2563-97-5]\) M 238.5, m 95°. Crystd from *benzene.
Trichloroacetic acid [76-03-9] $M_1$ 163.4, m 59.4-59.8°, $pK_{1}^{25}$ 0.51. Purified by fractional crystn from its melt, then crystd repeatedly from dry *benzene and stored over conc H$_2$SO$_4$ in a vac desiccator. It can also be crystd from CHCl$_3$ or cyclohexane, and dried over P$_2$O$_5$ or Mg(Clo$_4$)$_2$ in a vac desiccator. Trichloroacetic acid can be fractionally distd under reduced pressure from MgSO$_4$. Layne, Jaffé and Zimmer [J Am Chem Soc 85 435 1963] dried trichloroacetic acid in *benzene by distilling off the *benzene-water azeotrope, then crystd the acid from the remaining *benzene soln. Manipulations were carried out under nitrogen. [Use a well ventilated fume cupboard].

2,3,4-Trichloroaniline [634-67-3] $M_1$ 196.5, m 67.5°, b 292°/774mm, $pK_{ES}$ ~1.3. Crystd from ligroin.

2,4,5-Trichloroaniline [636-30-6] $M_1$ 196.5, m 96.5°, b 270°/760mm, $pK_{1}$ 1.09. Crystd from ligroin.

2,4,6-Trichloroaniline [634-93-5] $M_1$ 196.5, m 78.5°, b 127°/14mm, 262°/746mm, $pK_{1}$ 0.03. Crystd from ligroin.

1,2,3-Trichlorobenzene [87-61-6] $M_1$ 181.5, m 52.6°. Crystd from EtOH.

1,2,4-Trichlorobenzene [120-82-1] $M_1$ 181.5, m 17°, b 210°. Separated from a mixture of isomers by washing with fuming H$_2$SO$_4$, then water, drying with CaSO$_4$ and slowly fractionally distilling. [Jensen, Marino and Brown J Am Chem Soc 81 3303 1959.]

1,3,5-Trichlorobenzene [108-70-3] $M_1$ 181.5, m 64-65°. Recrystd from dry *benzene or toluene.

3,4,5-Trichloro-o-cresol (3,4,5-trichloro-2-methylphenol) [608-92-4] $M_1$ 211.5, m 77°, $pK_{ES}$ ~7.6. Crystd from pet ether.


1,1,1-Trichloroethane [71-55-6] $M_1$ 133.4, f -32.7°, b 74.0°, d 1.337, n 1.4385. Washed successively with conc HCl (or conc H$_2$SO$_4$), aq 10% K$_2$CO$_3$ (Na$_2$CO$_3$), aq 10% NaCl, dried with CaCl$_2$ or Na$_2$SO$_4$, and fractionally distd. It can contain up to 3% dioxane as preservative. This is removed by washing successively with 10% aq HCl, 10% aq NaHCO$_3$ and 10% aq NaCl; and distd over CaCl$_2$ before use.

1,1,2-Trichloroethane [79-00-5] $M_1$ 133.4, f -36.3°, b 113.6°, d 1.435, n 1.472. Purification as for 1,1,1-trichloroethane above.

Trichloroethylene [79-01-6] $M_1$ 131.4, f -88°, b 87.2°, d 1.463, $n_2$1 1.4767. Undergoes decomposition in a similar way to CHC$_3$, giving HCl, CO, COCl$_2$ and organic products. It reacts with KOH, NaOH and 90% H$_2$SO$_4$, and forms azeotropes with water, MeOH, EtOH, and acetic acid. It is purified by washing successively with 2M HCl, water and 2M K$_2$CO$_3$, then dried with K$_2$CO$_3$ and CaCl$_2$, and fractionally distd immediately before use. It has also been steam distd from 10% Ca(OH)$_2$ slurry, most of the water being removed from the distillate by cooling to -30° to -50° and filtering off the ice through chamois skin: the trichloroethylene was then fractionally distd at 250mm pressure and collected in a blackened container. [Carlisle and Levine Ind Eng Chem (Anal Ed) 24 1164 1932.]

2,4,5-Trichloro-1-nitrobenzene [89-69-0] $M_1$ 226.5, m 57°. Crystd from EtOH.

3,4,6-Trichloro-2-nitrophenol [82-62-2] $M_1$ 242.4, m 92-93°, $pK_{ES}$ -4.1. Crystd from pet ether or EtOH.

2,4,5-Trichlorophenol [95-95-4] $M_1$ 197.5, m 67°, b 72°/1mm, $pK_{1}^{25}$ 7.0. Crystd from EtOH or pet ether.

3,4,5-Trichlorophenol [609-19-8] M 197.5, m 100°, pK<sub>2</sub> 7.84. Crystd from pet ether/*benzene mixture.

2,4,5-Trichlorophenoxyacetic acid (2,4,5-T) [93-76-5] M 255.5, m 153°, 155-158°, pK<sub>2</sub> 2.83. Crystd from *benzene. (CANCER SUSPECT)

1,1,2-Trichlorotrifluoroethane [76-13-1] M 187.4, b 47.6°/760mm, d 1.576, n 1.360. Washed with water, then with weak alkali. Dried with CaCl<sub>2</sub> or H<sub>2</sub>SO<sub>4</sub> and distd. [Locke et al. J Am Chem Soc 56 1726 1934.1

Tricycloquinazoline [195-84-6] M 230.3, m 322-323°. Crystd repeatedly from toluene, followed by vac sublimation at 210° at a pressure of 0.15-0.3 Torr in subdued light.

Tridecanoic acid [638-53-9] M 214.4, m 41.8°, 44.5-45° (several forms), b 199-200°/24mm, pK<sub>em</sub> ~5.0. Crystd from acetone.

7-Tridecanone [462-18-0] M 198.4, m 33°, b 255°/766mm. Crystd from EtOH.

Tri-n-dodecylammonium nitrate [2305-34-2] M 585.0. Crystd from n-hexane/acetone (95:5) and kept in a desiccator over P<sub>2</sub>O<sub>5</sub>.

Tri-n-dodecylammonium perchlorate [5838-82-4] M 622.4. Recrystd from n-hexane or acetone and kept in a desiccator over P<sub>2</sub>O<sub>5</sub>.


1,1,2-Triethoxyethane [4819-77-6] M 162.2, b 164°, d 0.897, n 1.401. Dried with Na<sub>2</sub>SO<sub>4</sub>, and distd.

Triethylamine [121-44-8] M 101.2, b 89.4°, d 0.7280, n 1.4005, pK<sub>2</sub> 10.82. Dried with CaSO<sub>4</sub>, LiAlH<sub>4</sub>, Linde type 4A molecular sieves, CaH<sub>2</sub>, KOH, or K<sub>2</sub>CO<sub>3</sub>, then distd, either alone or from BaO, sodium, P<sub>2</sub>O<sub>5</sub> or CaH<sub>2</sub>. It has also been distd from zinc dust, under nitrogen. To remove traces of primary and secondary amines, triethylamine has been refluxed with acetic anhydride, benzoic anhydride, phthalic anhydride, then distd, refluxed with CaH<sub>2</sub> (ammonia-free) or KOH (or dried with activated alumina), and again distd. Another purification involved refluxing for 2h with p-toluenesulfonyl chloride, then distd. Grovesstein and Williams [J Am Chem Soc 83 412 1961] treated triethylamine (500mL) with benzoyl chloride (30mL), filtered off the ppt, and refluxed the liquid for 1h with a further 30mL of benzoyl chloride. After cooling, the liquid was filtered, distd, and allowed to stand for several hours with KOH pellets. It was then refluxed with, and distd from, stirred molten potassium. Triethylamine has been converted to its hydrochloride, crystd from EtOH (to m 254°), then liberated with aq NaOH, dried with solid KOH and distd from sodium under nitrogen.

Triethylammonium hydrobromide [636-70-4] M 229.1, m 248°. Equimolar portions of triethylamine and aqueous solutions of HBr in acetone were mixed. The ppted salt was washed with anhydrous acetone and dried in vacuum for 1-2h. [Odinekov et al. J Chem Soc, Faraday Trans 2 80 899 1984.] Recrystd from CHCl<sub>3</sub> or EtOH.

Triethylammonium hydroiodide \[4636-73-1\] M 229.1, m 181°. Purified as for triethylammonium bromide, except the soln for pptn was precooled acetone at -10° and the ppte was twice recrystd from a cooled acetone/hexane mixture at -10°.

Triethylammonium trichloroacetate \[4113-06-8\] M 263.6. Equimolar solns of triethylamine and trichloroacetic acid in n-hexane were mixed at 10°. The solid so obtained was recrystd from CHCl₃/benzene.

Triethylammonium trifluoroacetate \[454-49-9\] M 196.2. Purified as for the corresponding trichloroacetate. The salt was a colourless liquid at ambient temperature.

1,2,4-Triethylbenzene \[877-44-1\] M 162.3, b 96.8-97.1°/12.8mm, d 0.8738, n 1.5015. For separation from a commercial mixture see Dillingham and Reid \[J Am Chem Soc 60 2606 1938\].

1,3,5-Triethylbenzene \[102-25-0\] M 162.3, b 102-102.5°, d 0.8631, n 1.4951. For separation from a commercial mixture see Dillingham and Reid \[J Am Chem Soc 60 2606 1938\].

Triethylene glycol \[112-27-6\] M 150.2, b 115-117°/0.1mm, 278°/760mm, n₁5 1.4578, d₁5 1.1274. Dried with CaSO₄ for 1 week, then repeatedly and very slowly fractionally distd under vacuum. Stored in a vacuum desiccator over P₂O₅. It is very hygroscopic.

Triethylene glycol dimethyl ether (triglyme) \[112-49-2\] M 178.2, b 225°, d 0.987, n 1.425. Refluxed with, and distd from sodium hydride or LiAlH₄.

Triethylenetetramine (TRIEN, TETA, trientine) \[112-24-3\] M 146.2, m 12°, b 157°/20mm, d 0.971, n 1.497, pK₇ 3.32, pK₂ 6.67, pK₃ 9.20, pK₄ 9.92. Dried with sodium, then distd under vac. Further purification has been via the nitrate or the chloride. For example, Jonassen and Strickland \[J Am Chem Soc 80 312 1958\] separated TRIEN from admixture with TREN (38%) by soln in EtOH, cooling to approximately 50° in an ice-bath and adding conc HCl dropwise from a burette, keeping the temperature below 10°, until all of the white crystalline ppte of TREN.HCl had formed and been removed. Further addition of HCl then ppte thick creamy white TRIEN.HCl which was crystd several times from hot water by adding an excess of cold EtOH. The crystals were finally washed with Me₂CO, then Et₂O and dried in a vacuum desiccator.

Triethylenetetramine tetrahydrochloride (TRIEN.HCl) \[4961-10-4\] M 292.1, m 266-270°. Crystd repeatedly from hot water by pptn with cold EtOH or EtOH/HCl. Washed with acetone and abs EtOH and dried in a vacuum oven at 80° (see TRIEN above).

Triethyl orthoformate (1,1,1-triethoxymethane) \[122-51-0\] M 148.2, m 30°, b 60°/30mm, 144-146°, d 0.891, n 1.392. Fractionate first at atm press, then in a vac. If impure, then wash with H₂O, dry over anhyd K₂CO₃, filter and fractionate through a Widmer column. \[Conway and Novak J Phys Chem 81 1459 1977; Ohme and Schmitz Justus Liebigs Ann Chem 716 207 1968\] IRRITANT and FLAMMABLE.

Triethyloxonium fluoroborate \[368-39-8\] M 190.0, m 92-93°(dec). Crystd from diethyl ether. Very hygroscopic, and should be handled in a dry box and stored at 0°. \[Org Synth 46 113 1966\]. Pure material should give a clear and colourless soln in dichloromethane (1 in 50, w/v).

Trifluoroacetic acid \[76-05-1\] M 114.0, f -15.5°, b 72.4°, d 1.494, n 1.2850, pK₂ 0.52. The purification of trifluoroacetic acid, reported in earlier editions of this work, by refluxing over K₂MnO₄ for 24h and slowly distilling has resulted in very SERIOUS EXPLOSIONS on various occasions, but not always. This apparently depends on the source and/or age of the acid. The method is NOT RECOMMENDED. Water can be removed by adding trifluoroacetic anhydride (0.05%, to diminish water content) and distd. \[Conway and Novak J Phys Chem 81 1459 1977\]. It can be refluxed and distd from P₂O₅. It is further purified by fractional crystn by partial freezing and again distd. Highly TOXIC vapour.
Trifluoroacetic anhydride [407-25-0] M 210.0, b 38-40°/760mm, d 1.508. Purification by distilling over KMnO4, as for the acid above is EXTREMELY DANGEROUS due to the possibility of EXPLOSION. It is best purified by distilling from P2O5 slowly, and collecting the fraction boiling at 39.5°. Store in a dry atmosphere. Highly TOXIC vapour.

1,1,1-Trifluoro-2-bromoethane [421-06-71 M 163.0. See 1-bromo-3,3,3-trifluoroethane on p. 142.

2,2,2-Trifluoroethanol [75-89-8] M 100.0, b 72.4°/738mm, d 1.400, pK2' 12.8. Dried with CaSO4 and a little NaHCO3 (to remove traces of acid). Highly TOXIC vapour.

Trifluoromethanesulfonic anhydride (triflic anhydride) [358-23-6] M 282.1, b 82-85°, 84°, d 1.71, n 1.322. Distil through a short Vigreux column. Could be freshly prepd from the anhydrous acid (11.5g) and P2O5 (11.5g, or half this weight) by setting aside at room temp for 1h, distilling off volatile products then through a short Vigreux column. Readily hydrolysed by H2O and decomposes appreciably after a few days to liberate SO2 and produce a viscous liquid. Store dry at low low temp. [Burdon et al. J Chem Soc 2574 1957; Beard et al. J Org Chem 38 373 1973.] Highly TOXIC vapour.

4-(Trifluoromethyl)acetophenone [709-63-7] M 188.2, m 31-33°, b 79-81°/9mm. Purified by distillation or sublimation in vacuo.

3-Trifluoromethyl-4-nitrophenol [88-30-21 M 162.1, m 81°, pK2', 3.4, pK3', 7.8, pK5, >12. Crystd from water.

a,a,a-Trifluorotoluene (benzotrifluoride) [98-08-8] M 144.1, b 102.5°, d 1.190, n30 1.4100. Purified by repeated treatment with boiling aqueous Na2CO3 (until no test for chloride ion was obtained), dried with K2CO3, then with P2O5, and fractionally distd.


Trigonelline (1-methylnicotinic acid zwitterion) [535-83-1] M 137.1, m 218°(dec). Crystd (as monohydrate) from aqueous EtOH, then dried at 100°.


4',5,7-Trihydroxyflavone (apigenin) [520-36-5] M 270.2, m 296-298°, 300-305°, 345-350° (pK's 7—10, for phenolic OH). Crystd from aq pyridine or aq EtOH. Dyes wool yellow when with added Cr.

3,4,5-Triiodobenzoic acid [2338-20-7] M 499.8, m 289-290°, 293°, pK2', 0.65. Crystd from aqueous EtOH or water.


3,3',5-Triido-S-thyronine [6893-02-3] M 651.0, m 236-237°(dec), [a]29.5 + 21.5° (EtOH/1M aq HCl, 2:1), pK1' 6.48, pK2' 7.62, pK3' 7.82. Likely impurities are as in thyroxine. Purified by dissolving in dilute NH3 at room temperature, then crystd by addition of dilute acetic acid to pH 6.

Trimellitic (benzene-1,2,4-tricarboxylic) acid [528-44-9] M 210.1, m 218-220°, pK1' 2.42, pK2' 3.71, pK3' 5.01. Crystd from acetic acid or aqueous EtOH.
1,2,3-Trimethoxybenzene [634-36-6] M 168.2, m 45-46°. Sublimed under vacuum.


Trimethylamine [75-50-3] M 59.1, b 35°, pK25 9.80. Dried by passage of the gas through a tower filled with solid KOH. Water and impurities containing labile hydrogen were removed by treatment with freshly sublimed, ground, P2O5. Has been refluxed with acetic anhydride, and then distd through a tube packed with HgO and BaO. [Comyns J Chem Soc 1557 1955.] For more extensive purification, trimethylamine has been converted to the hydrochloride, crystd (see below), and regenerated by treating the hydrochloride with freshly sublimed, ground, P2O5. Has been refluxed with acetic anhydride, and then distd through a tube packed with HgO and BaO. [Day and Felsing J Am Chem Soc 72 1698 1950.]

Trimethylamine hydrochloride [593-81-7] M 95.7, m >280°(dec). Crystd from CHCl3, EtOH or n-propanol, and dried under vacuum. It has also been crystd from *benzene/Methanol, MeOH/diethyl ether and dried under vacuum over paraffin wax and H2SO4. Stood over P2O5. It is hygroscopic.

Trimethylamine hydroiodide [20230-89-1] M 186.0, m 263°. Crystd from MeOH.

1,2,4-Trimethylbenzene (pseudocumene) [95-63-6] M 120.2, m -43.8°, b 51.6°/10mm, 167-168°/760mm, d 0.889, n 1.504. Refluxed over sodium and distd under reduced pressure.


R-(-)-2,2,6-Trimethyl-1,4-cyclohexanedione [60046-49-3] M 154.2, m 88-90°, 91-92°, [α]20D -270° (c 0.4%, MeOH), [α]19D -275° (c 1, CHCl3). Obtained from fermentation and purified by recrystn from diisopropyl ether. [ORD: Leuenberger et al. Helv Chim Acta 59 1832 1976.] The racemate has m 65-67° and the 4-(4-phenyl)semicarbazone has m 218-220° (from CH2Cl2-MeOH) [Isler et al. Helv Chim Acta 39 2041 1956].

2,2,5-Trimethylhexane [3522-94-9] M 128.3, m -105.8°, b 124.1°, d 0.716, n 1.39971, n25 1.39727. Extracted with conc H2SO4, washed with H2O, dried (type 4A molecular sieves), and fractionally distd.

Trimethyl-1,4-hydroquinone (2,3,5-trimethylbenzene-1,4-diol) [700-13-0] M 152.2, m 173-174°, pK_Eh(1)~ 11.1, pK_Eh(2)~ 12.7. Recrystd from water, under anaerobic conditions.


2,2,3-Trimethylpentane [564-02-3] M 114.2, b 109.8°, d 0.7161, n 1.40295, n25 1.40064. Purified by azotropic distn with 2-methoxyethanol, which was subsequently washed out with water. The trimethylpentane was then dried and fractionally distd. [Forziati et al. J Res Nat Bur Stand 36 129 1946.]

2,2,4-Trimethylpentane (iso-octane) [540-84-1] M 114.2, b 99.2°, d 0.693, n 1.39145, n25 1.38898. Distd from sodium, passed through a column of silica gel or activated alumina (to remove traces of
olefins), and again distd from sodium. Extracted repeatedly with conc H₂SO₄, then agitated with aqueous KMnO₄, washed with water, dried (CaSO₄) and distd. Purified by azeotropic distn with EtOH, which was subsequently washed out with water, and the trimethylpentane was dried and fractionally distd. [Forziati et al. J Res Nat Bur Stand 36 126 1946.] Also purified by fractional crystn.


2,4,5-Trimethylphenol [497-78-6] M 136.2, m 70.5-71.5°, pK₂⁵ 10.57. Crystd from water.

2,4,6-Trimethylphenol [527-60-6] M 136.2, m 69°, b 220°/760mm, pK₂⁵ 10.86. Crystd from water and sublimed in vacuo.


2,2,4-Trimethyl-6-phenyl-1,2-dihydroquinoline [3562-69-4] M 249.3, m 102°. Vacuum distd, then crystd from absolute EtOH.

2,4,6-Trimethylpyridine (sym-collidine) [10a-75-8] M 121.2, m -46°, b 10°/2.7mm, 36-37°/2mm, 60.7°/13mm, 65°/31mm, 170.4°/760mm, 175-178°/atm, d₂⁵ 0.9100, nD²⁵ 1.4939, 1.4981, n²⁵ 1.4959, pK²⁵ 6.69. Commercial samples may be grossly impure. Likely contaminants include 3,5-dimethylpyridine, 2,3,6-trimethylpyridine and water. Brown, Johnson and Podall [J Am Chem Soc 76 5556 1954] fractionally distd 2,4,6-trimethylpyridine under reduced pressure through a 40-cm Vigreux column and added to 430mL of the distillate slowly, with cooling to 0°, 45g of BF₃-diethyl etherate. The mixture was again distd, and an equal volume of dry *benzene was added to the distillate. Dry HCl was passed into the soln, which was kept cold in an ice-bath, and the hydrochloride was filtered off. It was recrystd from abs EtOH (1.5mL/g) to m 286-287°(sealed tube). The free base was regenerated by treatment with aq NaOH, then extracted with *benzene, dried (MgSO₄) and distd under reduced pressure. Sisler et al. [J Am Chem Soc 75 446 1953] ppted trimethylpyridine as its phosphate from a soln of the base in MeOH by adding 85% H₃PO₄, shaking and cooling. The free base was regenerated as above. Garrett and Smythe [J Chem Soc 763 1903] purified the trimethylpyridine via the HgCl₂ complex. It is more soluble in cold than hot H₂O [sol 20.8% at 6°, 3.5% at 20°, 1.8% at 100°]. Also purified by dissolving in CHCl₃, adding solid K₂CO₃ and Drierite, filtering and fractionally distilling through an 8in helix packed column. The sulfate has m 205°, and the picrate (from hot H₂O) has m 155-156°. [Frank and Meikle J Am Chem Soc 72 4184 1950.] Trimethylsulfuronium iodide [2181-42-2] M 204.1, m 215-220°(dec). Crystd from EtOH.


2,4,6-Trinitroanisole [606-35-9] M 243.1, m 68°. Crystd from EtOH or MeOH. Dried under vac.
1,3,6-Trinitrobenzene [99-35-4] M 213.1, m 122-123°. Crystd from glacial acetic acid, CHCl₃, CCl₄, EtOH aq EtOH or EtOH/* benzene, after (optionally) heating with dil HNO₃. Air dried. Fused, and crystd under vacuum.

2,4,6-Trinitrobenzenesulfonic acid hydrate (TNBS, picrylsulfonic acid) [2508-19-2] M 293.2, m 180°, λ max 240nm (ε 650 M⁻¹cm⁻¹), pKₑ₅ₒ ~ <0. It is also available as 0.1M and 5%w/v solns in H₂O. Recrystd from 1M HCl and dried at 100° or a mixt of EtOH (50mL), H₂O (30mL) and conc HCl (70mL) for 65g of acid. The diethanolamine salt had m 182-183° [Golumbic J Org Chem 11 518 1946].

2,4,6-Trinitrobenzoic acid [129-66-8] M 225.1, m 227-228°, pK² 0.65. Crystd from distilled water. Dried in a vacuum desiccator.

2,4,6-Trinitro-m- cresol [602-99-3] M 243.1, m 107.0-107.9°, pK 2.8. Crystd successively from H₂O, aq EtOH and *benzene/cyclohexane, then dried at 80° for 2h. [Davis and Paabo J Res Nat Bur Stand 64A 533 1960.]

2,4,7-Trinitro-9-fluorenone [129-79-3] M 315.2, m 176°. Crystd from nitric acid/water (3:1), washed with water and dried under vacuum over P₂O₅, or recrystd from dry * benzene.

2,4,6-Trinitrotoluene (TNT) [118-96-7] M 227.1, m 81.0-81.9°, pK 2.5 dissolved TNT in acetone and added cold water (1:2:15), the ppt was filtered, washed free from solvent and stirred with five parts of aq 8% Na₂SO₃ at 50-60° for 10min. It was filtered, washed with cold water until the effluent was colourless, and air dried. The product was dissolved in five parts of hot CCl₄, washed with warm water until the washings were colourless and TNT was recovered by cooling and filtering. It was recrystd from 95% EtOH and carefully dried over H₂SO₄. The dry solid should not be heated without taking precautions for a possible EXPLOSION.


Tri-n-octylamine [1116-76-3] M 353.7, b 164-168°/0.7mm, 365-367°/760mm, d 0.813, n 1.450, pK² 10.65. It was converted to the amine hydrochloride etherate which was recrystd four times from diethyl ether at -30° (see below). Neutralisation of this salt regenerated the free amine. [Wilson and Wogman J Phys Chem 66 1552 1962.]


1,3,5-Trioxane [110-88-3] M 90.1, m 64°, b 114.5°/759mm. Crystd from sodium-dried diethyl ether or water, and dried over CaCl₂. Purified by zone refining.

Trioxsalen (2,5,9-trimethyl-7H-furo[3,2-g]benzopyran-7-one) [3902-71-4] M 228.3, m 233-235°, 234.5-235°. Purified by recrystn from CHCl₃. If too impure it is fractionally crystd from CHCl₃-pet ether (b 30-60°) using Norit and finally crystd from CHCl₃ alone to give colourless prisms, m 234.5-235°. It is a photosensitisier so it should be stored in the dark. [UV: Kaufmann J Org Chem 26 117 1961; Baeme et al. J Chem Soc 2976 1949.]

Tripalmitin [555-44-2] M 807.4, m 66.4°. Crystd from acetone, diethyl ether or EtOH.

Triphenylamine [603-34-9] M 245.3, m 127.3-127.9°, pK -5.0 (in fluorosulfuric acid). Crystd from EtOH or from *benzene/aq EtOH, diethyl ether and pet ether. It was sublimed under vacuum and carefully dried in a vacuum line. Stored in the dark under nitrogen.
1,3,5-Triphenylbenzene [612-71-5] M 306.4, m 173-175°. Purified by chromatography on alumina using *benzene or pet ether as eluents.

Triphenylene [217-59-4] M 228.3, m 198°, b 425°. Purified by zone refining or crystn from EtOH or CHC13, and sublimed.

1,2,3-Triphenylguanidine [101-01-9] M 287.3, m 144°, pK 9.10. Crystd from EtOH or EtOH/water, and dried under vacuum.

Triphenylmethane M 244.3, m 92-93°. Crystd from EtOH or *benzene (with one molecule of *benzene of crystallisation which is lost on exposure to air or by heating on a water bath). It can also be sublimed under vacuum. It can also be given a preliminary purification by refluxing with tin and glacial acetic acid, then filtered hot through a glass sinter disc, and ppted by addition of cold water.

Triphenylmethanol (triphenylcarbinol) [76-84-6] M 260.3, m 164°, b 198°, pK2' -6.63 (aq H2SO4). Crystd from EtOH, MeOH, CCl4 (4mL/g), *benzene, hexane or pet ether (b 60-70°). Dried at 90°. [Ohwada et al. J Am Chem Soc 108 3029 1986;]

Triphenylmethyl chloride (trityl chloride) [76-83-5] M 278.9, m 111-112°. Crystd from iso-octane. Also crystd from 5 parts of pet ether (b 90-100°) and 1 part of acetyl chloride using 1.8g of solvent per g of chloride. Dried in a desiccator over soda lime and paraffin wax. [Org Synth Coll Vol III 841 1955; Thomas and Rochow J Am Chem Soc 79 1843 1957; Moisel et al. J Am Chem Soc 108 4706 1986.]

2,3,5-Triphenyltetrazolium chloride (TTC) [298-96-4] M 334.8, m 243°(dec). Crystd from EtOH or CHC13, and dried at 105°.

Tri-n-propylamine [102-69-2] M 143.3, b 156.5°, d 0.757, n 1.419, pK2' 10.66. Dried with KOH and fractionally distd. Also refluxed with toluene-p-sulfonyl chloride and with KOH, then fractionally distd. The distillate, after addn of 2% phenyl isocyanate, was redistd and the residue fractionally distd from sodium. [Takahashi et al. J Org Chem 52 2666 1987.]

Tripyridyl triazine [3682-35-7] M 312.3, m 245-248°. Purified by repeated crystn from aq EtOH.

Tris-(2-aminoethyl)amine (TREN) [4097-89-6] M 146.2, b 114°/15mm, 263°/744mm, d 0.977, n 1.498, pK2' 8.42, pK2' 4.94, pK2' 10.13. For a separation from a mixture containing 62% TRIEN, see entry under triethylenetetramine. Also purified by conversion to the hydrochloride (see below), recryst and regeneration of the free base [Xie and Hendrickson J Am Chem Soc 109 6981 1987].

Tris-(2-aminoethyl)amine trihydrochloride [14350-52-8] M 255.7, m 300°(dec). Crystd several times by dissolving in a minimum of hot water and precipitating with excess cold EtOH. The ppte was washed with acetone, then diethyl ether and dried in a vacuum desiccator.

Tris(d, d-dicampholylmethanato)europium (III) [52251-64-1] M 108.5, m 220-227.5°, 229-232°, [α]25D +28.6° (c 5.4, CCl4; and varies markedly with concentration). Dissolve in pentane, filter from any insol material, evaporate to dryness and dry the residue (white powder) at 100°/0.1mm for 36h. The IR has v 1540 cm⁻¹. [McCrea et al. J Am Chem Soc 96 1038 1974.]


Tris-(hydroxymethyl)methylamine (TRIS) [77-86-1] M 121.1, m 172°, pK25 8.07. Tris can ordinarily be obtained in highly pure form suitable for use as an acidimetric standard. If only impure material is available, it should be crystd from 20% EtOH. Dry in a vacuum desiccator over P2O5 or CaCl2.
Alternatively, it is dissolved in twice its weight of water at 55-60°, filtered, concd to half its volume and poured slowly, with stirring, into about twice the volume of EtOH. The crystals which separate on cooling to 3-4° are filtered off, washed with a little MeOH, air dried by suction, then finally ground and dried in a vacuum desiccator over P₂O₅. It has also been crystd from water, MeOH or aq MeOH, and vacuum dried at 80° for 2 days.

**Tris-(hydroxymethyl)methylamonium hydrochloride (TRIS-HCl)** [1185-53-1] M 157.6, m 149-150°(dec). Crystd from 50% EtOH, then from 70% EtOH. Tris-hydrochloride is also available commercially in a highly pure state. Otherwise, crystd from 50% EtOH, then 70% EtOH, and dried below 40° to avoid risk of decomposition.

**1,1,1-Tris-(hydroxymethyl)ethane (2-hydroxymethyl-2-methyl-1,3-propanediol)** [77-85-0] M 120.2, m 200°. Dissolved in hot tetrahydrofuran, filtered and pptd with hexane. It has also been crystd from acetone/water (1:1). Dried in vacuum.


**Tris-(hydroxymethyl)nitromethane [2-(hydroxymethyl)-2-nitro-1,3-propanediol]** [126-11-4] M 151.1, m 174-175°(dec, tech grade), 214°(pure). Crystd from CHCl₃/ethyl acetate or ethyl acetate/*benzene. It is an acid and a 0.1M sol in H₂O has pH 4.5. IRRITANT.

**Tris-[3-(3-trifluoromethylhydroxymethylene)-d-camphorato] europium (III) [Eu(tfc)₃]** [34830-11-0] M 893.6, m 195-299° (dec), ~220°, [α] D° +152° (c 2, CCl₄; and varies markedly with concentration). Purified by extraction with pentane, filtered and filtrate evapd and the residual bright yellow amorphous powder is dried at 100°/0.1mm for 36h. A sample purified by fractional molecular distn at 180-200°/0.004mm gave a liquid which solidified and softened at ~130° and melted at ~180° and was analytically pure. IR (CCl₄) v: 1630-1680cm⁻¹ and NMR (CCl₄) 6: broad: -1.3 to 0.5, -0.08 (s), 0.41 (s), 1.6-2.3 and 3.39 (s). [McCreary et al. J Am Chem Soc 96 1038 1974; Goering et al. J Am Chem Soc 93 5913 1971.] 1,3,5-Trithiane [291-21-4] M 138.3, m 220°(dec). Cryst from acetic acid.


**Tropaeolin 000 (see Orange II p. 477 in Chapter 5).** Purified by salting out from hot distilled water using sodium acetate, then three times from distilled water and twice from EtOH.


**Tropolone** [533-75-5] M 122.1, m 49-50°, b 81-84°/0.1mm, pK₁° -0.53 (protonation of CO, aq H₂SO₄), pK₂ 6.67 (acidic OH). Cryst from hexane or pet ether and sublimed at 40°/4mm.

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Tryptamine hydrochloride \([343-94-2]\) M 196.7, m 252-253°. Crystd from EtOH/water.

L-Tryptophan \([73-22-3]\) M 204.3, m 278°, \([\alpha]_D^{20}\) -33.4° (EtOH), \([\alpha]_D^{20}\) -36° (c 1, H₂O), pK₁ 15 -6.23 (aq H₂SO₄), pK₂ 2.46, pK₃ 9.41, pK₄ 14.82 (acidic NH, in aq NaOH). Crystd from water/EtOH, washed with anhydrous diethyl ether and dried at room temperature under vac over P₂O₅.

L-Tryptophan \(\text{water/EtOH, washed with anhydrous diethyl ether and dried at room temperature under vac over P}_2\text{O}_5\). Crystd from water/EtOH, washed with anhydrous diethyl ether and dried at room temperature under vac over P₂O₅.

Tryptophol \([3-(2-hydroxyethyl)indole]\) M 196.7, m 252-253°. Crystd from EtOH/water.

L-Tryptophan \([526-55-6]\) M 161.2, m 59°, b 174°/2mm. Crystd from diethyl ether/pet ether, *C₆H₆, *C₆H₄pet ether. The picrate has m 98-100° (from *C₆H₆).

(+)–Tubocurarine chloride \((5\text{H}_2\text{O})\) \([57-94-3]\) M 771.7, m 274-275°(dec) (anhydrous), \([\alpha]^{20}_D\) +235° (c 0.5, H₂O), pKₑst, \(-8.5, \sim\text{K}_3\sim 9.41, \text{pK}_1\sim 14.82\) (acidic NH, in aq NaOH). Crystd from water and forms various hydrates.

D(+)–Turanose \([547-25-1]\) M 342.3, m 168-170°, \([\alpha]_D^{20} +88°\) (c 4, H₂O). Crystd from water by addition of EtOH.

Tyramine \((4\text{-hydroxybenzylamine})\) \([51-67-2]\) M 137.2, m 164-165°, pK₁ 9.74 (OH), pK₂ 10.52 (NH₂). Crystd from *benzene or EtOH.

Tyramine hydrochloride \([60-19-5]\) M 173.6, m 274-276°. Crystd from EtOH by addition of diethyl ether, or from conc HCl.

Tyrocidine A \((\text{cyclic decapptide antibiotic with two D-Phe amino acids})\) \([1481-70-5]\) M 1268.8, m 240°(dec), \([\alpha]_D^{20} -115°\) (c 0.91, MeOH). Crystd as hydrochloride from MeOH or EtOH and HCl. [Paladin and Craig J Am Chem Soc 76 688 1954; King and Craig J Am Chem Soc 77 6624 1955; Okamoto et al. Bull Chem Soc Jpn 50 231 1977.]

L-Tyrosine \([60-18-4]\) M 181.2, m 290-295°(dec), \([\alpha]_D^{20} -10.0°\) (5M HCl), pK₁ 2.18 (CO₂H), pK₂ 9.21 (OH), pK₃ 10.47 (NH₂). Likely impurities are L-cysteine and the ammonium salt. Dissolved in dilute ammonia, then crystd by adding dilute acetic acid to pH 5. Also crystd from water or EtOH/water, and dried at room temperature under vacuum over P₂O₅.

Umbelliferone \((7\text{-hydroxycoumarin})\) \([93-35-6]\) M 162.2, m 225-228°, pKₑst ~8.0. Crystd from water.

Undecan-1-ol \([112-42-5]\) M 172.3, m 165°. Purified by repeated fractional crystn from its melt or by distn in a vacuum.

Undec-10-enolic acid \([112-38-9]\) M 184.3, m 25-25.5°, b 131°/1mm, 168°/15mm, pKₑst ~5.0. Purified by repeated fractional crystn from its melt or by distn in a vacuum.

Uracil \(\text{(5-aminobarbituric acid)}\) \([118-78-5]\) M 143.1, m 310-312°, 320°, >400°(dec), pKₑst(1) ~3.9, pKₑst(2) ~8.0, pKₑst(3) ~12.5. Crystd from water.

Urea \([57-13-6]\) M 60.1, m 132.7-132.9°, pK₂ 0.12. Crystd twice from conductivity water using centrifugal drainage and keeping the temperature below 60°. The crystals were dried under vacuum at 55° for 6h. Levy and Margoulis [J Am Chem Soc 84 1345 1962] prepared a 9M soln in conductivity water (keeping the temperature below 25°) and, after filtering through a medium-porosity glass sinter, added an equal volume of absolute EtOH. The mixture was set aside at ~27° for 2-3 days and filtered cold. The ppte was washed with a small amount of EtOH and dried in air. Cryst from 70% EtOH between 40° and -9° has also been used. Ionic impurities such as ammonium isocyanate have been removed by treating the conc aqueous soln at 50° with
Amberlite MB-1 cation- and anion-exchange resin, and allowing to crystallise. [Benesch, Lardy and Benesch *J Biol Chem* 216 663 1955.] Also crystd from MeOH or EtOH, and dried under vacuum at room temperature.

**Urea nitrate** [124-47-0] M 123.1, m 152°(dec). Crystd from dilute HNO₃.

**Uric acid** [69-93-2] M 168.1, m >300°, pK₁ 5.75, pK₂ 10.3. Crystd from hot distilled water.

**Uridine** [58-96-8] M 244.2, m 165°, [α]D⁰ +4.0° (H₂O), pK₂⁰ 9.51 (9.25). Crystd from aqueous 75% MeOH.

**Urocanic acid (4-imidazolylacrylic acid)** [104-98-3] M 138.1, m 225°, 226-228°, pK₁ 2.5, pK₂ 6, pK₃ 11. Crystd from water and dried at 100°.

**Ursodeoxycholic acid** [128-13-2] M 392.5, m 203°, +60° (c 0.2, EtOH), pKₑ₅ 4.8. Crystd from EtOH.

*(+)-Usnic acid* [2,6-diacetyl-3,7,9-trihydroxy-8,9b-dimethyl dibenzofuran-1(2H)-one] [7562-61-0] M 344.3, m 204°. See (+)-usnic acid on p. 573 in Chapter 6.

**trans-Vaccenic acid (octadec-11-enolic acid)** [693-72-1] M 282.5, m 43-44°, pKₑ₅ 4.9. Crystd from acetone. The methyl ester has b 174-175°/5mm.


**Valeric acid (n-pentanoic acid)** [109-52-4] M 102.1, b 95°/22mm, 186.4°/atm, d 0.938, n₁ 1.4080, pK₂⁰ 4.81. Water was removed from the acid by distn using a Vigreux column, until the boiling point reached 183°. A few crystals of KMnO₄ were added, and after refluxing, the distn was continued, [Andrews and Keefer *J Am Chem Soc* 83 3708 1961.]


**γ-Valerolactone** (± 4,5-dihydro-5-methyl-2(3H)-furanone) [108-29-2] M 100.1, m -37°, 36°, b 82-85°/10mm, 102-103°/28mm, 123.5°/68mm, 136°/100mm, 205.75-206.25°/754mm, d₄ 1.072, n₁ 1.4322. Purified by repeated fractional distillation [Boorman and Linstead *J Chem Soc* 577, 580 1933]. IR v: 1790 (CS₂), 1775 (CHCℓ₃) cm⁻¹ [Jones et al. *Can J Chem* 37 2007 1959]. The BF₃-complex distills at 110-111°/20mm [Repp et al. *Justus Liebigs Ann Chem* 596 179 1955]. It is characterised by conversion to γ-hydroxy-n-valeramide by treatment with NH₃, m 51.5-52° by slow evapn of a CHCl₃ soln.

**δ-Valerolactone** (tetrahydro-2H-pyran-2-one) [542-28-9] M 100.1, m -13°, -12°, b 88°/4mm, 97°/10mm, 124°/24mm, 145-146°/40mm, 229-229.5°/atm, d₄ 1.1081, a₂ 1.4568. Purified by repeated fractional distn. IR v: 1750 (in CS₂), 1732 (in CHCℓ₃), 1748 (in CCl₄) and 1733 (in MeOH) cm⁻¹. [Huisgen and Ott *Tetrahedron* 6 253 1959; Linstead and Rydon *J Chem Soc* 580 1933; Jones et al. *Can J Chem* 37 2007 1959.]
Valeronitrile  [110-59-8]  M 83.1, b 142.3°, d 0.799, n\textsuperscript{15} 1.39913, n\textsuperscript{30} 1.39037. Washed with half its volume of conc HCl (twice), then with saturated aqueous NaHCO\textsubscript{3}, dried with MgSO\textsubscript{4} and fractionally distd from P\textsubscript{2}O\textsubscript{5}.

L-Valine  [72-18-4]  M 117.2, m 315°, [\alpha]\textsubscript{D}\textsuperscript{25} +266.7° (6M HCl), pK\textsubscript{1} 2.26, pK\textsubscript{2} 9.68. Crystd from water by addition of EtOH.

Vanillin (4-hydroxy-3-methoxybenzaldehyde)  [121-33-5]  M 152.2, m 83°, b 170°/15mm, pK\textsuperscript{2} 7.40. Crystd from water or aqueous EtOH, or by distn in vacuo.

Veratraldehyde  [120-14-9]  M 166.2, m 42-43°. Crystd from diethyl ether, pet ether, C\textsubscript{6}H\textsubscript{6} or toluene.

Variamine Blue RT  [4-(phenylamino)benzenediazonium sulfate (1:1)]  [4477-28-5]  M 293.3, CI 37240, \lambda\textsubscript{max} 377 nm. Dissolved 10g in 100mL of hot water. Sodium dithionite (0.4g) was added, followed by active carbon (1.5g) and filtered hot. To the colourless or slightly yellow filtrate a soh of saturated NaCl was added and the mixture cooled. The needles were filtered off, washed with cold water, dried at room temperature, and stored in a dark bottle (light sensitive). [Erdey Chem Analyst 48 106 1959.]

Vicine (2,4-diamino-5-\beta-D-glucopyranosidoxy-6-hydroxypyrimidine)  [152-93-2]  M 304.3, m 243-244°, [\alpha]\textsubscript{D}\textsuperscript{19} -12° (c 4, 0.2N NaOH). Crystd from water or aqueous 85% EtOH, and dried at 135°.

Vinyl acetate  [108-05-4]  M 86.1, b 72.3°, d 0.938, n 1.396. Inhibitors such as hydroquinone, and other impurities are removed by drying with CaCl\textsubscript{2} and fractionally distilling under nitrogen, then refluxing briefly with a small amount of benzoyl peroxide and redistilling under nitrogen. Stored in the dark at 0°.


Vinyl butoxyethyl ether  [4223-11-4]  M 144.2. Washed with aqueous 1% NaOH, dried with CaH\textsubscript{2}, then refluxed with and distd from, sodium.


Vinyl chloroformate  [5130-24-5]  M 106.5, b 46.5°/80mm, 67-69°/atm, 109-110°/760mm, d\textsubscript{4} 1.136, n\textsubscript{D}\textsuperscript{25} 1.420. It has been fractionated through a Todd column (Model A with ~60 plates, see p. 174) under atmospheric pressure and purity can be checked by gas chromatography. It has IR with v at 3100 + 2870 (CH\textsubscript{2}), 1780 (C=O), 1640 (C=C) and 940 (CH\textsubscript{2} out-of-plane) and 910 (CH\textsubscript{2} wagging) cm\textsuperscript{-1}. [IR: Lee J Org Chem 30 3943 1965; Levaillant Ann Chim (Paris) 6 504 1936.] Used for protecting NH\textsubscript{2} groups in peptide synthesis [Olofson et al. Tetrahedron Lett 1563 1977].

1-Vinylnaphthalene  [826-74-4]  M 154.2, b 124-125°/15mm. Fractionally distd under reduced pressure on a spinning-band column, dried with CaH\textsubscript{2} and again distd under vacuum. Stored in sealed ampoules in a freezer.

2-Vinylpyridine monomer  [100-69-6]  M 105.1, b 79-82°/29mm, d 0.974, n 1.550, pK\textsuperscript{25} 4.92. Steam distd, then dried with MgSO\textsubscript{4} and distd under vacuum.

4-Vinylpyridine monomer  [100-43-6]  M 105.1, b 40-41°/1.4mm, 54°/5mm, 58-61°/12mm, 68°/18mm, 79°/33mm, d\textsubscript{4} 0.9836, n\textsubscript{D}\textsuperscript{20} 1.5486, pK\textsuperscript{25} 5.62. Purified by fractional distillation under a good vacuum and in a N\textsubscript{2} atmosphere and stored in sealed ampoules under N\textsubscript{2}, and kept in the dark at -20°.

**Vinyl stearate** [111-63-7] M 310.5, m 35°, b 166°/1.5mm. Vacuum distd under nitrogen, then crystd from acetone (3mL/g) or ethyl acetate at 0°.

**Violanthrene** (dibenzanthrene, 5,10-dihydroviolanthrene A) [81-31-2] M 428.5. Purified by vacuum sublimation over Cu in a muffle furnace at 450°/25mm in a CO₂ atmosphere [Scholl and Meyer *Chem Ber* 67 1229 1934]. Violanthrene A (anthracene-9,12-dicarboxylic acid) has m 506°. [Clar *Chem Ber* 76 458 1943.]

**Viologen** (4,4′-dipyridyl dihydrochloride) [27926-72-3] M 229.1, m >300°. Purified by pptn on adding excess of acetone to a concentrated solution in aqueous MeOH. It has also been recrystd several times from MeOH and dried at 70° under vacuum for 24h [Prasad et al. *J Am Chem Soc* 108 5135 1986], and recrystd three times from MeOH/isopropanol [Stramel and Thomas *J Chem SOC, Faraday Trans* 82 799 1986].

**Visnagin** (4-methoxy-7-methyl-5H-furo[3,2-g][1]benzopyran-5-one) [82-57-5] M 230.2, m 142-145°. Crystd from water.

**dl-Warfarin** (4-hydroxy-3-(3-oxo-1-phenylbutyl)-2H-1-benzopyran-2-one) [81-81-2] M 308.3, m 161°. Crystd from MeOH. The acetate has m 182-183° and 2,4-dinitrophenylhydrazone has m 215-216°. Effective anticoagulant and rodenticide.

**Xanthatin** (3-methylene-7-methyl-6-[3-oxo-1-buten-1-yl]cyclohept-5-ene-[10,11-b]furan-2-one) [26791-73-1] M 246.3, m 114.5-115°, [α]D -20° (EtOH). Crystd from MeOH or EtOH. UV: λmax 213 and 275nm (ε 22800 and 7300).

**Xanthene** [92-83-1] M 182.2, m 100.5°, b 310-312°/760mm. Crystd from *benzene or EtOH.

**9-Xanthenone** (xanthone) [90-47-1] M 196.2, m 175.6-175.4°. Crystd from EtOH (25mL/g) and dried at 100°. It has also been recrystd from n-hexane three times and sublimed in vacuo. [Saltiel *J Am Chem Soc* 108 2674 1986].

**Xanthopterin** (H₂O) see entry on p. 576 in Chapter 6.

**Xanthopterin** [1324-63-6] M 770.7, m 195°, [α]D20 +3.75° (EtOH). Crystd from a mixture of ethyl and isopropyl alcohols, air dried, then dried for several hours at 110°.

**Xanthosine** (2H₂O) [9-(β-D-ribofuranosyl)purin-2,6(1H,3H)-dione] [5968-90-1] M 320.3, [α]D20 -53° (c 8, 0.3M NaOH), pK₁<sub>1</sub> 2.5, pK₂<sub>2</sub> 5.67, pK₃<sub>3</sub> 12.85. Crystd from EtOH or water (as dihydrate).

**Xanthurenic acid** (5,8-dihydroxyquinoline-2-carboxylic acid) [59-00-7] M 205.2, m 286°, 290-295°(dec), pK<sub>Est</sub>(1)~ 1.5, pK<sub>Est</sub>(3)~ 4.9, pK<sub>Est</sub>(5)~ 9.8. Ppted by the addition of 2N formic acid to its soln in hot 2M ammonia (charcoal). Filter solid off, dry in a vac at ~80° in the dark. UV (H₂O) has λmax nm (ε M⁻¹cm⁻¹): 243 (30,000) and 342 (6,500). The *methyl ester* has m 262° (from MeOH).

Purification of Organic Chemicals

**Xylene [1330-20-7] M 106.1 (mixed isomers).** Usual impurities are ethylbenzene, paraffins, traces of sulfur compounds and water. It is not practicable to separate the m- and p-isomers of xylene by fractional distillation, although, with a sufficiently efficient still, o-xylene can be fractionally distilled from a mixture of isomers. Purified (and dried) by fractional distillation from LiAlH₄, P₂O₅, CaH₂ or sodium. This treatment can be preceded by shaking successively with conc H₂SO₄, water, aqueous 10% NaOH, water and mercury, and drying with CaCl₂ for several days. Xylene can be purified by azeotropic distillation with 2-ethoxyethanol or 2-methoxyethanol, the distillate being washed with water to remove the alcohol, then dried and fractionally distilled.

**o-Xylene [95-47-6] M 106.2, f -25.2°, b 84°/14mm, 144.4°/760mm, d 0.88020, d² 0.87596, n 1.50543, n² 1.50292.** The general purification methods listed under xylene are applicable. [Clarke and Taylor J Am Chem Soc 45 831 1923] o-Xylene (4.4Kg) is sulfonated by stirring for 4h with 2.5L of conc H₂SO₄ at 95°. After cooling, and separating the unsulfonated material, the product was diluted with 3L of water and neutralised with 40% NaOH. On cooling, sodium o-xylene sulfonate separated and was recrystallized from half its weight of water. [A further crop of crystals was obtained by concentrating the mother liquor to one-third of its volume]. The salt was dissolved in the minimum amount of cold water, then with the same amount of cold water, and with the same volume of conc H₂SO₄ and heated to 110°. o-Xylene was regenerated and steam distilled. It was then dried and redistilled.

**m-Xylene [108-38-3] M 106, f -47.9°, b 139.1°, d 0.86417, d² 0.85990, n 1.49721, n² 1.49464.** The general purification methods listed under xylene are applicable. The o- and p-isomers can be removed by their selective oxidation when a m-xylene sample containing them is boiled with dilute HNO₃ (one part conc acid to three parts water). After washing with water and alkali, the product can be steam distilled, then distillate purified by sulfonation.  [Clarke and Taylor J Am Chem Soc 45 831 1923] m-Xylene is selectively sulfonated when a mixture of xylenes is refluxed with the theoretical amount of 50-70% H₂SO₄ at 85-95° under reduced pressure. By using a still resembling a Dean and Stark apparatus, water in the condensate can be progressively withdrawn while the xylene is returned to the reaction vessel. Subsequently, after cooling, then adding water, unreacted xylene are distilled off under reduced pressure. The m-xylene sulfonic acid is subsequently hydrolysed by steam distillation up to 140°, the free m-xylene being washed, dried with silica gel and again distilled. Stored over molecular sieves Linde type 4A.

**p-Xylene [106-42-3] M 106.2, f 13.3, b 138.3°, d 0.86105, d² 0.85669, n 1.49581, n² 1.49325.** The general purification methods listed for xylene are applicable. p-Xylene can readily be separated from its isomers by crystallization from such solvents as MeOH, EtOH, isopropanol, acetone, butanone, toluene, pentane or pentene. It can be further purified by fractional crystallization by partial freezing, and stored over sodium wire or molecular sieves Linde type 4A. [Stokes and French J Chem Soc, Faraday Trans I 76 537 1980].

**Xylenol Orange [3H-2,1-benzoxathiol-3-ylidene-bis-[(6-hydroxy-5-methyl-2-phenylene)-methyleneitrilio]tetraacetic acid, S,S-dioxide] [1611-35-4] M 672.6, m 210°(dec), ε 678 6.09 x 10⁴ (pH 14), ε 435 2.62 x 10⁴ (pH 3.1), pK₁ -1.74, pK₂ -1.09 (aq H₂SO₄-HNO₃), pK₃ 2.58, pK₄ 3.23, pK₅ 6.46, pK₆ 10.46, pK₇ 12.28. Generally contaminated with starting material (cresol red) and semixylenol orange. Purified by ion-exchange chromatography using DEAE-cellulose, eluting with 0.1M NaCl soln which will give the sodium salt. Cresol Red, semixylenol orange and iminodiacetic acid bands elute first. This procedure will give the sodium salt of the dye. To obtain the free acid dissolve the salt in H₂O and acidify with AcOH. Filter off, wash with H₂O and dry first in air and then in a vac desiccator over P₂O₅ in the dark [Sato, Yokoyama and Momoki Anal Chim Acta 94 317 1977].

**α-D-Xylose [58-86-6] M 150.1, m 146-147°, [α]D² 18.8° (c 4, H₂O).** Purified by slow crystallization from aqueous EtOH or EtOH, then dried at 60° under vac over P₂O₅. Stored in a vacuum desiccator over CaSO₄.

**m-Xylylene diisocyanate [3634-83-1] M 188.2, b 88-89°/0.02mm, 130°/2mm, d₁² 1.204, n₁² 1.4531.** Purified by repeated distillation through a 2 plate column. [Ferstundig and Scherrer J Am Chem Soc 81 4838 1959]
α-Yohimbine [146-48-5] M 354.5, m 278°(dec), $[\alpha]_D^{20}$ +55.6° (c 2, EtOH), pK$a_{2}$ 3.0, pK$b_{2}$ 7.45. Crystd from EtOH, and dried to remove EtOH of crystn. For γ-Yohimbine see ajmalicine on p. 98.

Zeaxanthin [all trans-β-carotene-3,3′(R,R′)-diol] [144-68-3] M 568.9, m 207°, 215.5°, $\lambda_{\text{max}}$ 275 (log ε 4.34), 453 (log ε 5.12), 480 (log ε 5.07) in EtOH. Yellow plates (with a blue lustre) from MeOH or EtOH.
CHAPTER 5

PURIFICATION OF INORGANIC AND METAL ORGANIC CHEMICALS
(Including Organic compounds of B, Bi, P, Se, Si, and ammonium and metal salts of organic acids)

The most common method of purification of inorganic species is by recrystallisation, usually from water. However, especially with salts of weak acids or of cations other than the alkaline and alkaline earth metals, care must be taken to minimise the effect of hydrolysis. This can be achieved, for example, by recrystallising acetates in the presence of dilute acetic acid. Nevertheless, there are many inorganic chemicals that are too insoluble or are hydrolysed by water so that no general purification method can be given. It is convenient that many inorganic substances have large temperature coefficients for their solubility in water, but in other cases recrystallisation is still possible by partial solvent evaporation.

Organo-metallic compounds, on the other hand, behave very much like organic compounds, e.g. they can be redistilled and may be soluble in organic solvents. A note of caution should be made about handling organo-metallic compounds, e.g. arsines, because of their potential toxicities, particularly when they are volatile. Generally the suppliers of such compounds provide details about their safe manipulation. These should be read carefully and adhered to closely. If in any doubt always assume that the materials are lethal and treat them with utmost care. The same safety precautions about the handling of substances as stated in Chapter 4 should be followed here (see Chapter 1).

For information on ionization (pK) see Chapter 1, p. 7, and Chapter 4, p. 80. In order to avoid repetition, the literature (or predicted) pK values of anionic and/or cationic species are usually reported at least once, and in several cases is entered for the free acid or free base, e.g. Na₂SO₄ will have a pK value for Na⁺ at the entry for NaOH and the pK values for SO₄²⁻ at the entries for H₂SO₄. When the pK values of the organic counter-ions are not given in this Chapter, as in case of sodium benzoate, the reader is referred to the value(s) in Chapter 4, e.g. of benzoic acid.

Abbreviations of titles of periodical are defined as in the Chemical Abstracts Service Source Index (CASSI). A note on other abbreviations is in Chapter 1, p. 30.

Benzene, which has been used as a solvent successfully and extensively in the past for reactions and purification by chromatography and crystallisation is now considered a very dangerous substance so it has to be used with extreme care. We emphasised that an alternative solvent to benzene (e.g. toluene, toluene-petroleum ether, or a petroleum ether to name a few) should be used first. However, if benzene has to be used then all operations have to be performed in a well ventilated fume hood and precautions taken to avoid inhalation and contact with skin and eyes. Whenever benzene is mentioned in the text and asterisk e.g. *C₆H₆ or *benzene, is inserted to remind the user that special precaution should be adopted.

Organic dyes which are not complexed or are salts of metals are included in Chapter 4 (use the CAS Registry Numbers to find them). Commercially available polymer supported reagents are indicated with § under the appropriate reagent.

Acetarsol see *N*-Acetyl-4-hydroxy-*m*-arsanilic acid.
Acetonitrilephosphonium chloride \( [1235-21-8] \) M 354.8, m 237-238°, 244-246° (dec). Recrystd from CHCl₃ + *C₆H₆ + pet ether (b 60-80°) and by dissolving in CHCl₃ and pouring it into dry Et₂O. \( \lambda_{\text{max}} \) nm (e) 255(3,600), 262(3,700), 268(4,000) and 275(3,100). The iodide salt crystallises from H₂O and has m 207-209°. [J Org Chem 22 41 1957] IRITANT and hygroscopic. When shaken with a 10% aqueous soln of Na₂CO₃ (8h) it gives acetylmethylene triphenyl phosphorane which is recrystd from MeOH-H₂O and after drying at 70°/0.1mm has m 205-206°. UV: \( \lambda_{\text{max}} \) nm (e) 268 (6600), 275 (6500) and 288 (5700); IR: v (cm⁻¹) 1529 (s), 1470 (m), 1425 (s), 1374 (m), 1105 (s) and 978 (s). [J Org Chem 22 41, 44 1957.]

**Acetylenedicarboxylic acid monopotassium salt** \([928-04-1] \) M 152.2. Very soluble in H₂O, but can be crystd from small volume of H₂O in small crystals. These are washed with EtOH and dried over H₂SO₄ at 125°. [Chem Ber 10 841 1877; Justus Liebigs Ann Chem 272 133 1893.]

**Allyl trimethylsilane** \([762-72-1] \) M 114.3, b 83.0-84.5°, 84-88°, 85.5-86.0°, d 0.713, n 1.405. Fractionate through an efficient column at atm pressure. If impure dissolve in THF, shake with H₂O (2x), dry (Na₂SO₄) and fractionate. [Cudlin and Chvalovský Collect Czech Chem Commun 27 1658 1962.]

**Alumina (neutral)** \([1344-28-1] \) M 102.0 (anhyd.). Stirred with hot 2M HNO₃, either on a steam bath for 12h (changing the acid every hour) or three times for 30min, then washed with hot distilled water until the washings had pH 4, followed by three washings with hot MeOH. The product was dried at 270° [Angyal and Young J Am Chem Soc 81 5251 1959]. For the preparation of alumina for chromatography see Chapter 1.

**Aluminum acetylacetonate** \([13963-57-0] \) M 324.3, m 192-194°, 195°. Crystd several times from *benzene or aqueous MeOH, \( \lambda_{\text{max}} \) 216 and 286nm. [J Phys Chem 62 440 1958.] It can be purified by sublimation and has the following solubilities in g per cent: \( * \)C₆H₆ 35.9 (20°), 47.6 (40°), toluene 15.9 (20°), 22.0 (40°) and acetylacetone 6.6 (20°), 10.4 (40°). [Inorg Synth 5 105 1957.]
Aluminium ammonium sulfate (10H2O) [7784-26-1] M 453.3, m 93°, pK2^+ 4.89, pK3^+ 5.43, pK4^+ 5.86 (fAl^{3+} aquo), pK5^+ 11.22 [aluminate Al(OH)4^-]. Crystd from hot H2O and cool in ice.

Aluminium bromide [7727-15-3] M 266.7, m 97°, b 114°/10mm. Refluxed and then distilled from pure aluminium chips in a stream of nitrogen into a flask containing more of the chips. It was then distd under vacuum into ampoules [Tipper and Walker J Chem Soc 1352 1959]. Anhydrous conditions are essential, and the white to very light brown solid distillate can be broken into lumps in a dry-box (under nitrogen). Fumes in moist air.

Aluminium caesium sulfate (12H2O) [7784-17-0 (12H2O); 14284-36-7] M 568.2. Crystd from hot water (3mL/g).

Aluminium chloride (anhydrous) [77846-70-0] M 133.3, m 192.6°. Sublimed several times in an all glass system under nitrogen at 30-50mm pressure. Has also been sublimed in a stream of dry HCl and has been subjected to a preliminary sublimation through a section of granular aluminium metal [for manipulative details see Jensen J Am Chem Soc 79 1226 1957]. Fumes in moist air.

Aluminium ethoxide [555-75-9] M 162.3, m 119°, b 135°/10mm. Distd under vacuum. Hygroscopic.

Aluminium fluoride (anhydrous) [7784-18-4] M 84.0, m 250°. Technical material may contain up to 15% alumina, with minor impurities such as aluminium sulfate, cryolite, silica and iron oxide. Reagent grade AlF3 (hydrated) contains only traces of impurities but its water content is very variable (may be up to 40%). It can be dried by calcining at 600-800° in a stream of dry air (some hydrolysis occurs), followed by vacuum distn at low pressure in a graphite system, heated to approximately 925° (condenser at 900°) [Henry and Dreisbach J Am Chem Soc 81 5274 1959].

Aluminium isopropoxide [555-31-7] M 204.3, m 119°, b 94°/0.5mm, 135°/10mm. Distd under vacuum. Hygroscopic.

Aluminium nitrate (9H2O) [7784-27-2 (9H2O); 13473-90-0] M 375.1. Crystd from dilute HNO3, and dried by passing dry nitrogen through the crystals for several hours at 40°. After 2 recrystns of ACS grade it had S, Na and Fe at 2.2, 0.01 and 0.02 ppm resp.

Aluminium potassium sulfate (12H2O, alum) [7784-24-9] M 474.4, m 92°. Crystd from weak aqueous H2SO4 (ca 0.5mL/g).

Aluminium rubidium sulfate (12H2O) [7784-29-4] M 496.2. Crystd from aq H2SO4 (ca 2.5mL/g).

Aluminium sulfate (anhydrous) [10043-01-3] M 342.2, m 765°(dec); Al2O3 14-18 H2O [17927-65-0]; Al2O3 18 H2O [7784-31-8]. Crystd from hot dilute H2SO4 (1 mL/g) by cooling in ice. When a soln of alumina (Al2O3) in conc H2SO4 is slowly cooled, Al2SO4 17 or 18H2O deposits as a crystalline mass. Al2SO4 17H2O is the stable form in equilibrium with its saturated aqueous soln at 25° [Smith J Am Chem Soc 64 41 1942]. This is purified by dissolving in a small vol of H2O and adding EtOH until the sulfate readily crystallises from the oily supersaturated soln. It forms Al2O3 16H2O between 0-112°. On gradual heating the hydrate melts giving the anhydrous salt at ca 250°. Several hydrates up to 27H2O have been described. Further heating to red heat (~ 600-800°) causes decomposition to Al2O3 + SO3 + SO2 and O2. [Cobb J Soc Chem Ind 29 250 1910]. ACS reagent is Al2O3 18H2O (98+%).

Aluminium triethyl (triethyl aluminum) [97-93-8] M 114.2, b 69°/1.5mm, 76°/2.5mm, 129-131°/55mm, d30 0.695, nD 1.394. Purified by fractionation in an inert atmosphere under vacuum in a 50cm column containing a heated nichrome spiral, taking the fraction 112-114°/27mm. It is very sensitive to H2O and should be stored under N2. It should not contain chloride which can be shown by hydrolysis and testing with AgNO3. [J Am Chem Soc 75 4828 5193/1953; NMR: J Am Chem Soc 81 3826 1959.]

Aluminium trimethanide (trimethyl aluminium) [75-24-1] M 72.1, m 15.2°, b 111.5°/488.2mm, 124.5°/atm, d²⁰ 0.725. Distd through a 10-20 theoretical plates column under 1 atm of N₂ (better with very slow take-off). Attacks grease (use glass joints). Also vac distd over Al in absence of grease, into small glass vials and sealed under N₂. Purity is measured by freezing point. Reacts with H₂O, is non-conducting in C₆H₆ and is HIGHLY FLAMMABLE. [J Chem Soc 4681946; J Am Chem Soc 68 2204 1946.]


Ammonia (gas) [7664-41-7] M 17.0, pK₂⁵ 9.25. Major contaminants are water, oil and non-condensible gases. Most of these impurities are removed by passing the ammonia through a trap at -22° and condensing it at -176° under vacuum. Water is removed by distilling the ammonia into a tube containing a small lump of sodium. Also dried by passage through porous BaO, or over alumina followed by glass wool impregnated with sodium (prepared by soaking the glass wool in a solution of sodium in liquid ammonia, and evaporating off the ammonia). It can be rendered oxygen-free by passage through a soln of potassium in liquid ammonia.

Ammonia (liquid) [7664-41-7] M 17.0, m -77.7°, b -33.4°, nD 1.325, d 0.597, d²⁰ 0.817g/mL. Dried, and stored, with sodium in a steel cylinder, then distd and condensed by means of liquid air, the non-condensable gases being pumped off. In order to obtain liquid NH₃ from a cylinder turn the cylinder up-side-down (i.e. with the valve at the bottom, use a metal stand to secure it in this position) and lead a plastic tube from the tap to a measuring cylinder placed in an efficient fume cupboard which is kept running. Turn the tap on and allow the ammonia to be released. At first, gas and liquid will splatter out (make sure that the plastic tube is secure) but soon the liquid will drip into the measuring cylinder. The high latent heat of evaporation will cool the ammonia so that the liquid will remain cool and not boil vigorously. If the ammonia is required dry the necessary precautions should be taken, i.e. the gas is allowed to flow through tubes packed with coarse CaO pellets.

Ammonia (aqueous) [7664-41-7] M 17.0 + H₂O, d 0.90 (satd, 27% w/v, 14.3 N), pK₂⁵ 9.25. Obtained metal-free by saturating distilled water, in a cooling bath, with ammonia (from tank) gas. Alternatively, can use isothermal distn by placing a dish of conc aq ammonia and a dish of pure water in an empty desiccator and leaving for several days. AMMONIA (gas, liquid or aq soln) is very irritating and should not be inhaled in large volumes as it can lead to olfactory paralysis (temporary and partially permanent).

Ammonium acetate [631-61-8] M 77.1, m 112-114°, d 1.04. Crystd twice from anhydrous acetic acid, dried under vacuum for 24h at 100° [Proll and Sutcliff Trans Faraday Soc 57 1078 1961].


Ammonium bisulfate (ammonium hydrogen sulfate) [7803-63-6] M 115.1°, m ~147°, d 1.79, pK₂⁵ 1.96 (HSO₄⁻). Crystd from water at room temperature (1mL/g) by adding EtOH and cooling.

Ammonium bromide [12124-97-9] M 98.0, m 450°(sublimes), d 2.43. Crystd from 95% EtOH.

Ammonium chloride [12125-02-9] M 53.5, m 338°(sublime point, without melting), d 1.53. Crystd several times from conductivity water (1.5mL/g) between 90° and 0°. Sublimes. After one crystn, ACS grade had: metal(ppm) As (1.2), K (1), Sb (7.2), V (10.2).

Ammonium chromate [7788-98-9] M 152.1, m 185°(dec), d 1.81, pK₂⁵ 0.74, pK₂¹⁵ 6.49 (for H₂CrO₄). Crystd from weak aqueous ammonia (ca 2.5mL/g) by cooling from room temperature.
Ammonium dichromate \([7789-09-5]\) \(M \ 252.1\), m 170°(dec), d 1.26. Crystd from weak aq HCl \((ca 1\text{mL/g})\). (Possible carcinogen)

Ammonium dihydrogen arsenate \([13462-93-6]\) \(M \ 159.0\), m 300°(dec). Crystd from water \((1\text{mL/g})\).

Ammonium dihydrogen orthophosphate \([7722-76-1]\) \(M \ 115.0\), m 190°, d 1.80. Crystd from water \((0.7\text{mL/g})\) between 100° and 0°.

Ammonium dodecylsulfate \([2235-54-3]\) \(M \ 283.4\). Recrystd first from 90% EtOH and then twice from abs EtOH, finally dried in a vacuum.

Ammonium ferric oxalate \((3\text{H}_2\text{O})\) \([13268-42-3]\) \(M \ 428.1\), m 160°(dec), d 1.77. Crystd from hot water \((0.5\text{mL/g})\).

Ammonium ferric sulfate \((12\text{H}_2\text{O})\) \([7783-85-9 (12\text{H}_2\text{O}); 10045-89-3 (anhydr)]\) \(M \ 392.1\), m 100°(dec), d 1.86. A soln in warm water \((1.5\text{mL/g})\) was cooled rapidly to 0°, and the resulting fine crystals were filtered at the pump, washed with cold distilled water and pressed between sheets of filter paper to dry.

Ammonium formate \([540-69-2]\) \(M \ 63.1\), m 116.0, 117.3°, d 1.280. Heat solid in NH₃ vapour and dry in vacuum till NH₃ odour is faint. Recryst from abs EtOH and then keep in a desiccator over 99% H₂SO₄ in vacuo. It is very hygroscopic. Exists in two forms, stable needles and less stable plates. Also forms acid salts, i.e. HCO₂NH₄·3HCO₂H and HCO₂NH₄·HCO₂H. [J Am Chem Soc 43 1473 1921; 63 3124 1941.]

Ammonium hexachloroiridate \((IV)\) \([16940-92-4]\) \(M \ 441.0\). Ppted several times from aqueous soln by saturation with ammonium chloride. This removes any palladium and rhodium. Then washed with ice-cold water and dried over conc H₂SO₄ in a vacuum desiccator. If osmium or ruthenium is present, it can be removed as the tetroxide by heating with conc HNO₃, followed by conc HClO₄, until most of the acid has been driven off. (This treatment is repeated). The near-dry residue is dissolved in a small amount of water and added to excess NaHCO₃ soln and bromine water. On boiling, iridic (but not platinic) hydroxide is ppted. It is dissolved in HCl and ppted several times, then dissolved in HBr and treated with HNO₃ and HCl to convert the bromides to chlorides. Saturation with ammonium chloride and cooling precipitates ammonium hexachloroiridate which is filtered off and purified as above [Woo and Yost J Am Chem Soc 53 884 1931].

Ammonium hexacyanoferrate \((II)\) \([14481-29-9]\) \(M \ 284.1\), m dec on heating. The pale yellow trihydrate powder can be washed with 10% aq NH₃, filt, then washed several times with EtOH and Et₂O, and dried at room temp. Decomposes in vacuum above 100° and should be stored away from light and under N₂. In light and air it decomposes by losing NH₃. [Handbook of Preparative Inorganic Chem (Ed. Brauer) Vol II 1509 1965.]

Ammonium hexafluorophosphate \([16941-11-0]\) \(M \ 163.0\), d\(1^\text{st}\) 2.181, \(pK_{1}^{2.5}\) 0.5, \(pK_{2}^{5.12}\) \(\text{(for fluoro phosphoric acid H}_2\text{PO}_3\text{F)}\). Crystallises from H₂O in square plates. Decomposes on heating before melting. Soluble in H₂O at 20° (74.8% w/w), also very soluble in Me₂CO, MeOH, EtOH and MeOAc and is decomposed by boiling acids. [Chem Ber 63 1063 1930.]

Ammonium hexafluorosilicate \([16941-19-0]\) \(M \ 178.1\), \(pK_{1}^{5.92}\) \(\text{(for H}_2\text{SiF}_6\text{)}\). Crystd from water \((2\text{mL/g})\). After 3 recrystns of Tech grade it had Li, Na, K and Fe at 0.3, 0.2, 0.1 and 1.0 ppm resp.

Ammonium hypophosphite \([7803-65-8]\) \(M \ 83.0\). Crystd from hot EtOH.
Ammonium iodate [13446-09-8] M 192.9, pK$_{25}$ 0.79 (IO$_3^{3+}$). Crystd from water (8mL/g) between 100° and 0°.


Ammonium magnesium chloride (6H$_2$O) [60314-43-4] M 256.8. Crystd from water (6mL/g) by partial evapn in a desiccator over KOH (deliquescent).

Ammonium magnesium sulfate (6H$_2$O) [20861-69-2] M 360.6. Crystd from water (1mL/g) between 100° and 0°.

Ammonium manganous sulfate (6H$_2$O) [13566-22-8] M 391.3. Crystd from water (2mL/g) by partial evapn in a desiccator.


Ammonium molybdate [13106-76-8] M 196.0, pK$_{25}$ 0.9 (proton addition), pK$_{25}^2$ 3.57, pK$_{35}^2$ 4.08 (for H$_2$MoO$_4$). Crystd from water (2.5mL/g) by partial evapn in a desiccator.

Ammonium nickel sulfate (6H$_2$O) [7785-20-8 (6H$_2$O); 15699-18-0 (anhydr)] M 395.0, d 1.923. Crystd from water (3mL/g) between 90° and 0°.

Ammonium nitrate [6484-52-2] M 80.0, m 210°(dec explosively), d 1.72. Crystd twice from distilled water (1mL/g) by adding EtOH, or from warm water (0.5mL/g) by cooling in an ice-salt bath. Dried in air, then under vacuum. After 3 recrysts of ACS grade it contained Li and B at 0.03 and 0.74 ppm resp.

Ammonium oxalate (H$_2$O) [6009-70-7] M 142.1, d 1.50. Crystd from water (10mL/g) between 50° and 0°.

Ammonium perchlorate [7790-98-9] M 117.5, d 1.95, pK$_{25}$ -2.4 to -3.1 (for HClO$_4$). Crystd twice from distilled water (2.5mL/g) between 80° and 0°, and dried in a vacuum desiccator over P$_2$O$_5$. Drying at 110° might lead to slow decomposition to chloride. POTENTIALLY EXPLOSIVE.

Ammonium peroxydisulfate [7727-54-0] M 228.2, m dec when heated wet liberating oxygen, d 1.98. Recrystd at room temperature from EtOH/water.


Ammonium reineckate (Reineckate salt) [13573-16-5] M 345.5, m 270-273°(dec). Crystd from water, between 30° and 0°, working by artificial light. Solns of reineckate decompose slowly at room temperature in the dark and more rapidly at higher temperatures or in diffuse sunlight.

Ammonium selenate [7783-21-3] M 179.0, d 2.19, m dec on heating. Crystd from water at room temperature by adding EtOH and cooling.

Ammonium sulfamate [7773-06-0] M 114.1, m 132-135°, dec at 160°. Crystd from water at room temperature (1mL/g) by adding EtOH and cooling.
Ammonium sulfate [7783-20-2] M 132.1, m 230°(dec), 280°(dec), d 1.77. Crystd twice from hot water containing 0.2% EDTA to remove metal ions, then finally from distilled water. Dried in a desiccator for 2 weeks over Mg(ClO4)2. After 3 recrystns ACS grade had Ti, K, Fe, Na at 11, 4.4, 4.4, 3.2 ppm resp.

Ammonium tetrafluoroborate [13826-83-0] M 104.8, pK25 2.77 (for HBF4). Crystd from conductivity water (1mL/g) between 100° and 0°.

Ammonium tetraphenylborate [14637-34-4] M 337.3, m ca 220°(dec). Dissolve in aqueous Me2CO and allow crystn to proceed slowly otherwise very small crystals are formed. No trace of Me2CO was left after drying at 120° [Trans Faraday Soc 53 1957]. The salt was pptd from dilute AcOH soln of sodium tetraphenylborane in the presence of NH4 ions. After standing for 5min, the ppt was filtered off onto a sintered porcelain crucible, washed with very dilute AcOH and dried at room temp for at least 24h [Anal Chem 28 1001 1956]. Alternatively a soln of sodium tetraphenylborane (5% excess) in H2O is added to NH4Cl soln. After 5min the ppt is collected, washed several times with H2O and recryst from aqueous Me2CO. [Analyst Chim Acta 19 342 1958.]

Ammonium thiocyanate [1762-95-4] M 76.1, m 138°(dec), 149°(dec), pK25 -1.85 (for HSCN), 149. Crystd three times from dilute HC104, to give material optically transparent at wavelengths longer than 270nm. Has also been crystd from absolute MeOH and from acetonitrile.


Ammonium (meta) vanadate [7803-55-6] M 117.0, d15 2.326. Wash with H2O until free from Cl- and dry in air. It is soluble in H2O (5.18g/100mL at 15°, 10.4g/100mL at 32°) but is more soluble in dilute NH3. Crystd from conductivity water (20mL/g). When heated at relatively low temperatures it loses H2O and NH3 to give vanadium oxide (V2O5) and at 210° it forms lower oxides. [Znorg Synth 3 117 1950. After washing Tech grade with H2O it had Na, Mn and U at 0.06, 0.2 and 0.1 ppm resp.


Anthraquinone Blue B (Acid Blue 45, 1,5-diamino-4,8-dihydroxy-9,10-anthraquinone-3,7-disulfonic acid di-Na salt) [2861-02-1] M 474.3, m >300°, CI 63010, hmax 595nm, pK595nm <0, pK525-2, pK53-9. Purified by salting out three times with sodium acetate, followed by repeated extraction with EtOH [McCrew and Schneider J Am Chem Soc 72 2547 1950].


Anthraquinone Green G [Acid Green 25, Alizarin Cyanine Green F, 1,4-bis-(4-methyl-2-sulfophenyl-1-amino)-9,10-anthraquinone di-Na salt] [4403-90-1] M 624.6, m 235-238°, CI 61570, λmax 642nm, pK >0. Purified by salting out three times with sodium acetate, followed by repeated extraction with EtOH [McCrew and Schneider J Am Chem Soc 72 2547 1950]. It is a green powder that slightly sol in Me2CO, EtOH and pyridine. Sol in conc H2SO4 to give a blue soln which becomes turquoise on dilution. [Allen et al. J Org Chem 7 63 1942.]


Antimony (V) pentafluoride [7783-70-2] M 216.7, m 7.0°, 8.3°, b 141°, 150°, 148-150°, d 2.99, pK25 2.55 [for HSb(OH)6 = Sb(OH)6^- + H^+]. Purified by vacuum distillation preferably in a
quartz apparatus, and stored in quartz or aluminum bottles. It is a hygroscopic viscous liquid which reacts violently with H₂O and is hydrolysed by alkalis. It is POISONOUS and attacks the skin. [J Chem Soc 2200 1950; Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol I 200 1965.]

Antimony trichloride [10025-91-9] M 228.1, m 73°, b 283°, pk₁ 15 1.4, pk₂ 11.0 (11.8), pk₃ 12.95 (for Sb³⁺ aquo). Dried over P₂O₅ or by mixing with toluene or xylene and distilling (water is carried off with the organic solvent), then distd twice under dry nitrogen at 50mm, degassed and sublimed twice in a vacuum into ampoules. Can be crystd from CS₂. Deliquescent. Fumes in moist air.

Antimony trifluoride [7783-56-4] M 178.8, m 292°. Crystd from MeOH to remove oxide and oxyfluoride, then sublimed under vacuum in an aluminium cup on to a water-cooled copper condenser [Woolf J Chem Soc 279 1955].


Antimony trioxide [1309-64-4] M 291.5, m 656°. Dissolved in minimum volume of dilute HCl, filtered, and six volumes of water were added to ppte a basic antimonous chloride (free from Fe and Sb₂O₃). The ppte was redissolved in dilute HCl, and added slowly, with stirring, to a boiling soln (containing a slight excess) of Na₂CO₃. The oxide was filtered off, washed with hot water, then boiled and filtered, the process being repeated until the filtrate gave no test for chloride ions. The product was dried in a vacuum desiccator [Schuhmann J Am Chem Soc 46 52 1924]. After on cryst(pptn?), the oxide from a Chinese source had: metal (ppm) Al (8), Ag (0.2), As (56), Cr (6), Ge (0.4), Mn (0.2), Na (16), Ni (2.2) Pb (2.4), Sn (0.4) and V (32).

Aqua regia. This is prepared by adding slowly concentrated HNO₃ (1 vol) to concentrated hydrochloric acid (3 vols) in a glass container. This mixture is used to dissolve metals, including noble metals and alloys, as well as minerals and refractory substances. It is done by suspending the material and boiling [EFFICIENT FUME CUPBOARD — EYE PROTECTION] to dryness and repeating the process until the residue dissolves in H₂O. If the aqua regia is to be stored for long periods it is advisable to dilute it with one volume of H₂O which will prevent it from releasing chlorine and other chloro and nitrous compounds which are objectionable. Store cool in a fume cupboard. However, it is good laboratory practice to prepare it freshly and dispose of it down the fume cupboard sink with copious amounts of water.

Argon [7440-37-1] M 39.95, b -185.6°. Rendered oxygen-free by passage over reduced copper at 450°, or by bubbling through alkaline pyrogallol and H₂SO₄, then dried with CaSO₄, Mg(ClO₄)₂, or Linde 5A molecular sieves. Other purification steps include passage through Ascarite (asbestos impregnated with sodium hydroxide), through finely divided uranium at about 800° and through a -78O cold trap. Alternatively the gas is passed over CuO pellets at 300° to remove hydrogen and hydrocarbons, over Ca chips at 600° to remove oxygen and, finally, over titanium chips at 700° to remove nitrogen. Also purified by freeze-pump-thaw cycles and by passage over sputtered sodium [Arnold and Smith J Chem Soc, Faraday Trans 2 77 861 1981].

-o-Arsanilic acid [2045-00-3] M 216.1, m 153°, pk₁ 3.77 (AsO₂H₂), pk₂ 8.66 (AsO₃H⁻). Crystd from water or ethanol/ether. POISONOUS.

-p-Arsanilic acid [198-50-0] M 216.1, m 232°, pk₁ 4.05 (AsO₂H₂), pk₂ 8.66 (AsO₃H⁻). Crystd from water or ethanol/ether. POISONOUS.

Arsenazo I [3(2-arsonophenylazo)-4,5-dihydroxy-2,7-naphthalenedisulfonic acid di Na salt] [66019-20-3] M 614.3, ε 2.6 x 10⁴ at 500nm, pH 8.0; pk₁ 0.6(0.8), pk₂ 3.52, pk₃ 2.97(AsO₃H₂), pk₄ 8.20(AsO₃H⁻), pk₅ 9.98(OH), pk₆ 15.0. A saturated aqueous soln of the free acid was slowly added to an equal volume of conc HCl. The orange ppte was filtered, washed with acetonitrile and dried for 1-2h at 110° [Fritz and Bradford Anal Chem 30 1021 1958].

Arsenazo III [3,6-bis(2-arsonophenylazo)-4,5-dihydroxy-2,7-naphthalenedisulfonic acid di Na salt] [62337-00-2] M 776.4, pk₁ -2.7, pk₂ -2.7, pk₃ 0.6, pk₄ 0.8, pk₅ 1.6, pk₆ 3.4,
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\[ pK_1 \ 6.27, \ pK_2 \ 9.05, \ pK_9 \ 11.98, \ pK_{10} \ 15.1. \]

Contaminants include monoazo derivatives, starting materials for synthesis and by-products. Partially purified by pptn of the dye from aqueous alkali by addition of HCl. More thorough purification by taking a 2g sample in 15-25mL of 5% aq NH\(_3\) and filter. Add 10mL HCl (1:1) to the filtrate to ppte the dye. Repeat procedure and dissolve solid dye (0.5g) in 5mL of a 1:1:1 mixture of n-propanol:conc NH\(_3\):water at 50°. After cooling, filter soh and treat the filtrate on a cellulose column using 3:1:1 mixture of n-propanol:conc NH\(_3\):water as eluent. Collect the blue band and evaporate to 10-15mL below 80°, then add 10mL conc HCl to ppte pure Arsenazo In. Wash with EtOH and air-dry [Borak et al. Talanta 17 215 1970]. The purity of the dye can be checked by paper chromatography using M HCl as eluent.

**Arsenic** [7440-38-2] M 74.9, m 816°. Heated under vacuum at 350° to sublime oxides, then sealed in a Pyrex tube under vacuum and sublimed at 600°, the arsenic condensing in the cooler parts of the tube. Stored under vacuum [Shih and Peretti J Am Chem Soc 75 608 1953]. POISONOUS.

**Arsenic acid** (arsenic pentoxide hydrate, arsenic V oxide hydrate, orthoarsenic acid) [12044-50-7] M 229.8 + xH\(_2\)O, pK\(_{1}^A\)2.26, pK\(_{2}^B\)6.76, pK\(_{3}^B\)11.29 (H\(_3\)AsO\(_4\)). Cryst from conc solns of boiling conc HNO\(_3\) as rhombic crystls. Dried in vac to give hemihydrate (hygroscopic). Heating above 300° yields As\(_2\)O\(_5\). [Thaler Z Anorg Allg Chem 246 19 1941.] POISONOUS.

**Arsenic tribromide** [7784-33-0] M 314.6, m 31.1°, b 89°/11mm, 221°/760mm. Distd under vacuum. POISONOUS.

**Arsenic trichloride** (butter of arsenic) [7784-34-1] M 181.3, b 259°/11mm, 130.0°. Refluxed with arsenic for 4h, then fractionally distd. The middle fraction was stored with sodium wire for two days, then again distd [Lewis and Sowerby J Chem Soc 336 1957]. Fumes in moist air and readily hydrolysed by H\(_2\)O. POISONOUS.

**Arsenic triiodide** [7784-45-4] M 455.6, m 146°, b 400°/atm. Crystd from acetone, sublimes below 100°. POISONOUS.

**Arsenic III oxide** (arsenic trioxide, arsenious oxide) [1327-53-3] M 197.8, three forms: m ~200°(amorphous glass), m 275°(sealed tube, octahedral, common form, sublimes > 125° without fusion but melts under pressure), m ~312°, pK\(_{1}^A\)9.27, pK\(_{2}^B\)13.54, pK\(_{3}^B\)13.89 (for H\(_3\)AsO\(_3\)). Cryst in octahedral form from H\(_2\)O or from dil HCl (1:2), washed, dried and sublimed (193°/760mm). Analytical reagent grade material is suitable for use as an analytical standard after it has been dried by heating at 105° for 1-2h or has been left in a desiccator for several hours over conc H\(_2\)SO\(_4\). POISONOUS (particulary the vapour, handle in a ventilated fume cupboard).

**Aurothioglucose** (gold thioglucose) [12192-57-3] M 392.2. Purified by dissolving in H\(_2\)O (0.05g in 1mL) and pting by adding EtOH. Yellow cryst with slight mercaptan odour. Decomposes slowly in EtOH, sol in propylene glycol but insol in EtOH and other common organic solvents. [FEBS Lett 98 351 1970.]

**Barium** (metal) [7440-39-3] M 137.3, m 727°. Cleaned by washing with diethyl ether to remove adhering paraffin, then filed in an argon-filled glove box, washed first with ethanol containing 2% conc HCl, then with dry ethanol. Dried under vacuum and stored under argon [Addison, Coldrey and Halstead J Chem Soc 3868 1962]. Has also been purified by double distn under 10mm argon pressure.

**Barium acetate** [543-80-6] M 255.4. Crystd twice from anhydrous acetic acid and dried under vacuum for 24h at 100°.

**Barium bromate** [13967-90-3] M 265.3. Crystd from hot water (20mL/g). The monohydrate melts at 260°(dec).
Barium bromide (2H₂O) [7791-28-8]  M 333.2, m at 75° loses first H₂O and at 120° loses the second H₂O. Crystd from water (1mL/g) by partial evaporation in a desiccator.

Barium chlorate (H₂O) [10294-38-9 (hydrate); 13477-00-4 (anhydr)]  M 322.3, m 414°. Crystd from water (1mL/g) between 100° and 0°.

Barium chloride (2H₂O) [10326-27-9]  M 244.3, m ~120°(dec, hydrate), 963° (anhyd). Twice crystd from water (2mL/g) and oven dried to constant weight.

Barium dithionate (2H₂O) [13845-17-5]  M 333.5, m >150° loses SO₂, pK₂^{25} 0.49 (for H₂S₂O₆, theory pK₁ -3.4, pK₂ -0.2). Crystd from water.

Barium ferrocyanide (6H₂O) [13821-06-2] ferrocyanide. Crystd from hot water (100mL/g).

Barium fluoride [7787-32-8]  M 175.3, m 1353°, 1368°, b 2260°, d 4.83. Washed well with distd H₂O and dried in vacuum. Sol in H₂O (1.6g (10°), 1.6g (20°) and 1.62g (30°) per L), mineral acids and aq NH₄Cl. May be stored in glass bottles. [Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol I 234 1963.]

Barium formate [541-43-5]  M 277.4, pK₂^{25} 3.74 (for HCₐO₂H). Crystd from warm water (4mL/g) by adding EtOH and cooling.

Barium hydroxide (8H₂O) [12230-71-6]  M 315.5, m 78°, pK₂^{15} 13.13, pK₁^{15} 13.36. Crystd from water (1mL/g).

Barium hypophosphite (H₂O) [14871-79-5]  M 285.4. Pptd from aq soln (3mL/g) by adding EtOH.

Barium iodate (H₂O) [7787-34-0]  M 487.1, m 130°(loses H₂O), 476°(dec). Crystd from a large volume of hot water by cooling.

Barium iodide (2H₂O) [7787-33-9 (2H₂O); 13718-50-8 (anhydr)]  M 427.2, m 740°(dec). Crystd from water (0.5mL/g) by partial evapn in a desiccator. POISONOUS.

Barium ionophore I [N,N,N',N'-tetracyclohexyloxy-bis-(o-phenylenedioxy)diacetamide] [96476-01-6]  M 644.9, m 156-158°. Purified by chromatography on a Kieselgel column and eluted with CH₂Cl₂-EtOAc (5:1), and recryst from EtOH-Me₂CO as colourless crystals. It is an electrically neutral ionophore with high selectivity for Ba²⁺ ions and with high lipophilicity. [Chem Ber 118 1071 1985.]

Barium manganate (barium permanganate) [7787-35-1]  M 256.3, d 3.77. Wash with conductivity H₂O by decantation until the supernatant gives a faint test for Ba²⁺. Remove excess H₂O in vac (IMPORTANT), then heat at 100° and the last traces of H₂O are removed in a vac desiccator over P₂O₅. Store over KOH. It disproportionates in hot H₂O or dil acid to Ba(MnO₂)₂ and MnO₂, and is a mild oxidant. [J Am Chem Soc 44 1965 1924; Inorg Synth 11 56 1960.]

Barium nitrate [10022-31-8]  M 261.4, m 593°(dec). Cryst twice from water (4mL/g) and dried overnight at 110°. POISONOUS.

Barium nitrite (H₂O) [7787-38-4]  M 247.4, m 217°(dec). Crystd from water (1mL/g) by cooling in an ice-salt bath. POISONOUS.

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Barium propionate (H$_2$O) [5908-77-0] M 301.5, pK$_{24}$ 4.88 (for propionic acid). Crystd from warm water (50mL/g) by adding EtOH and cooling.

Barium sulfate [7722-43-7] M 233.4, m >1580°. Washed five times by decantation with hot distilled water, dialysed against distd water for one week, then freeze-dried and oven dried at 105° for 12h.

Barium tetrathionate [82203-66-5] M 361.6. Purified by dissolution in a small volume of water and ppted with EtOH below 5O. After drying the salt was stored in the dark at 0°.

Barium thiocyanate (2 H$_2$O) [2092-17-3] M 289.6, pK$_{25}$ -1.85 (for HSCN). Crystd from water (2.5mL/g) by partial evaporation in a desiccator.

Barium thiosulfate [35112-53-9] M 249.5, m 220°(dec), pK$_{15}$ 0.6, pK$_{15}$ 1.74 (for H$_2$S$_2$O$_3$). Very slightly soluble in water. Washed repeatedly with chilled water and dried in air at 40°.

Benzaldehyde-2-sulfonic acid sodium salt [1008-72-6] M 208.2, m dec on heating. Forms prisms or plates by extracting with boiling EtOH, filtering, evaporate to dryness and recrystallise the Na salt from a small volume of H$_2$O. The N-phenylhydrazone sodium salt recrysts from H$_2$O, m 174.5°. [Gnehm and Schüle Justus Liebigs Ann Chem 299 363 1898.]


Benzeneselenenyl chloride (benzeneselenyl chloride, phenylselenyl chloride) [S 707-04-0] M 191.5, m 59-60°, 64-65°, b 92O/5mm, 120°/20mm. Purified by distn in vac and recrystn (orange needles) from hexane [Foster J Am Chem Soc 55 822 1933, Foster et al. Recl Trav Chim, Pays-Bas 53 405, 408 1934; Behaghel and Seibert Chem Ber 66 714 1933]. HIGHLY TOXIC.

Benzeneseleninic acid [6996-92-5] M 189.1, m 122-124°, pK$_{25}$ 4.70. Add 10% excess of 15M NH$_3$ to the solid acid and stir until the solid dissolves, filter, decolorise with charcoal (2x, Norite) and acidify by slow addn of 6M HCl, filter solid and wash with H$_2$O. Dissolve the acid in the minimum vol of MeOH and this soln is added dropwise to boiling H$_2$O until cloudiness appears. At this point add 25% more boiling H$_2$O, filter hot (decolorise if necessary) and cool rapidly with scratching to 0°. After 30min the solid is filtd off and recryst as before but with very slow cooling. The colorless needles are filtered off and dried in a vac desiccator (CaC$_2$) before the melting point is measured [McCullough and Gould J Am Chem Soc 71 674 1949].

Benzeneseleninic anhydride [17697-12-0] M 360.1, m 124-126°, 164-165°, 170-173°. When the anhydride is recrystd from *C$_6$H$_5$H$_4$ it has m 124-126° but when this is heated at 140/1h in a vac or at 90°/2h it had m 164-165° and gives a solid m 124-126° when recrystd from *C$_6$H$_4$. Both depress the melting point of the acid PhSeO$_2$H. If the high melting anhydride is dissolved in *C$_6$H$_4$ and seeded with the high melting anhydride, the high melting anhydride crystallises out. It readily absorbs H$_2$O to form the acid (PhSeO$_2$H, m 122-124°). Because of this the commercial anhydride could contain up to 30% of the acid. Best purified by converting to the HNO$_3$ complex (m 112°) and heating this in vacuo at 120°/72h to give the anhydride as a white powder m 164-165°. Alternatively heat the anhydride in vacuo at 120°/72 h until IR shows no OH band. [Ayvrey et al. J Chem Soc 2089 1962; Barton et al. J Chem Soc, Perkin Trans 1 567 1977] TOXIC solid.

Benzeneselenol (phenylselenol, selenophenol) [645-96-5] M 157.1, b 57-59°/8mm, 71-72°/18mm, 84-86°/25mm, d 1.480, m 1.616. Dissolve in aq N NaOH, acidify with conc HCl and extract with Et$_2$O, dry over CaCl$_2$, filter, evap on a steam bath and distil from a Claisen flask or through a short
column collecting the middle fraction and seal immediately in a glass vial, otherwise the colourless liquid becomes yellow. The alkali insol materials consist of diphenylselenide (b 167°/16mm) and diphenyldiselenide, m 63° (from EtOH). TOXIC, use rubber gloves. It has a foul odour. [Foster Org Synth Coll Vol III 771 1955.]


Benzenestibonic acid [535-46-6] M 248.9, m >250°(dec). Crystd from acetic acid, or from EtOH-CHCl₃ mixture by addition of water.

Benzenesulfonic acid Na salt [873-55-2] M 164.2, m >300°, pK₂ 2.16 (2.74; for PhSO₂H). Dissolve in the minimum vol of O₂ free H₂O (prepared by bubbling N₂ through for 2 h) and adding O₂ free EtOH (prepared as for H₂O), set aside at 4° overnight under N₂, filtd, washed with abs EtOH, then Et₂O and dried in a vac. The Na salt is relatively stable to air oxidation, but is best kept under N₂ in the dark. Also recryst from EtOH and dried at 120° for 4h in a vacuum [Kornblum and Wade J Org Chem 52 5301 1987].

Benzopurpurin 4B [3,3'-(3,3'-dimethyl[1,1'-biphenyl]-4,4'-diyl)bis(azo)]bis[4-amino-1-naphthalenesulfonic acid di-Na salt, Direct red 2) [992-59-6] M 724.7, λ max 500nm, CI 23500, pK<0. Crystd from H₂O. It is a biological stain that is violet at pH 1.2 and red at pH 4.0 and is used for detecting Al, Mg, Hg, Au and U.

Benzotriazol-1-yloxytris(dimethylamino)phosphonium hexafluorophosphate (BOP reagent) [12257-42-0] M 442.29, m >130° (dec), 147-149° (dec). Dissolve in CH₂Cl₂, dry (MgSO₄), filter, conc under vac then add dry Et₂O and filter off first crop. Add CH₂Cl₂ to the filtrate and concentrate again to give a second crop. Solid is washed with dry Et₂O and dried in vac. Also recryst from dry Me₂CO/Et₂O and check purity by NMR. Store in the dark. [Castro et al. Synthesis 751 1976.]

Benzylidene-bis-(tricyclohexylphosphine) dichlororuthenium (Grubbs catalyst) [172222-30-9] M 823.0. Repeatedly wash with Me₂CO and MeOH and dry in vac. Alternatively dissolve in CH₂Cl₂, dry concentrated to half vol, filter, add MeOH to ppte it as purple microcrystals. Filter off, wash several times with Me₂CO and MeOH and dry in a vac for several hours. [Scwab, Grubbs and Ziller J Am Chem Soc 118 100 1996; Miller, Blackwell and Grubbs J Am Chem Soc 118 9606 1996.]

Bicyclo[2.2.1]hepta-2,5-diene rhodium (I) chloride dimer (norbornadiene rhodium chloride complex dimer) [12257-42-0] M 462, m 240°(dec). Recryst from hot CHCl₃-pet ether as fine crystals soluble in CHCl₃ and C₆H₆ but almost insoluble in Et₂O or pet ether. [J Chem Soc 3178 1959.]
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*S-(+)-1,1′-Binaphthyl-2,2′-diylhydrogen phosphate* [35193-64-7] M 348.3, [α]D+608° (c 1, MeOH), pH 0.74. Recrystallise from EtOH. Reflux for 3h in N NaOH is required to hydrolyse the cyclic phosphate. [Tetrahedron Lett 4617 1971; Tetrahedron Lett 24, 343 1983.]


2,2′-Bipyridinium chlorochromate [76899-34-8] M 292.6. Washed with cold conc HCl then H2O (sintered glass funnel) and dried in vacuum (CaCl2). Stored in the dark. [Synthesis 691 1980; Synth Commun 10 951 1980. SUSPECTED CARCINOGEN.]


Bis-(p-tert-butylphenyl)phenyl phosphate [I 15-87-7] M 438.5, b 281°/5mm, n25 1.5412. Same as for 2-biphenylyl diphenyl phosphate (above).

Bis-(2-chlorophenyl) phenyl phosphate [597-80-8] M 395, b 254°/4mm, n25 1.5767. Same as for bis-phenylphenyl diphenyl phosphate above.

Bis-(1,5-cyclooctadiene)nickel (0) [1295-35-8] M 275.0, m 142° (dec). Available in sealed ampoules under N2. All procedures should be carried out in a dry box and in an atmosphere of N2 or Argon in subdued light because the complex is light and oxygen sensitive and flammable. The solid is washed with dry Et2O (under Ar) and separates from toluene as yellow crystals. Filter under Ar gas pressure, place the crystals in a container and dry under a vac of 0.01 mm to remove adhered toluene, flush with Ar and seal under Ar or N2 in glass ampoules. [Semmelhack Org Reactions 19 115 and 178 1972; Wilke et al. Justus Liebig’s Ann Chem 699 1 1966.] SUSPECTED CARCINOGEN.

Bis(2,9-dimethyl-1,10-phenanthroline) copper(1) perchlorate [54816-44-5] M 579.6, pH 25 -2.4 to -3.1 (for HClO4). Cryst from acetone.

2,2′-Bis-(diphenylphosphinopheno)-1,1′-binaphthyl (BINAP) [RS 98327-87-8] M 622.7, m 283-286°, [R-(+)-76189-55-4] m 241-242°, [S-(−)-76189-56-5] m 241-242°, [α]D+20° (+) and (−) 233° (c 0.3 toluene). Dissolve the individual enantiomers in toluene, wash with 30% aq NaOH, three times with H2O, dry (Na2SO4), evap to ~15% of its vol and add an equal vol of degassed MeOH. Collect the solid, wash with MeOH and dry at 80°/0.005mm for 6h. Recryst from 1:1 mixt of toluene-EtOH to optical purity (m 241-242°).[Takaya et al. Org Synth 67 20 1989]. § A polymer supported version is available.


2R,3R-(−)-2,3-Bis(diphenylphosphino)butane (R,R-CHIRAPHOS) [74839-84-2], 25,3S-(−)-2,3-bis(di-phenylphosphino)butane (S,S-CHIRAPHOS) [64896-28-2] M 426.5, m 108-109°, [α]D+20° and (−) 200° (c 1.5 CHCl3). Recryst from abs EtOH (~6g in 60mL) as colorless plates [Fryzuk and Bosnich J Am Chem Soc 99 6262 1977 and 101 3043 1979].
1,2-Bis-(diphenylphosphino)ethane (DIPHOS) \[1663-45-2\] M 398.4, m 139-140°, 140-142°, 143-144°, pK\text{est} -4.5. Recrystd from aq EtOH or \(*\text{C}_6\text{H}_6\). The dimethiodide recrystd from MeOH has m 305-307° and the dioxide recrystd from toluene or DMF (needles), or \(*\text{C}_6\text{H}_6\) (plates) has m 252-254° (276-278°) [Isslieb et al. Chem Ber 92 3175 1959; NMR: Aquiar et al. J Org Chem 29 1660 1964; Bäckvall et al. J Org Chem 52 5430 1987].

1,1’-Bis-(diphenylphosphino)ferrocene \[12150-46-8\] M 554.4, m 181-183°, 184-194°. Wash with distilled H\(_2\)O and dry in a vacuum. Dissolve in ca 5 parts of hot dioxane and cool to give orange crystals m 181-183°. Recrystn from \(*\text{C}_6\text{H}_6\)-heptane (1:2) gives product with m 183-184°. [J Organomet Chem 27 241 1971.]

Bis-(2-ethylhexyl) 2-ethylhexyl phosphonate \[25103-23-5\] M 434.6, n\(^{25} \) 1.4473. Purified by stirring an 0.4M soln in \(*\text{benzene}\) with an equal volume of 6M HCl at ca 60° for 8h. The \(*\text{benzene}\) layer was then shaken successively with equal volumes of water (twice), aqueous 5% Na\(_2\text{CO}_3\) (three times), and water (eight times), followed by evaporation of the \(*\text{benzene}\) and distilled under reduced pressure at room temperature (using a rotating evacuated flask). Stored in dry, dark conditions [Peppard et al. J Znorg Nucl Chem 24 1387 1962]. Vacuum distilled, then percolated through an alumina column before finally passed through a packed column maintained at 150° where residual traces of volatile materials were removed by a counter-current stream of N\(_2\) at reduced pressure [Dobry and Keller J Phys Chem 61 1448 1957].

Bis-(2-ethylhexyl) phosphoric acid \[298-07-7\] M 322.4. See di-(2-ethylhexyl) phosphoric acid on p. 418.

Bis(ethyl)titanium(IV) chloride \[2247-00-9\] M 177.0. Crystd from boiling toluene.

Bis(ethyl)zirconium(IV) chloride \[92212-70-9\] M 220.3. Crystd from boiling toluene.

2,4-Bis-(methylthio)-1,3,2\(h^5\),4\(h^5\)-dithiadiphosphetane-2,4-dithione (Davy’s reagent) \[82737-61-9\] M 284.4, m 160°. Recrystd from \(*\text{C}_6\text{H}_6\) in yellow plates or from hot trichlorobenzene. The low m observed in the literature (1 12O with gradual softening at 68-102°) has been attributed to the presence of elemental sulfur in the crystals. [Tetrahedron 40 2663 1984; J Org Chem 22 789 1957.]


Bismuthiol I (2,5-dimercapto-1,3,4-thiadiazole) potassium salt \[4628-94-8\] M 226.4, m 275-276°(dec), pK\text{est}(1)-4.1. Usually contaminated with disulfide. Purified by crystn from EtOH. Reagent for detection of Bi,Cu, Pb and Sb.

Bismuth trichloride \[7787-60-2\] M 315.3, m 233.6°, pK\text{25} 1.58 (Bi\(^{3+} = \text{BiOH}_2^{+} + \text{H}^+\)). Sublimed under high vacuum, or dried under a current of HCl gas, followed by fractional distn, once under HCl and once under argon.

\(N,N'\)-Bis-(salicylidene)ethylenediamine cobalt (II) \[Co(SALEN)\text{2}, \text{salcomine}\] \[14167-18-1\] M 325.2. The powder should have an oxygen capacity of 4.7-4.8% as measured by the increase in wt under O\(_2\) at 100 pounds pressure at ca 20°. The O\(_2\) is expelled on heating the material to 65°. Recryst from pyridine, CHCl\(_3\) or \(*\text{C}_6\text{H}_6\) and the solvent may be removed by heating at 120° in a vac. However this heating may mean reduced O\(_2\) capacity. In the dry state it absorbs O\(_2\) turning from maroon colour to black. [Diehl and Hack Inorg Synth 3 196 1950.]

Bis-(tetrabutylammonium) dichromate \[56660-19-6\] M 700.9, m 139-142°. Wash with water and dry in a vacuum. Crystallizes from hexane (m 79-80°). [Synth Commun 10 75 1980.] (Possible CARCINOGEN).
Bis-[4-(1,1,3,3-tetramethylbutyl)phenyl]phosphate calcium salt (Selectophore) [40835-97-0] M 987.3. The Ca diester salt is washed with H2O (x3) and MeOH (x3) alternately and dried in a vacuum oven at 50°C. If the Ca salt is contaminated with much Ca salt of the monoester then it (10g) is converted to the free acid by adding 6N HCl (ca 10vols) and Et2O (> 50vols) to it and stirred vigorously to form the free acids. When no white ppt remained, the Et2O is separated, washed with H2O (2 x > 50 mL) and dried by filtering through a bed of anhydrous Na2SO4 (11 x 5 cm) which is then washed with Et2O (2 x >50 mL). Evap gives an oil (TLC Rf 0.81 for diester and 0.50 for monoester). The oil is dissolved in benzene and dry in vac at 50°C. If the Ca salt is contaminated with much Ca salt of the monoester then it (log) is converted to the free acid by adding 6N HCl to it and stirred vigorously to form the free acids. When no white ppt remained, the Et2O is separated, washed with H2O (2 x > 50 mL) and dried by filtering through a bed of anhydrous Na2SO4 (11 x 5 cm) which is then washed with Et2O (2 x >50 mL). Evap gives an oil (TLC Rf 0.81 for diester and 0.50 for monoester). The oil is dissolved in benzene (ca 25 mL) and extracted with ethane-1,2-diol (25 mL, 10x). After ten washings, a small sample of the benzene layer is washed twice with H2O to remove the diol and showed that it is pure bis-[4-(1,1,3,3-tetramethylbutyl)]-phenylphosphoric acid by TLC, i.e. no monophosphate. To form the Ca salt the oil is dissolved in MeOH and to it is added the equivalent amount of CaCl2 together with aq NaOH to keep the pH >10. The resulting white ppt is collected washed alternately with 3 batches of H2O and MeOH and dried in a vacuum oven at 50°C. [J Inorg Nucl Chem 40 1483 1978.]

2,4-Bis-(p-tolylthio)-1,3,2,5,4,5-dithiadiphosphetane-2,4-dithione (Heimgartner’s reagent) [114234-09-2] M 436.6, m 175-176°. Recrystallise from toluene (light yellow solid), wash with Et2O and dry in vac. [Helm Chim Acta 70 1001 1987.]

N,O-Bis-(trimethylsilyl)acetamide (BSA) [10416-59-8] M 203.4, b 71-73°/35mm, d 0.836, 1.4150. Fractionate through a spinning band column and collect liquid b 71-73°/35mm, and not higher because the main impurity MeCONHSiMe3 distills at 61.8 260, b 134-136°/atm. Dissolve in pet ether, wash with ice-cold dilute HCI. The pet ether extract is dried (MgSO4), evaporated and fractionated at atmospheric pressure. [J Organomet Chem 37 45 1972.]

Bis-(trimethylsilyl)acetylene [14630-40-1] M 170.4, m 26°, b 134-136°/atm. Dissolve in pet ether, wash with ice-cold dilute HCl. The pet ether extract is dried (MgSO4), evaporated and fractionated at atmospheric pressure. [J Organomet Chem 37 45 1972.]

Bis-(trimethylsilyl)sulfide (hexamethyldisilathiane) [3385-94-2] M 178.5, b 65-67°/16mm, 162.5-163.5°/750mm corr, 164°/760mm, d 0.85, n 1.4598. Dissolve in pet ether (b ca 40°), remove solvent and distilled. Redistilled under atmospheric pressure of dry N2. It is colourless liquid which solidifies to a white solid in Dry-ice. Store below 4°C under dry N2.


Boric acid (boracic acid) [10043-35-3] M 61.8, m 171°, pK29 9.23. Cryst beds three times from H2O (3ml/kg) between 100° and 0°, after filtering through sintered glass. Dried to constant weight. [J Chem Soc 719 1958.]

9-Borabicyclo[3.3.1]nonane (9BBN) [monomer 280-64-8] [dimer 21205-91-4 or 70658-61-6] [1:1 coordination compound with tetrahydrofuran 76422-63-4] M 122.0 (monomer), 244.0 (dimer), M 141-143° (monomer), 150-152°, 154-155° (dimer), b 195°/12mm. Available as the solid dimer or in tetrahydrofuran soln. The solid is relatively stable and can be purified by distn in a vacuum (as dimer) and by recrystn from tetrahydrofuran (solubility at room temp is 9.5%, 0.78M), filter solid under N2 wash with dry pentane and dry in vacuo. The solid dimer or in tetrahydrofuran soln also (IR 1567 cm-1). It is sensitive to hydride activity. It is a dimer in tetrahydrofuran soln also (IR 1567 cm-1). It is sensitive to H2O and air (O2) in soln. Concentration in soln can be determined by reaction with MeOH and measuring the vol of H2 liberated, or it can be oxidised to cis-cyclooctane-1,5-diol (m 73.5-74.5°). [IR: J Am Chem Soc 90 5280 1968, 96 7765 1974; J Org Chem 41 1778 1976, 46 3978 1981.]

Borane pyridine complex [110-51-0] M 92.9, m 8-10°, 10-11°, b 86°/7mm, 100-101°/12mm, d20° 0.785. Dissolve in Et2O and wash with H2O in which it is insol. Evap Et2O and distil
(gives better than 99.8% purity). Its vap pressure is less than 0.1mm at room temp. [J Am Chem Soc 77 1506 1955.]

**Borane triethylamine complex** [1722-26-5] M 115.0, b 76°/4mm, 97.0°/12mm, d² 0.78. Distil in a vacuum using a 60cm glass helices packed column. [J Am Chem Soc 64 325 1942, 84 3407 1962; Tetrahedron Lett 4703 1968.]

**Borane trimethylamine complex** [1722-26-5] M 115.0, b 76°/4mm, 97.0°/12mm, d² 0.78. Distil in a vacuum using equipment described in [J Am Chem Soc 59 780 1937]. Its vapour pressure is 86mm at 100°. Colourless hexagonal crystals varying from needles to short lumps, slightly soluble in H₂O (1.48% at 30°), EtOH (1%), hexane (0.74%) but very soluble in Et₂O, C₆H₁₂ and AcOH. Stable at 125°. [J Am Chem Soc 59 780 1939, 104 325 1942.]

**Boron trichloride** (trichloroborane) [10294-34-5] M 117.2, b 0°/476mm. Purified (from chlorine) by passage through two mercury-filled bubblers, then fractionally distd under vacuum. In a more extensive purification the nitrobenzene addition compound is formed by passage of the gas over nitrobenzene in a vacuum system at 10°. Volatile impurities are removed by warming the addition compound at 50°. Passage through a trap at -78° removes entrained nitrobenzene; the BCl₃ finally condensing in a trap at -112° [Brown and Holmes J Am Chem Soc 78 2173 1956]. Also purified by condensing into a trap cooled in acetone/Dry-ice, where it was pumped for 15min to remove volatile impurities. It was then warmed, recondensed and again pumped.

**Boron trifluoride** [7637-07-2] M 67.8, b -101°/760mm. The usual impurities - bromine, BF₃, HF and non-volatile fluorides - are readily separated by distn. Brown and Johannesen [J Am Chem Soc 72 2934 1950] passed BF₃ into benzonitrile at 0° until the latter was satd. Evacuation to 10⁻⁵mm then removed all traces of SiF₄ and other gaseous impurities. [A small amount of the BF₃-benzonitrile addition compound sublimed and was collected in a U-tube cooled to -80°]. Pressure was raised to 20mm by admitting dry air, and the flask containing the BF₃ addition compound was warmed with hot water. The BF₃ evolved was passed through a -80° trap (to condense any benzonitrile) into a tube cooled in liquid air. The addition compound with anisole can also be used. For drying, BF₃ can be passed through H₂SO₄ saturated with boric oxide. Fumes in moist air. [Commercially available as a 1.3M soln in MeOH or PrOH.]

**Boron trifluoride diethyl etherate** [109-63-7] M 141.9, b 67°/43mm, b 126°/760mm, d 1.154, n 1.340. Treated with a small quantity of diethyl ether (to remove an excess of this component), and then distd under reduced pressure, from CaH₂. Fumes in moist air. TOXIC.

**Bromine** [7726-95-6] M 159.8, b 59°, d 3.102, n 1.661. Refluxed with solid KBr and distd, dried by shaking with an equal volume of conc H₂SO₄, then distd. The H₂SO₄ treatment can be replaced by direct distn from BaO or P₂O₅. A more extensive purification [Hildenbrand et al. J Am Chem Soc 80 4129 1958] is to reflux about 1L of bromine for 1h with a mixture of 16g of CrO₃ in 200mL of conc H₂SO₄ (to remove organic material). The bromine is distilled into a clean, dry, glass-stoppered bottle, and chlorine is removed by dissolving ca 25g of freshly fused CsBr in 500mL of the bromine and standing overnight. To remove HBr and water, the bromine was then distd back and forth through a train containing alternate tubes of MgO and P₂O₅. HIGHLY TOXIC.

**Bromine pentfluoride** [7789-30-2] M 174.9, m -60.5°, b 41.3°, d 2.466. Purified via its KF complex, as described for chlorine trifluoride. HIGHLY TOXIC.


2-Bromo-1,3,2-benzodioxaborole [51901-85-0] M 198.8, m 47°, 51-53°, b 76°/9mm. Keep at 20°/15mm for some time and then fractionally distil. [J Chem Soc 1529 1959.]
IR(endo,anti)-3-Bromocamphor-8-sulfonic acid ammonium salt [55870-50-3] M 328.2, m 284-285°(dec), [α]$_D^2$+84.8° (c 4, H$_2$O). Passage of a hot aqueous soln through an alumina column removed water-soluble coloured impurities which remained on the column when the ammonium salt was eluted with hot water. The salt was crystd from water and dried over CaCl$_2$ [Craddock and Jones J Am Chem Soc 84 1098 1962; Kauffmann J Prakt Chem 33 295 1966].


Bromosulfalein (phenol tetra bromophthalein 3',3'-disulfonic acid disodium salt) [71-67-0] M 838.0. Purified by TLC on silica Gel G (Merck 250μ particle size) in two solvent systems (BuOH-AcOH-H$_2$O 30:7.5:12.5 v/v; and BuOH-propionic acid-H$_2$O 30:20:7.5 v/v). When the solvent reached a height of 10cm the plate was removed, dried in air and developed with NH$_3$ vapour giving blue coloured spots. Also the dye was chromatographed on MN Silica Gel with f-BuOH-H$_2$O-n-BuOH (32:10:5 v/v and visualised with a dilute KOH (or NaOH if the Na salt is required) spray. The product corresponding to bromosulfalein was scraped off and eluted with H$_2$O, filtered and evap to dryness in a vacuum. It was dissolved in H$_2$O and filtered through Sephadex G-25 and evaporated to dryness. [UV and IR identification: J Pharm Sci 57 819 1968; NMR: Chem Pharm Bull Jpn 20 581 1972; Anal Biochem 83 75 1977.]

Bromtrimethylsilane (trimethylbromosilane, trimethylsilyl bromide) [2857-97-8] M 153.1, m -43.5° to -43.2°; b 900/0.015mm, d 1.057, n 1.568. Purified by repeated fractional distillation and stored in sealed ampoules in the dark. [J Am Chem Soc 75 1583 1953.]

n-Butylmercuric chloride [543-63-5] M 293.1, m 130°. Crystd from EtOH.

n-Butylphenyl n-butylphosphonate [36411-99-1] M 270.3. Crystd three times from hexane as its compound with uranyl nitrate. See tri-n-butyl phosphate below.

p-tert-Butylphenyl diphenyl phosphate [981-40-8] M 382.4, b 261°/66mm, n$^2$ 1.5522. Purified by vacuum distrn, and percolation through an alumina column, followed by passage through a packed column maintained at 150° to remove residual traces of volatile materials in a counter-current stream of N$_2$ at reduced pressure [Dobry and Keller J Phys Chem 61 1448 1957].


Cacodylic acid (dimethylarsinic acid) [75-60-5] M 138.0, m 195-196°, pK$^{25}$ 6.15 [Me$_2$As(O)OH]. Crystd from warm EtOH (3mL/g) by cooling and filtering. Dried in vacuum desiccator over CaCl$_2$. Has also been twice recrystd from propan-2-ol. [Koller and Hawkridge J Am Chem Soc 107 7412 1985.]
Purification of Inorganic and Metal-Organic Chemicals

Cadion [1-(4-nitropheno|yl)-3-(4-phenylazophenyl)-triazene] (5392-67-6) M 346, m 198°. Commercial cadion is purified by recrystn from 95% EtOH and dried. It is stable in 0.2 N KOH (in 20% aqueous EtOH) at 25°. It is a sensitive reagent for Cd, and the Cd complex has λmax (EtOH) 475 nm. [Aust Chem Inst J Proc 4 26 1937; Anal Chim Acta 19 377 1958.]

Cadmium (7440-43-9) M 112.4, m 321.1°, b 767°. Oxide has been removed by filtering the molten metal, under vacuum through quartz wool.

Cadmium acetate (2H2O) (5743-04-4) M 230.5, m 255° (anhyd), d 2.01 (hydr), 2.34 (anhyd), pK2 = 9.7, pK2 = 11.0 (for Cd2+). Crystd twice from anhydrous acetic acid and dried under vacuum for 24 h at 100°.

Cadmium bromide (4H2O) (13464-92-1 (4H2O); 7789-42-6 (anhyd)) M 344.2, m 566°, b 963, d 5.19°. Crystd from water (0.6 mL/g) between 100° and 0°, and dried at 110°. Forms monohydrate below 36° and the 4H2O above 36°.

Cadmium chloride (10108-64-2) M 183.3, m 568°, b 960°, d 4.06. Crystd from water (1 mL/g) by addition of EtOH and cooling.

Cadmium fluoride (17790-79-6) M 328.6. Crystd from ethanol (2 mL/g) by partial evaporation.

Cadmium ionophore I [N,N,N',N'-tetramethyl-3,6-dioxooctanedi-(thioamide)] (73487-00-0) M 432.7, m 35-36°. Wash well with pet ether, then several times with 2N HCl (if it has a slight odour of pyridine) then H2O and dry in a vacuum over H2SO4. It is a polar selectrophore for Cd. [Helv Chim Acta 63 217 1980.]

Cadmium lactate (16039-55-7) M 290.6. Crystd from water (10 mL/g) by partial evapn in a desiccator.

Cadmium nitrate (4H2O) (10022-68-1) M 308.5, m 59.5°. Crystd from water (0.5 mL/g) by cooling in ice-salt.

Cadmium potassium iodide (13601-63-3) M 532.2. Crystd from ethanol by partial evapn.


Cadmium sulfate (7790-84-3 (for 3CdSO4 8H2O); 10124-36-4 (anhyd)) M 208.4 (anhyd), 769.5 (hydrate). Crystd from distd water by partial evapn in a desiccator. On heating gives monohydrate at 80°.

Calcein sodium salt [2',7'-bis-{N,N-di(carboxymethyl)aminomethyl}fluorescein Na salt, Fluorexon, Fluorescein Complexon] (1461-15-0) M 666.5, pKfst (1) = 1.9, pKfst (2) = 2.5, pKfst (3) = 8.0, pKfst (4) = 10.5 (all for N-CH2COOH), and pKfet (5) = 3.5 (for benzoic COOH). Dissolve in distilled H2O and acidify with dilute HCl to pH 3.5. Filter off the solid acid and wash well with H2O. Redissolve ca 10 g in 300 mL H2O containing 12 g of NaOAc. Ppt again by adding HCl, filter and wash with H2O. Add the solid to 200 mL of EtOH stir for 1 h and filter. Repeat the EtOH wash and dry the bright yellow solid in a vacuum. This acid decomposes on heating at ca 180°. See below for the prepн of the Na salt. [Anal Chem 28 882 1956.]

Dissolve in H2O and acidify with 3N HCl to pH 3.5. Collect the solid and wash with H2O. The air-dried ppt is extracted with 70% aqueous EtOH, filtered hot and cooled slowly. Fine yellow needles of the acid crystallise out, are filtered and dissolved in the minimum quantity of 0.01 N NaOH and reppt in N HCl to pH 3.5. It is then recrystd from 70% aqueous EtOH (3x). The final product (acid) is dried at 80° in a vacuum for 24 h, m >300° (dec). It contains one mol of water per mol of acid (C30H36N4O13H2O). The product is pure as revealed
by electrophoresis at pH 5.6 and 8.6, and by TLC in i-BuOH-i-PrOH-AcOH-H2O (60:60:5:5 by vol) or i-PrOH or pH 8.0 borate buffer. [Wallach et al. Anal Chem 31 456 1959.]

The Na salt is prepared by dissolving the acid reagent in H2O containing 2 mols of NaOH per mol of acid reagent and lyophilising. It complexes with Ca and Mg ions.

**Calcium** [7440-70-2] M 40.1, m 845°. Cleaned by washing with ether to remove adhering paraffin, filed in an argon-filled glove box, and washed with ethanol containing 2% of conc HCl. Then washed with dry ethanol, dried in a vac and stored under pure argon [Addison, Coldrey and Halstead, J Chem Soc 3868 1962].

**Calcium acetate monohydrate** [5743-26-0 (H2O), 62-54-4 (xH2O)] M 176.2 (H2O), m 150° (loses H2O), pK25 12.7 (for Ca2+). Crystd from water (3mL/g) by partial evapn in a desiccator.

**Calcium benzoate (3H2O)** [2090-05-3] M 336.4. Crystd from water (10mL/g) between 90° and 0°.

**Calcium bromide (H2O)** [62648-72-0; 71626-99-8 (xH2O); 7789-41-5 (anhydr)] M 217.9, d 3.35. Crystd from EtOH or Me2CO. It loses H2O on heating and is anhydrous at 75° then it loses Br. Deliquescent.

**Calcium butyrate** [5743-36-2] M 248.2. Crystd from water (5mL/g) by partial evapn in a desiccator.


**Calcium chloride (anhydrous)** [10043-52-4] M 111.0, m 772°, b >1600°, d15 2.15. Available as fused granules or cubic crystals. It is very hygroscopic. Very soluble in H2O (exothermic), and EtOH. Store in a tightly closed container.

**Calcium chloride (2H2O)** [10035-04-8] M 147.0, m 175°(dehydr), 772°(dec). Crystd from ethanol, and is hygroscopic. Loses H2O at 200° so it can be dried at high temperatures to dehydrate. Hexahydrate [7774-34-7] has m 30° and d 1.67.

**Calcium dithionite** [13812-88-9] M 168.2, m dec on heating. Crystd from water, or water followed by acetone and dried in air at room temperature.

**Calcium d-gluconate monohydrate** [299-28-5] M 448.4, m dec on heating, [α]D 20° +11.0°, [α]D 25° +9.0° (c 1.2, H2O). It is sol in H2O (3.5g in 100g at 25°). Dissolve in H2O, filter and ppte by adding MeOH. Filter off solid and dry in a vacuum at 85°. Alternatively, dissolve in H2O, filter (from insol inorganic Ca) and evaporate to dryness under vacuum at 85°. [J Am Pharm Assoc 41 366 1952.]


**Calcium formate** [544-17-2] M 130.1, m dec on heating, d 2.01. Crystd from water (5mL/g) by partial evaporation in a desiccator.

**Calcium hexacyanoferrate (II) (11H2O)** [13821-08-4] M 490.3. Recrystd three times from conductivity H2O and air dried to constant weight over partially dehydrated salt. [Trans Faraday Soc 45 855 1949.] Alternatively the Ca salt can be purified by pptn with absolute EtOH in the cold (to avoid oxidation) from an air-free saturated aqueous soln. The pure lemon yellow crystals are centrifuged, dried in a vacuum desiccator first over dry charcoal for 24h, then over partly dehydrated salt and stored in a dark glass stoppered bottle. No deterioration occurred after 18 months. No trace of Na, K or NH4 ions could be detected in the salt from the residue after decomposition of the salt with conc H2SO4. Analyses indicate 11mols of H2O per mol of salt. The solubility in H2O is 36.45g (24.9°) and 64.7g (44.7°) per 100g of solution. [J Chem Soc 50 1926.]

**Calcium hydroxide** [1305-62-0] M 74.1, m loses H2O on heating, pK25 12.7 (for Ca2+). Heat analytical grade calcium carbonate at 1000° during 1h. Allow the resulting oxide to cool and add slowly to
water. Heat the suspension to boiling, cool and filter through a sintered glass funnel of medium porosity (to remove soluble alkaline impurities). Dry the solid at 110° and crush to a uniformly fine powder.

**Calcium iodate** [7789-80-2 (H₂O)] M 389.9, m >540°, pK₂ 0.79 (for HIO₃). Crystd from water (100mL/g).

**Calcium iodide** (xH₂O) [7162-98-7 (xH₂O); 10102-68-8 (anhyd)] M 293.9 (for 4H₂O), m 740°, b 1100°. Dissolved in acetone, which was then diluted and evaporated. This drying process was repeated twice, then the Ca₂⁺ was crystd from acetone-diethyl ether and stored over P₂O₅. Very hygroscopic when anhydrous and is light sensitive [Cremlyn et al. *J Chem Soc* 528 1958]. *Hexahydrate* has m 42°.

**Calcium ionophore I** (ETH 1001) [58801-34-6] M 685.0. This is a neutral Ca selectophore. It can be purified by thick layer (2mm) chromatography (Kieselgel F₂45) and eluted with Me₂CO-CHCl₃ (2:1). [Helv Chim Acta 56 1780 1973.]

**Calcium ionophore II** (ETH 129) [74267-27-9] M 460.7, m 153-154°. Recrystd from Me₂CO. It forms 1:2 and 1:3 metal/ligand complexes with Mg²⁺ and Ca²⁺ ions respectively, and induces selectivity in membranes for Ca²⁺ over Mg²⁺ by a factor of ca 10⁴. [Helv Chim Acta 63 191 1980.]

**Calcium ionophore III** [A23187 calcimycin] [52665-69-7] M 523.6, m 181-182°, [α]D² -56.0° (c 1, CHCl₃). Recrystallises from Me₂CO as colourless needles. Protect from light and moisture, store in a refrigerator. Soluble in Me₂SO or EtOH and can be stored for 3 months without loss of activity. Mg and Ca salts are soluble in organic solvents and cross biological membranes. It has a pKa of 6.9 in 90% Me₂SO. The Ca complex cryst from 50% EtOH as colourless prisms. Highly TOXIC [Ann Rev Biochem 45 501 1976; J Am Chem Soc 96 1932 1974, J Antibiotics 29 424 1976.]

**Calcium isobutyrate** [533-90-4] M 248.2. Crystd from water (3mL/g) by partial evapn in a desiccator.

**Calcium lactate** (5H₂O) [814-80-2] M 308.3, m anhyd at 120°. Crystd from warm water (10mL/g) by cooling to 0°.

**Calcium nitrate** (4H₂O) [13477-34-4] M 236.1, m 45°(dehydr), 560°(anhyd). Crystd four times from water (0.4mL/g) by cooling in a CaCl₂-ice freezing mixture. The tetrahydrate was dried over cone H₂SO₄ and stored over P₂O₅, to give the anhydrous salt. It is deliquescent. After 3 recrystns of ACS grade it had Co, Fe, Mg, Sr and Zn at 0.2, 1.0, 0.02, 10 and 0.02 ppm resp.

**Calcium nitrite** (2H₂O) [13780-06-8 (30%w/w aq soln)] M 150.1(hyd), m dec on heating, d 2.22. Crystd from hot water (1.4mL/L by adding ethanol and cooling to give the hydrate. It is deliquescent.

**Calcium propionate** (2H₂O) [4075-81-4] M 150.1(hyd), m dec on heating, d 2.22. Crystd from water (3mL/g) by partial evapn in a desiccator. It is deliquescent.

**Calcium salicylate** (2H₂O) [824-35-1] M 350.4. Crystd from water (3mL/g) between 90° and 0°.

**Calcium sulfate dihydrate** [10101-41-4] M 172.1, m 150(dec), d 2.32. Loses only part of its H₂O at 100-150° (see below). Soluble in H₂O and very slowly soluble in glycerol. Insoluble in most organic solvents.
Calcium sulfate hemihydrate \([10034-76-1]\) M 145.2. Sol in H_2O (0.2 parts/100 at 18.75\(^\circ\)). Completely dehydrated >650\(^\circ\). Dry below 300\(^\circ\) to give a solid with estimated pore size ca 38% of vol. Anhydrous CaSO_4 has high affinity for H_2O and will absorb 6.6% of its weight of H_2O to form the hemihydrate (gypsum). It sets to a hard mass with H_2O, hence should be kept in a tightly sealed container.

Calcium thiosulfate \([10124-41-1]\) M 152.2, m 43-49\(^\circ\), pK_1 0.6, pK_2 1.74 (for H_2S_2O_3). Recrystd from water below 60\(^\circ\) in a N_2 atmosphere, followed by drying with EtOH and Et_2O. Stored in a refrigerator. [Pethybridge and Taba J Chem Soc, Faraday Trans 1 78 1331 1982.]

\((4\text{-Carbamylphenylarsylenedithio})\text{diacetic acid} \quad \{531-72-6\} \quad \text{M 345.1, pK}_{\text{EtOH}} -3.5. \quad \text{Crystd from MeOH or EtOH.}\]

Carbonate ionophore I \([\text{ETH 6010}]\) (heptyl 4-trifluoroacetylbenzoate) \([129476-47-7]\) M 316.3, b 170/0.02 Torr, d 0.909. Purified by flash chromatography (2g of reagent with 30g of Silica Gel 60) and eluted with EtOAc/hexane (1:19). The fractions that absorbed at 260nm were pooled, evapd and dried at room temp (10.3 Torr). The oily residue was distd in a bubbled-tube apparatus (170\(^\circ\)/0.02 Torr). Its IR (CHC_1_3) had peaks at 1720, 1280, 940cm\(^{-1}\) and its sol in tetrahydrofuran is 50mg/0.5mL. It is a lipophilic neutral ionophore selective for carbonate as well as being an optical humidity sensor. [Anal Chim Acta 233 41 1990.]

Carbon dioxide \([124-38-9]\) M 44.0, sublimes at -78.5\(^\circ\), pK_1 6.35, pK_2 10.33 (for H_2CO_3). Passed over CuO wire at 800\(^\circ\) to oxidise CO and other reducing impurities (such as H_2), then over copper dispersed on Kieselguhr at 180\(^\circ\) to remove oxygen. Drying at -78\(^\circ\) removed water vapour. Final purification was by vacuum distn at liquid nitrogen temperature to remove non-condensable gases [Anderson, Best and Dominey J Chem Soc 3498 1962]. Sulfur dioxide can be removed at 450\(^\circ\) using silver wool combined with a plug of platinised quartz wool. Halogens are removed by using Mg, Zn or Cu, heated to 450\(^\circ\).

Carbon disulfide, see entry on p. 156 in Chapter 4.

Carbon monoxide \([630-08-0]\) M 28.0, b -191.5\(^\circ\). Iron carbonyl is a likely impurity in CO stored under pressure in steel tanks. It can be decomposed by passage of the gas through a hot porcelain tube at 350-400\(^\circ\). Passage through alkaline pyrogallol soln removes oxygen (and CO_2). Removal of CO_2 and water are effected by passage through soda-lime followed by Mg(ClO_4)_2. Carbon monoxide can be condensed and distd at -195\(^\circ\). HIGHLY POISONOUS gas.

Carbonyl bromide \([593-95-3]\) M 187.8, b 64.5/760mm. Purified by distn from Hg and from powdered Sb to remove free bromine, then vacuum distd to remove volatile SO_2 (the major impurity) [Carpenter et al. J Chem Soc, Faraday Trans 2 384 1977]. TOXIC

Carbonyl sulfide \([463-58-1]\) M 60.1, m -138\(^\circ\), b -47.5\(^\circ\), -50\(^\circ\). Purified by scrubbing through three consecutive fritted washing flasks containing conc NaOH at 0\(^\circ\) (to remove HCN), and then through conc H_2SO_4 (to remove CS_2) followed by a mixture of NaN_3 and NaOH solution; or passed through traps containing satd aq lead acetate, then through a column of anhydrous CaSO_4. Then freeze-pumped repeatedly and distd through a trap packed with glass wool and cooled to -130\(^\circ\) (using an n-pentane slurry). It liquefies at 0/12.5mm. The gas is stored over conc H_2SO_4. TOXIC

Catecholborane (1,3,2-Benzodioxaborole) \([274-07-7]\) M 119.2, b 50/50mm, 66/80mm, 76-77/100mm, 88/165mm, d 1.125, n 1.507 (also available as a 1.0M soln in THF). A moisture sensitive flammable liquid which is purified by distn in a vacuum under a N_2 atmosphere and stored under N_2 at 0-4\(^\circ\). It liberates H_2 when added to H_2O or MeOH. A soln in THF after 25h at 25\(^\circ\) has residual hydride of 95% (under N_2) and 80% (under air) [Brown and Gupta J Am Chem Soc 97 5249 1975].

Celite 545 (diatomaceous earth) \([12003-10-0]\). Stood overnight in conc HCl after stirring well, then washed with distilled water until neutral and free of chloride ions. Washed with methanol and dried at 50\(^\circ\).
Ceric ammonium nitrate [16774-21-3] M 548.2, pK\textsubscript{2}^{25} -1.15, pK\textsubscript{2}^{25} -0.72, pK\textsubscript{2}^{25} 1.68, pK\textsubscript{2}^{25} 2.29 (for aquo Ce\textsuperscript{4+}). Ceric ammonium nitrate (125g) is warmed with 100mL of dilute HNO\textsubscript{3} (1:3 v/v) and 40g of NH\textsubscript{4}NO\textsubscript{3} until dissolved, and filtered off on a sintered-glass funnel. The solid which separates on cooling in ice is filtered off on a sintered funnel (at the pump) and air is sucked through the solid for 1-2 h to remove most of the nitric acid. Finally, the solid is dried at 80-85\textdegree.

Cerous acetate [537-00-8] M 317.3, pK\textsubscript{2}^{25} 8.1 (9.29), pK\textsubscript{2}^{25} 16.3, pK\textsubscript{2}^{25} 26.0 (for Ce\textsuperscript{3+}). Crystd twice from anhydrous acetic acid, then pumped dry under vacuum at 100\textdegree for 8h.

Cesium bromide [7787-69-1] M 212.8, m 636\textdegree, b ca 1300\textdegree, d 4.44. Very soluble in H\textsubscript{2}O, soluble in EtOH but insoluble in Me\textsubscript{2}CO. Dissolve in the minimum volume of H\textsubscript{2}O, filter and ppte by adding Me\textsubscript{2}CO. Filter solid and dry at 100\textdegree. Also recrystd from water (0.8mL/g) by partial evaporation in a desiccator.

Cesium carbonate [534-17-8] M 325.8, m 792\textdegree (at red heat). Crystd from ethanol (10mL/g) by partial evaporation.

Cesium chloride [7647-17-8] M 168.4, m 645\textdegree, b 1303\textdegree, d 3.99. Soluble in H\textsubscript{2}O but can be purified by crystn from H\textsubscript{2}O [sol in g per cent: 162.3(0.70), 182.2(16.20) and 290(at bp 119.40)] and dried in high vac. Sol in EtOH and is deliquescent, keep in a tightly closed container. [Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol I 951 1963.] For further purification of CsCl, a conc aqueous soln of the practically pure reagent is treated with an equivalent weight if I\textsubscript{2} and Cl\textsubscript{2} bubbled into the soln until pptn of CsCl ceased. Recrystn yields a salt which is free from other alkali metals. It is then decomposed to pure CsCl on heating. [J Am Chem Soc 52 3886 1930.] Also rerystd from acetone-water, or from water (0.5mL/g) by cooling in CaCl\textsubscript{2}/ice. Dried at 78\textdegree under vacuum.

Cesium chromate [56320-90-2] M 381.8, pK\textsubscript{2}^{25} 0.74, pK\textsubscript{2}^{25} 6.49 (for H\textsubscript{2}CrO\textsubscript{4}). Crystd from water (1.4mL/g) by partial evapn in a desiccator.

Cesium fluoride [13400-13-0] M 151.9, m 703\textdegree. Crystd from aqueous soln by adding ethanol.

Cesium iodide [7789-17-5] M 259.8, m 621\textdegree, b -1280\textdegree, d 4.5. Crystd from warm water (1mL/g) by cooling to -5\textdegree.

Cesium nitrate [7789-18-6] M 194.9, m 414\textdegree (dec), d 3.65. Crystd from water (0.6mL/g) between 100\textdegree and 0\textdegree. After 1 crystn of 99.9% grade it had K, Na and Se at 0.8, 0.4 and 0.2 ppm resp.

Cesium oleate [31642-12-3] M 414.4. Crystd from EtOAc, dried in an oven at 40\textdegree and stored over P\textsubscript{2}O\textsubscript{5}.

Cesium perchlorate [13454-84-7] M 232.4, pK\textsubscript{2}^{25} -2.4 to -3.1 (for HClO\textsubscript{4}). Crystd from water (4mL/g) between 100\textdegree and 0\textdegree.

Cesium perfluoro-octanoate [17125-60-9] M 546.0. Recrystd from a butanol-petroleum ether mixture, dried in an oven at 40\textdegree and stored over P\textsubscript{2}O\textsubscript{5} under vacuum.

Cesium sulfate [10294-54-9] M 361.9, m 1005\textdegree, d 4.24. Crystd from water (0.5mL/g) by adding ethanol and cooling.

Chloramine-T (N-chloro-p-toluenesulfonylamine sodium salt) 3H\textsubscript{2}O [7080-50-4] M 281.7, m 168-170\textdegree (dec). Crystd from hot water (2mL/g). Dried in a desiccator over CaCl\textsubscript{2} where it loses water. Protect from sunlight. Used for detection of bromate and halogens, and Co, Cr, Fe, Hg, Mn, Ni and Sb ions.

Chlorazol Sky Blue FF {6,6'-(3,3'-dimethoxy[1,1'-biphenyl]-4,4'-diyl)bis(azo)bis(4-amino-5-hydroxy-1,3-naphthlineisulfonyl acid) tetra-Na salt [2610-05-1] M 996.9, m
Freed from other electrolytes by adding aqueous sodium acetate to a boiling soh of the dye in distd water. After standing, the salted-out dye was filtered on a Büchner funnel, the process being repeated several times. Finally, the ppted dye was boiled several times with absolute EtOH to wash out any sodium acetate, then dried (as the sodium salt) at 105°. [McGregor, Peters and Petropolous Trans Faraday Soc 58 1045 1962.]

Chlorine [7782-50-5] M 70.9, m -101°, b -34.0°, d 2.898. Passed in succession through aqueous KMnO₄, dilute H₂SO₄, conc H₂SO₄, and a drying tower containing Mg(CI0₄)₂. Or, bubbled through with water, dried over P₂O₅ and distd from bulb to bulb in a vac line. HIGHLY TOXIC.

Chlorine trifluoride [7790-91-2] M 92.5, b 12.1°. Impurities include chloryl fluoride, chlorine dioxide and hydrogen fluoride. Passed first through two U-tubes containing NaF to remove HF, then through a series of traps in which the liquid is fractionally distd. Can be purified via the KF complex, KClF₄, formed by adding excess ClF₃ to solid KF in a stainless steel cylinder in a dry-box and shaking overnight. After pumping out the volatile materials, pure ClF₃ is obtained by heating the bomb to 100-150° and condensing the evolved gas in a -196° trap [Schack, Dubb and Quaglino Chem Znd (London) 545 1967]. HIGHLY TOXIC.

Chlorodiphenylphosphine (diphenylphosphinous chloride) [1079-66-9] M 220.6, m 15-16°, b 124-126°/0.6mm, 174°/5mm, 320°/atm, d 1.229, n 1.636. Air sensitive, pale yellow lachrymatory liquid which is purified by careful fractional distn and discarding the lower boiling fraction which contains the main impurity PhPCI₃ (b 48-50°/0.7mm); and checking for impurities by NMR. [Weinberg J Org Chem 40 3586 1975; Honer et al. Chem Ber 94 2122 1961.]

4-(Chloromercuri)benzenesulfonic acid monosodium salt [14110-97-5] M 415.2, dec on heating. The free acid is obtained by acidifying an aqueous solution, filtering off the acid, washing it with H₂O and recrystallising from hot H₂O to give a colourless solid which is dried in a vacuum over P₂O₅ and should give negative Cl⁻ ions. The Na salt is made by dissolving in one equivalent of aqueous NaOH and evaporate to dryness. [Chem Ber 67 130 1934; J Am Chem Soc 76 433 1954.]

HIGHLY TOXIC.

2-Chloro-2-oxo-1,3,2-dioxaphospholane [6609-64-9] M 142.5, m 12-14°, b 89-91°/0.8mm, d₂° 1.549, nD° 1.448. Should be distd at high vacuum as some polymerisation occurs on distn. It has IR bands at 3012, 2933, 1477, 1366, 1325, 1040, 924 and 858 cm⁻¹. In H₂O at 100° it is hydrolysed to HOCH₂CH₂OPO₃H₂ in 30min [IR: Cox and Westheimer J Am Chem Soc 80 5441 1958].

Chloro-(2,2'-6',2'-terpyridine)platinum (II) chloride (2H2O) [60819-00-3] M 535.3. Recrystd from hot dilute HCl and cooling to give the red dihydrate. The trihydrate crysts slowly from a cold aq soln and is air dried. The red dihydrate can be obtained from the trihydrate by desiccation over conc H2SO4, by washing with EtOH or by precipitating from a warm aq soln with HCl. The dihydrate is also formed by decomposing the black trihydrate form by heating in water (slowly), or more rapidly with hot 2N HCl. [J Chem Soc 1498 1934.]

Chloro-tri-isopropyl titanium [20717-86-6] M 260.6, m 45-50°, b 61-65°/0.1mm. Distd under vacuum and sets slowly to a solid on standing. Stock reagents are made by dissolving the warm liquid in pentane, toluene, Et20, THF, CH2C12, and can be stored in pure state or in soln under dry N2 for several months. The reagent is hygroscopic and is hydrolysed by H2O. [Chem Ber 118 1421 1985.]

Chlorotriphenylsilane (triphenylchlorosilane) [76-86-8] M 294.9, m 90-92°, 91-93°, 94-95°, 97-99°, b 156°/1mm, 161°/0.6mm. Likely impurities are tetraphenylsilane, small amounts of hexaphenyldisiloxane and traces of triphenylsilanol. Purified by distn at 2mm, then crystd from EtOH-free CHC13, and from pet ether (b 30-60°) or hexane by cooling in a Dry-icelacetone bath. [J Chem Soc 3671 1957; J Am Chem Soc 72 4471 1958, 77 6395 1955, 79 1843 1957.]

Chlorotris(triphenylphosphine) rhodium I (Wilkinson's catalyst) [14694-95-2] M 925.2, m 138°(dec), 140°(dec), 157-158°(dec). Forms dark burgundy crysts from hot EtOH after refluxing for 30min. When the soln is heated for only 5min orange crystals are formed. Heating the orange crystals in EtOH yields red crystals. Crystn from Me2C0 gives the orange crystals. The two forms have similar IR spectra but X-rays are slightly different. [Osborne et al. J Chem Soc (A) 1711 1966; Osborne and Wilkinson Inorg Synth 10 16 1977.] Sol in CH2C12 ~2% (25°), in toluene 0.2% (25°), and less sol in Me2C0, MeOH, BuOH and AcOH, but insol in pet ethers and cyclohexane. It reacts with donor solvents such as pyridine, DMSO and MeCN.

Chromeazurol S [1667-99-8] M 539.3, λmax 540nm, ε 7.80 x 104 (10M HCl), CI 43825, pk75 <0, pk45 2.25, pk65 4.88, pk35 11.75. Crude phenolic triphenylmethanecarboxysulfonic acid triNa salt (40g) is dissolved in water (250mL) and filtered. Then added conc HCl (50mL) to filtrate, with stirring. Ppte is filtered off, washed with HCl(2M) and dried. Redissolved in water (250mL) and pptn repeated twice more in water bath at 70°. Then dried under vacuum over solid KOH (first) then P2O5 [Martynov et al. Zh Analyt Khim 32 519 1977]. It has also been purified by paper chromatography using n-butanol, acetic acid and water (7:3:1). First and second spots were extracted. It chelates Al and Be. Used for estimating fluoride.

Chromic chloride (anhydrous) [10025-73-7] M 158.4, m 1152°, pk15 3.95, pk25 5.55, pk35 10.5 (for Cr3+). Sublimed in a stream of dry HCl. Alternatively, the impure chromic chloride (100g) was added to 1L of 10% aq K2Cr207 and several millilitres of conc HCl, and the mixture was brought to a gentle boil with constant stirring for 10 min. (This removed a reducing impurity.) The solid was separated, and washed by boiling with successive 1L lots of distilled water until the wash water no longer gave a test for chloride ion, then dried at 110° [Poulsen and Garner J Am Chem Soc 81 2615 1959].

Chromium (III) acetylacetonate [21679-31-2] M 349.3, m 212-216°, 216°, pk25 4.0 (see chromic chloride). Purified by dissolving 6g in hot *C6H6 (20mL) and adding 75mL of pet ether slowly. Cool to room temp then chill on ice, filter off and dry in air to give 2.9g. Also crystallises from EtOH. Sol in heptane, *C6H6, toluene and pentane-2,4-dione at 20-40°. It forms a 1:2 complex with CHCl3. [Inorg Synth 5 130 1957; J Am Chem Soc 80 1839 1958.]

Chromium ammonium sulfate (12H2O) [34275-72-4 (hydr); 13548-43-1 (anhydr)] M 478.4, m 94° loses 9H2O then dehydr at 300°, d 1.72. Cryst from a saturated aqueous soln at 55° by cooling slowly with rapid mechanical stirring. The resulting fine crystals were filtered on a Büchner funnel, partly dried on a porous plate, then equilibrated for several months in a vacuum desiccator over crude chromium ammonium sulfate (partially dehydrated by heating at 100° for several hours before use) [Johnson, Hu and Horton J Am Chem Soc 75 3922 1953].
Chromium (II) chloride (anhydrous) \( \text{[10049-05-5]} \) M 122.9, m 824°, d\(_4\) 2.75. Obtained from the dihydrate by heating in vacuo at 180°. It is a very hygroscopic white powder which dissolves in H\(_2\)O to give a sky blue solution. Stable in dry air but oxidises rapidly in moist air and should be stored in air tight containers. It sublimes at 800° in a current of HCl gas and cooled in the presence of HCl gas. Alternatively it can be washed with air-free Et\(_2\)O and dried at 110-120°. [Inorg Synth 3 150 1950.]

Chromium hexacarbonyl \( \text{[13007-92-6]} \) M 220.1, m 130°(dec), d 1.77. Wash with cold EtOH then Et\(_2\)O and allow to dry in air. Alternatively recrystallise from dry Et\(_2\)O. This is best accomplished by placing the hexacarbonyl in a Soxhlet extractor and extracting exhaustively with dry Et\(_2\)O. Pure Cr(CO)\(_6\) is filtered off and dried in air. Completely colourless refracting crystals are obtained by sublimation at 40-50° in a vacuum desiccator over NaOH pellets; hygroscopic, powerful oxidant, can ignite with organic compounds. It is a skin and pulmonary irritant. 

Chromium potassium sulfate (12\(\text{H}_2\)O) \( \text{[7788-99-0]} \) M 499.4, pK\(_{1}^\text{S} \) 0.74, pK\(_{2}^\text{S} \) 6.49 (for \(\text{H}_2\text{CrO}_4\), chromic acid). Crystd from hot water (2mL/g) by cooling.

Chromium trioxide (chromic anhydride) \( \text{[1333-82-0]} \) M 100.0, m 197°, dec at 250° to \(\text{Cr}_2\text{O}_3\), d 2.70 (pK\(_{1}^\text{S} \) 0.74, pK\(_{2}^\text{S} \) 6.49, for \(\text{H}_2\text{CrO}_4\), chromic acid). Red crystals from water (0.5mL/g) between 100° and 50°, or from water/conc H\(_2\)SO\(_4\) (1:5). It separates when potassium or sodium dichromate are dissolved in conc H\(_2\)SO\(_4\). Dried in a vacuum desiccator over NaOH pellets; hygroscopic, powerful oxidant, can ignite with organic compounds. It is a skin and pulmonary irritant. § Commercially available on polymer support. CANCER SUSPECT.

Chromium (III) tris-2,4-pentanedionate \( \text{[21679-31-2]} \) M 349.3, m 216°, pK\(_{25} \) 4.0 (see chromic chloride). See chromium (III) acetylacetonate on p. 412.

Chromoionophore I \( \text{[ETH 5294]} \) \( \text{[9-diethylaminom-5-octadecanoyl-imino-5-\text{H}-benzo[a]-phenoxazine]} \) \( \text{[125829-24-5]} \) M 583.9. Purified by flash chromatography (Silica Gel) and eluted with EtOAc. The coloured fractions are pooled, evaporated and recrystd from EtOAc. It is a lipophilic chromoionophore and is a selectophore for K and Ca ions. [Anal Chem 62 738 1990.]

Chromotropic acid (4,5-dihydroxynaphthalene-2,7-disulfonic acid di-Na salt) \( \text{[5808-22-0]} \) M 400.3, m >300°, pK\(_{1} \) 0.61(SO\(_3^\text{2-}\)), pK\(_{2} \) 0.7(SO\(_3^\text{2-}\)), pK\(_{3} \) 5.45(OH), pK\(_{4} \) 15.5(OH). See disodium 4,5(1,8)-dihydroxynaphthalene-2,7(3,6)-disulfonate (2\(\text{H}_2\)O) on p. 421.

Chromyl chloride \( \text{[14977-61-8]} \) M 154.9, b 115.7°, d 1.911. Purified by distn under reduced pressure. TOXIC.

Claissen alkali (alkali Claissen). Prepared from KGH (35g) in H\(_2\)O (25mL) and diluted to 100mL with MeOH. STRONGLY CAUSTIC.

Cobalt (II) meso-5,10,15,20-tetraphenylporphine complex \( \text{[14172-90-8]} \) M 671.7. Brown crystals from Et\(_2\)O or CHCl\(_3\)-MeOH (cf iron chloride complex). Recrystd by extraction (Soxhlet) with \( \text{C}_6\text{H}_5\text{Cl} \). Sol in most organic solvents except MeOH and pet ether. [UV, IR: J Am Chem Soc 70 1808 1948; 81 5111 1959.]

Cobaltous acetate (4\(\text{H}_2\)O) \( \text{[6147-53-1]} \) M 249.1, pK\(_{25}^\text{A} \) 9.85 (for Co\(^{2+}\)). Crystd several times as the tetrahydrate from 50% aqueous acetic acid. Converted to the anhydrous salt by drying at 80°/1mm for 60h.
Cobaltous acetylacetonate  \([14024-48-7]\) M 257.2, m 172°. Crystd from acetone.

Cobaltous ammonium sulfate \((6\text{H}_2\text{O})\)  \([13596-46-8]\) M 395.5, d 1.90. Crystd from boiling water \((2\text{mL}/\text{g})\) by cooling. Washed with ethanol.

Cobaltous bromide \((6\text{H}_2\text{O})\)  \([85017-77-2\ (\text{xH}_2\text{O});\ 7789-43-7\ (\text{anhydr})]\) M 326.9 \((6\text{H}_2\text{O})\), m 47°(dec), b 100°(dec), d 4.9. Crystd from water \((1\text{mL}/\text{g})\) by partial evaporation in a desiccator.

Cobaltous ammonium sulfate \((6\text{H}_2\text{O})\)  \([13596-46-8]\) M 395.5, d 1.90. Crystd from boiling water \((2\text{mL}/\text{g})\) by cooling. Washed with ethanol.

Cobaltous chloride \((6\text{H}_2\text{O})\)  \([7791-13-1\ (6\text{H}_2\text{O});\ 7878-43-7\ (\text{anhydr})]\) M 326.9, m 47°(dec), d 4.9. A saturated aqueous soln at room temperature was fractionally crystd by standing overnight. The first half of the material that crystd in this way was used in the next crystn. The process was repeated several times, water being removed in a dry-box using air filtered through glass wool and dried over CaCl\(_2\) [Hutchinson J Am Chem Soc 76 1022 1954]. Has also been crystd from dilute aq HCl.

Cobaltous perchlorate \((6\text{H}_2\text{O})\)  \([13478-33-6]\) M 365.9, pK\(_{\text{Z}}\) 5 -2.4 to -3.1 (for HCIO\(_4\)). Crystd from warm water \((0.7\text{mL}/\text{g})\) by cooling.

Cobaltous potassium sulfate  \([13596-22-0]\) M 329.4. Crystd from water \((1\text{mL}/\text{g})\) between 50° and 0°, and dried in a vacuum desiccator over conc H\(_2\)SO\(_4\).}

Cupferon ammonium salt \((N\text{-nitroso-N-phenylhydroxylamine ammonium salt})\)  \([I 0026-20-6]\) M 155.2, m 150-155°(dec), 162.5-163.5°, 163-164°, pK\(_{\text{Z}}\) 25 4.16 (free base). Recrystd twice from EtOH after treatment with Norite and finally once with EtOH. The crystals are washed with diethyl ether and air dried then stored in the dark over solid ammonium carbonate. A standard soln \((ca\ 0.05M\ prepared\ in\ air-\free\ H_2O)\) is prepared daily from this material for analytical work and is essentially 100% pure. [Anal Chem 26 1747 1954.1 Possible CARCINOGEN.}

Cupferon ammonium salt \((N\text{-nitroso-N-phenylhydroxylamine ammonium salt})\)  \([135-20-6]\) M 155.2, m 150-155°(dec), 162.5-163.5°, 163-164°, pK\(_{\text{Z}}\) 25 4.16 (free base). Recrystd twice from EtOH after treatment with Norite and finally once with EtOH. It is a green-brown powder which gives a yellow-green soln in pyridine. Wash with EtOH and dry in a vacuum. It can be ppted from a pyridine soln by addition of H\(_2\)O, collect ppte, wash with EtOH and dry in a vacuum. [Synthesis 662 1974; J Am Chem Soc 79 170 1957; Chem Ber 90 425 1957.]
Cupric bromide [7789-45-9] M 223.4, m 498°, d 4.7. Crystd twice by dissolving in water (140mL/g), filtering to remove any Cu₂Br₂, and concentrating under vac at 30° until crystals appeared. The cupric bromide was then allowed to crystallise by leaving the soln in a vac desiccator containing P₂O₅ [Hope, Otter and Prue J Chem Soc 5226 1960].

Cupric chloride [7447-39-4] M 134.4, m 498°, 630°(dec). Crystd from hot dilute aq HCl (0.6mL/g) by cooling in a CaCl₂-ice bath. Dehydrated by heating on a steam-bath under vacuum. It is deliquescent in moist air but efflorescent in dry air.

Cupric lactate (H₂O) [814-81-3] M 295.7. The monohydrate crysts from hot H₂O (3mL/g) on cooling.

Cupric nitrate (3H₂O) [10031-43-3 (3H₂O); 3251-23-8 (anhydr)] M 241.6, m 114°, b 170°(dec), d 2.0. Crystd from weak aqueous HNO₃ (0.5mL/g) by cooling from room temperature. The anhydrous salt can be prepared by dissolving copper metal in a 1:1 mixture of liquid NO₃ and ethyl acetate and purified by sublimation [Evans et al. J Chem Soc, Faraday Trans I 75 1023 1979]. The hexahydrate dehyd to trihydrate at 26°, and the anhydrous salt sublimes between 150 and 225°, but melts at 255-256° and is deliquescent.


Cupric perchlorate (6H₂O) [10294-46-9 (hydr); to -3.1 (for HCIO₄). Crystd from distilled water. The anhydrous salr is hygroscopic.

Cupric phthalocyanine [147-14-8] M 576.1. Precipitated twice from conc H₂SO₄ by slow dilution with water. Also purified by two or three sublimations at 580° in an argon flow at 300-400Pa.

Cupric sulfate [7758-98-7] M 159.6, m >560°. After adding 0.02g of KOH to a litre of nearly saturated aq soln, it was left for two weeks, then the ppte was filtered on to a fibreglass filter with pore diameter of 5-15 microns. The filtrate was heated to 90° and allowed to evaporate until some CuSO₄.5H₂O had crystall. The soln was then filtered hot and cooled rapidly to give crystals which were freed from mother liquor by filtering under suction [Geballe and Giauque J Am Chem Soc 74 3513 1952]. Alternatively crystd from water (0.6mL/g) between 100° and 0°.

Cupric trifluoromethylsulfonate (copper II triflate) [34946-82-2] M 361.7, pK₂⁵ <3.0 (for triflic acid). Dissolve in MeCN, add dry Et₂O until cloudy and cool at -20° in a freezer. The light blue ppte is collected and dried in a vacuum oven at 130°/20mm for 8h. It has λmax 737nm (ε 22.4M⁻¹cm⁻¹) in AcOH. [J Am Chem Soc 95 330 1973]. It has also been dried in a vessel at 0.1Torr by heating with a Fischer burner [J Org Chem 43 3422 1978]. It has been dried at 110-120°/5mm for 1h before use and forms a *benzene complex which should be handled in a dry box because it is air sensitive [Chem Pharm Bull Jpn 28 262 1980; J Am Chem Soc 95 330 1973].

Cuprous bromide [7787-70-4] M 143.4, m 497°, b 1345°, d 4.72. Purified as for cuprous iodide but using aqueous NaBr.

Cuprous bromide dimethylsulfide complex [54678-23-8] M 205.6, m ca 135°(dec). Purified by recrystn in the presence of Me₂S. A soln of the complex (1.02g) in Me₂S (5mL) is slowly diluted with hexane (20mL) and the pure colourless prisms of the complex (0.96g) separate and are collected and dried, m 124-129°dec. The complex is insoluble in hexane, Et₂O, Me₂CO, CHCl₃ and CCl₄. It dissolves in DMF and DMSO but the soln becomes hot and green indicating dec. It dissolves in *C₆H₆, Et₂O, MeOH and CHCl₃ if excess of Me₂S is added a colourless soln is obtained. [J Org Chem 40 1460 1975.] Prior to use, the complex was dissolved in Me₂S and evaporated to dryness in the weighed reaction flask [J Organomet Chem 228 321 1983].

Cuprous chloride [7758-89-6] M 99.0, m 430°, b~1400°. Dissolved in strong HCl, ppte by dilution with water and filtered off. Washed with ethanol and diethyl ether, then dried and stored in a vacuum desiccator [Osterlöf Acta Chem Scand 4 375 1950]. Alternatively, to an aq. soln of CuCl₂.2H₂O was added, with stirring,
an aqueous soln of anhydrous sodium sulfite. The colourless product was dried at 80° for 30min and stored under N₂. CuCl₂ can be purified by zone-refining [Hall et al. J Chem Soc, Faraday Trans 1 79 243 1983].

Cuprous cyanide [544-92-3] M 89.6, m 474°. Wash thoroughly with boiling H₂O, then with EtOH. Dry at 100° to a fine soft powd. [J Chem Soc 79 1943.]

Cuprous iodide [7681-65-4] M 190.5, m 605°, b 1336°, d₂⁵ 5.63. It can be freshly prepared by dissolving an appropriate quantity of Cul in boiling saturated aqueous NaI over 30min. Pure Cul is obtained by cooling and diluting the soln with water, followed by filtering and washing sequentially with H₂O, EtOH, EtOAc and Et₂O, pentane, then drying in vacuo for 24h [Dieter, J Am Chem Soc 107 4679 1985]. Alternatively wash with H₂O then EtOH and finally with Et₂O containing a little iodine. Traces of H₂O are best removed first by heating at 110° and then at 400°. Excess of I₂ is removed completely at 400°. It dissolves in Et₂O if an amine is present to form the amine complex. [Chem Ind (London) 1180 1957.]


Cuprous thiocyanate [18223-42-2] M 121.6, pK₂ -1.85 (for HSCN). Purified as for cuprous iodide but usingaq NaSCN.

Cyanamide [420-04-2] M 42.0, m 43°, 45°, 46°, 48°-87°/8.5mm, pK₂ -0.36 (1.1 at 29°), pK₂ -10.27. Purified by placing ca 15g in a Soxhlet thimble and extracting exhaustively (2-3h) with two successive portions of Et₂O (400mL, saturated with H₂O by shaking before use) containing two drops of 1N acetic acid. Two successive portions of Et₂O are used so that the NH₂CN is not heated for too long. Each extract is dried over Na₂SO₄(30g), then combined and evaporated under reduced pressure. The NH₂CN may be stored unchanged at 0° in Et₂O soln in the presence of a trace of AcOH. Extracts from several runs may be combined and evaporated together. The residue from evaporation of an Et₂O soln is a colourless viscous oil which sets to a solid, and can be recrystd from a mixture of 2 parts of C₆H₆ and 1 part of Et₂O. Concentrating an aqueous soln of NH₂CN at high temps causes EXPLOSIVE polymerisation. [Org Synth Coll Vol IV 645 1963; Inorg Synth 3 39 1950; J Org Chem 23 613 1958.] Hygroscopic.

Cyanogen bromide [506-68-3] M 105.9, m 49-51°, b 60-62°/atm. All operations with this substance should be performed in a very efficient fume cupboard - it is very POISONOUS and should be handled in small amounts. Fresh commercial material is satisfactory for nearly all purposes and does not need to be purified. It is a white crystalline solid with a strong cyanide odour. If it is reddish in colour and partly liquid or paste-like then it is too far gone to be purified, and fresh material should be sought. It can be purified by distn using small amounts at a time, and using a short wide-bore condenser because it readily solidifies to a crystalline white solid and may clog the condenser. An appropriate gas mask should be used when transferring the molten solid from one container to another and the operation should be done in an efficient fume cupboard. The melting point (m 49-51°) should be measured in a sealed tube. [Org Synth Coll Vol II 150 1948.]

Cyanogen iodide [506-78-5] M 152.9, m 146-147°. This compound is POISONOUS and the precautions for cyanogen bromide (above) apply here. The reagent (ca 5.9g) is dissolved in boiling CHCl₃ (15mL), filtered through a plug of glass wool into a 250mL Erlenmeyer flask. Cool to room temperature for 15min, then place in an ice-salt bath and cool to -10°. This cooling causes a small aqueous layer to separate as ice. The ice is filtered with the CNI, but melts on the filter and is also removed with the CHCl₃ used as washing liquid. The CNI which is collected on a sintered glass funnel is washed 3x with CHCl₃ (1.5mL at 0°) and freed from last traces of solvent by being placed on a watch glass and exposed to the atmosphere in a good fume cupboard at room temp for 1h to give colourless needles (ca 4.5g), m 146-147° (sealed capillary totally immersed in the oil bath). The yield depends slightly on the rapidity of the operation, in this way loss by sublimation can be minimised. If desired, it can be sublimed under reduced pressure at temps at which CNI is only slowly decomposed into I₂ and (CN)₂. The vacuum will need to be renewed constantly due to the volatility of CNI. [Org Synth 32 29 1952.]
Decaborane [17702-41-9] M 122.2, m 99.7-100°. Purified by vacuum sublimation at 80°/0.1mm, followed by crystallisation from methycyclohexane, CH₂Cl₂, or dry olefin-free n-pentane, the solvent being subsequently removed by storing the crystals in a vacuum desiccator containing CaCl₂.


Deuterium oxide [7789-20-0] M 20, f 3.89/760mm, b 101.4°/760mm, d 1.105. Distilled from alkaline KMnO₄ [de Giovanni and Zamenhof Biochem J 72 99 1963]. NOTE that D₂O invariably contains tritiated water and will therefore be RADIOACTIVE; always check the radioactivity of D₂O in a scintillation counter before using.


Diammonium hydrogen orthophosphate [7783-28-0] M 132.1. Crystallised from water (1mL/g) between 70° and 0°. After one crystallisation of ACS grade had Fe, Mo, Na, Se and Ti at 1, 0.2, 1.4, 0.2 and 0.8ppm resp.

Di-n-amyl n-amylphosphonate [6418-56-0] M 292.4, b 150-151°/2mm, n 1.4378. Purified by three crystallisations of its uranyl nitrate complex from hexane (see tributyl phosphate). Extracts Zr²⁺ from NaCl solutions.

6,6-Dibenzyl-14-crown-4 (lithium ionophore VI; 6,6-dibenzyl-1,4,8,11-tetra-oxa-cyclotetradecane) [106868-21-7] M 384.5, m 102-103°. Dissolve in CHCl₃, wash with saturated aqueous NaCl, dry with MgSO₄, evaporate and purify by chromatography on silica gel and gradient elution with *C₆H₆-MeOH followed by preparative reverse phase HPLC on an octadecyl silanised silica (ODS) column and eluting with MeOH. It can be crystallised from MeOH (νₓBr 1120 cm⁻¹, C-O-C). [J Chem Soc Perkin Trans 1 1945 1986.]

Di-n-butyl boron triflate (di-n-butylboryl trifluoromethanesulfonate) [60669-69-4] M 274.1, b 37°/0.12mm, 60°/2mm, pK₂5 < -3.0 (for triflic acid). Distilled in vacuum under argon and stored under argon. Should be used within 2 weeks of purchase or after redistillation. Use a short path distillation system. It has IR bands in CCl₄ at ν 1405, 1380, 1320, 1200 and 1550cm⁻¹; and 13C NMR (CDCl₃) with δ at 118.1, 25.1, 21.5 and 13.6. [Org Synth 68 83 1990; J Am Chem Soc 103, 3099 1981.] TOXIC

Di-n-butyl cyclohexylphosphonate [1095-92-3] M 254.4. The compound with uranyl nitrate was crystallised three times from hexane. For method see tributyl phosphate.

Di-tert-butyl dichlorosilane (DTBCl₂) [18395-90-9] M 213.2, m -15°, b 190°/729mm, 195-197°/atm, d 1.01. Purified by fractional distillation. It is a colourless liquid with a pleasant odour and does not fume in moist air, but does not titrate quantitatively with excess of dil alkali. [J Am Chem Soc 70 2877 1948.]

Di-n-butyl n-butylphosphonate [78-46-6] M 250.3, b 150-151°/10mm, 160-162°/20mm, n²5 1.4302. Purified by three recrystallisations of its compound with uranyl nitrate, from hexane. For method, see tributyl phosphate.

Di-tert-butyl silyl bis(trifluoromethanesulfonate) [85272-31-7] M 440.5, b 73.5-74.5°/0.35mm, d 1.36 (see pK for triflic acid). Purified by fractional distillation. It is a pale yellow liquid which should be stored under argon. It is less reactive than the disisopropyl analogue. The presence of the intermediate monochloro compound can be detected by ¹H NMR, (CHCl₃): tert-Bu₂Si(OTf)₂ [δ 1.25s]; but
impurities have $\delta$ 1.12s for tert-Bu$_2$Si(H)OTf and $\delta$ 1.19s for tert-Bu$_2$HSi(Cl)OTf. [Tetrahedron Lett 23 487 1982] TOXIC.

Di-n-butyltin oxide [818-08-6] M 248.9, m >300°. It is prepd by hydrolysis of di-n-butyltin dichloride with KOH. Hence wash with a little aq M KOH then HzO and dry at ~80°/10mm until the IR is free from OH bands. [Cummings Aust J Chem 18 98 1965.]

Dicarbonyl(cyclopentadienyl)Co (1) [1207-25-0] M 180.1, b 75°/22mm, b 139-140°(dec)/710mm. Best distd in an atmosphere of CO in a vac. The red brown liquid decomposes slightly on distn even in a vac to liberate some CO. Operations should be performed in an efficient fume cupboard. It is sol in organic solvents and stable in air but decomposes slowly in sunlight and rapidly under UV. [Piper et al. J Inorg Nucl Chem 1 165 1955.]


Diethyl aluminium chloride [96-10-6] M 120.6, m -75.5°, b 106.5-108°/24.5mm, d 0.96. Distd from excess dry NaCl (to remove ethyl aluminium dichloride) in a 50-cm column containing a heated nichrome spiral.


Di-(2-ethylhexyl)phosphoric acid (‘diisooctyl’ phosphate) [27215-10-7; 298-07-7] M 322.4, b 209°/10mm, d 0.965, pK$_{EH}$ -1.7. Contaminants of commercial samples include the monoester, polyphosphates, pyrophosphate, 2-ethylhexanol and metal impurities. Dissolved in n-hexane to give an 0.8M soln. Washed with an equal volume of M HNO$_3$, then with saturated (NH$_4$)$_2$CO$_3$ soln, with 3M HNO$_3$, and twice with water [Petrow and Allen Anal Chem 33 1303 1961]. Similarly, the impure sodium salt, after scrubbing with pet ether, was acidified with HCl and the free organic acid was extracted into pet ether and purified as above. [Peppard et al. J Inorg Nucl Chem 7 231 1958] or Stewart and Crandall [J Am Chem Soc 73 1377 1951]. Purified also via the copper salt [McDowell et al. J Inorg Nucl Chem 38 2127 1976].

Diethylmethylsilane [760-32-7] M 102.3, b 78.4°/760mm, 77.2-77.6°/atm, d 0.71. Fractionally distilled through a ca 20 plate column and the fraction boiling within a range of less than 0.5° is collected. [Izv Akad Nauk SSSR Otd Khim 1416 1937; J Am Chem Soc 69 2600 1947.]

Diethyl trimethylsilyl phosphate [13716-45-5] M 210.3, b 61°/10mm, 66°/15mm, d 0.9476, n 1.4113. Fractionated under reduced pressure and has $\delta_p$ -128 ±0.5 relative to H$_3$PO$_4$. [J Org Chem 46 2097 1981; J Gen Chem USSR (Engl Transl) 45 231 1975.]

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N,N’-Diheptyl-N,N’-5,5-tetramethyl-3,7-dioxanonediamide [lithium ionophore I (ETH 149)] [58821-96-8] M 442.7. Purified by chromatography on Kieselgel using CHCl₃ as eluent (IR v
1640cm⁻¹). [Helv Chim Acta 60 2326 1977.]


Dilongifolyl borane [77882-24-7] M 422.6, m 169-172°. Wash with dry Et₂O and dry in a vacuum under N₂. It has m 160-161° in a sealed evacuated capillary. It is sparingly soluble in pentane, tetrahydrofuran, carbon tetrachloride, dichloromethane, and chloroform, but the suspended material is capable of causing asymmetric hydroboration. Disappearance of solid indicates that the reaction has proceeded. [J Org Chem 46 2988 1981.]

Dimethyl carbonate [616-38-6] M 90.1, b 89.5°/755mm, 90.2°/atm, d 1.0446, n 1.3687. If the reagent has broad intense bands at 3300cm⁻¹ and above (i.e. OH stretching) then it should be purified further. Wash successively with 10% Na₂CO₃ soln, saturated CaCl₂, H₂O and dried by shaking mechanically for 1h with anhydrous CaCl₂, and fractionated. [J Chem Soc 78 1847 1948.]
Dinitrogen tetroxide (nitrogen dioxide, \( \text{N}_2\text{O}_4 \)) \([10544-72-6]\) M 92.0 m -11.2°, b 21.1°. Purified by oxidation at 0° in a stream of oxygen until the blue colour changed to red-brown. Distd from \( \text{P}_2\text{O}_5 \), then solidified on cooling in a deep-freeze (giving nearly colourless crystals). Oxygen can be removed by alternate freezing and melting. TOXIC VAPOUR.

Dioctyl phenylphosphonate \([1754-47-8]\) M 378.8, d 1.485, \( n^25 1.4780 \). Purified as described under diisooctyl phenylphosphonate.

(1,3-Dioxalan-2-ylmethyl)tri phenylphosphonium bromide \([52509-14-5]\) M 429.3, m 191.5-193°, 193-195°. Wash the crysts with \( \text{Et}_2\text{O} \), dry in a vac and recryst from \( \text{CH}_2\text{Cl}_2 \)-dry \( \text{Et}_2\text{O} \) to give prisms m 172-174°. which is raised to 191.5-193°, on drying at 56°/0.5mm. [Cresp et al. J Chem Soc, Perkin Trans 1 37 1974.]

Diphenyl diselenide \([1666-13-3]\) M 312.1, m 62-64. Crystd twice from hexane [Kice and Purkiss J Org Chem 52 3448 1987].

Diphenyl hydrogen phosphate \([838-85-7]\) M 250.2, m 99.5°, \( \text{pK}^{20} 0.26 \). Crystd from \( \text{CHCl}_3 \)-pet ether.

Diphenyl mercury \([587-85-9]\) M 354.8, m 125.5-126°. Sublimed, then crystd from nitromethane or ethanol. If phenylmercuric halides are present they can be converted to phenylmercuric hydroxide which, being much more soluble, remains in the alcohol or "benzene used for crystn. Thus, crude material (10g) is dissolved in warm ethanol (ca 150mL) and shaken with moist \( \text{Ag}_2\text{O} \) (ca 10g) for 30min, then heated under reflux for 30min and filtered hot. Concentration of the filtrate by evaporation gives diphenylmercury, which is recrystd from "benzene [Blair, Bryce-Smith and Pengilly J Chem Soc 3174 1959]. TOXIC.

4,7-Diphenyl-1,10-phenanthrolinedisulfonic acid, di-Na salt 3\( \text{H}_2\text{O} \) (bathophenanthroline-disulfonic acid di-Na salt) \([52746-49-3]\) M 590.6, m 300°, \( \text{pK}^{20} 0.26 \) (for free acid). Dissolve crude sample in the minimum volume of water and add \( \text{EtOH} \) to ppte the contaminants. Carefully evaporate the filtrate to obtain pure material.

It forms a dark red complex with \( \text{Fe}^{2+} \) with \( \lambda_{\text{max}} 535\text{nm} \) (\( \epsilon 2.23 \times 10^4\text{mol}^{-1}\text{cm}^{-1} \)) [Anal Chim Acta 115 407 1980]. Prepared by sulfonating bathophenanthroline with \( \text{Cl}_2\text{SO}_3\text{H} \): to 100g of bathophenanthroline was added 0.5mL of Fe free \( \text{Cl}_2\text{SO}_3\text{H} \) and heated over a flame for 30sec. Cool and carefully add 10mL of pure distd \( \text{H}_2\text{O} \) and warm on a water bath with stirring till all solid dissolved. A stock soln is made by diluting 3mL of this reagent to 100mL with 45% aq NaOAc, filter off the solid and store in a dark bottle. In this way it is stable for several months. [Am J Clinical Pathology 29 590 1958.]

Diphenylphosphinic acid \([1707-03-5]\) M 218.2, m 194-195°, \( \text{pK}^{20} 1.72 \). Recrystd from 95% \( \text{EtOH} \) and dried under vacuum at room temperature. [see Kosolapoff Organophosphorus Compounds J Wiley, NY, 1950; Kosolapoff and Maier Organic Phosphorus Compounds Wiley-Interscience, NY, 1972-1976.]

Diphenylsilane \([775-12-2]\) M 184.3, b 75-76°/0.5mm, 113-114°/9mm, 124-126°/11mm, 134-135°/16mm, d 1.0027, n 1.5802, 1.5756. Dissolve in \( \text{Et}_2\text{O} \), mix slowly with ice-cold 10% \( \text{HCl} \). The \( \text{Et}_2\text{O} \) layer is then shaken with \( \text{H}_2\text{O} \) until the washings are neutral to litmus. Dry over \( \text{Na}_2\text{SO}_4 \) and evaporate the \( \text{Et}_2\text{O} \) and distil the residual oil under reduced pressure using a Claisen flask with the take-off head modified into a short column. \( \text{Ph}_2\text{SiH}_2 \) boils at 257°/760mm but it cannot be distd at this temp because exposure to air leads to flashing, decomposition and formation of silica. It is a colourless, odourless oil, miscible with organic solvents but not \( \text{H}_2\text{O} \). A possible impurity is \( \text{Ph}_3\text{SiH} \) which has m 43-45° and would be found in the residue. [J Org Chem 18 303 1953; J Am Chem Soc 74 648 1952, 81 5925 1959.]

Diphenylsilanediol \([947-42-2]\) M 216.3, m 148°(dec). Crystd from \( \text{CHCl}_3 \)-methyl ethyl ketone.

Diphenyl tolyl phosphate \([26444-49-5]\) M 340.3, n \( ^25 1.5758 \). Vac distd, then percolated through a column of alumina. Finally, passed through a packed column maintained at 150° to remove traces of volatile
impurities in a countercurrent stream of nitrogen at reduced pressure. [Dobry and Keller *J Phys Chem* 61 1448 1947.]

**Disodium calcium ethylenediaminetetraacetate [39208-14-5]** M 374.3, (see pKs for EDTA in entry below). Dissolved in a small amount of water, filtered and ppted with excess EtOH. Dried at 80°.

**Disodium dihydrogen ethylenediaminetetraacetic acid (2H2O) [6381-92-6]** M 372.2, m 248°(dec), pK1 0.26, pK2 0.96, pK3 2.60, pK4 2.67, pK5 6.16, pK6 10.26 (see EDTA in Chapter 4). Analytical reagent grade material can be used as primary standard after drying at 80°. Commercial grade material can be purified by crystn from water or by preparing a 10% aqueous soln at room temperature, then adding ethanol slowly until a slight permanent ppt is formed, filtering, and adding an equal volume of ethanol. The ppt is filtered off on a sintered-glass funnel, is washed with acetone, followed by diethyl ether, and dried in air overnight to give the dihydrate. Drying at 80° for at least 24h converts it to the anhydrous form.

**Disodium 4,5(1,8)-dihydroxynaphthalene-2,7(3,6)-disulfonate (2H2O) [5808-22-0]** M 400.3, m >300°, pK1 0.61(SO3''), pK2 0.7(SO3''), pK3 5.45(OH), pK4 15.5(OH). Crystd from H2O or H2O by addition of EtOH. Complexes with Ag, ClO4', Cr, Hg, NO3', NO3' and Ti. [cf Chromotropic acid p. 413.]

**Disodium ethylenebis[dithiocarbamate] [142-59-6]** M 436.5, pK_{Est} ~ 3.0. Crystd (as hexahydrate) from aqueous ethanol.

**Disodium-β-glycerophosphate [819-83-0 (4H2O)]** M 216.0, m 102-104°, pK2 6.66 (free acid). Crystd from water.

**Disodium hydrogen orthophosphate (anhydrous) [7558-79-4]** M 142.0, (see pK of H3PO4). Crystd twice from warm water, by cooling. Air dried, then oven dried overnight at 130°. Hygroscopic: should be dried before use.

**Disodium magnesium ethylenediaminetetraacetate [14402-88-1]** M 358.5, pK1 0.26, pK2 0.96, pK3 2.60, pK4 2.67, pK5 6.16, pK6 10.26 (see EDTA on p. 237 in Chapter 4). Dissolved in a small amount of water, filtered and ppted with an excess of MeOH. Dried at 80°.


**Disodium 4-nitrophenylphosphate (6H2O) [4264-83-9]** M 371.1 Dissolve in hot aqueous MeOH, filter and ppt by adding Me2CO. Wash the solid with Me2CO and repeat the purification. The white fibrous crystals contain less than 1% of free 4-nitrophenol [assay: *J Biol Chem* 167 57 1947].

**Disodium phenylphosphate (2H2O) [3279-54-7]** M 254.1, pK2 1.46, pK3 6.29 [for PhPO(OH)2]. Dissolved in a minimum amount of methanol, filtering off an insoluble residue of inorganic phosphate, then ppted by adding an equal volume of diethyl ether. Washed with diethyl ether and dried [Tsuboi *Biochim Biophys Acta* 8 173 1952].

**Disodium succinate [150-90-3]** M 162.1. Crystd twice from water (1.2mL/g) and dried at 125°. Freed from other metal ions by passage of a 0.1M soln through a column of Dowex resin A-1 (Na form).

**Di-p-tolylmercury [50696-65-6]** M 382.8, m 244-246°. Crystd from xylene.

**Di-p-tolyl phenylphosphonate [94548-75-1]** M 388.3, n25 1.5758. Purified as described under diisoctyl phenylphosphonate.
1,3-Divinyl-1,1,3,3-tetramethyldisiloxane \[2627-95-4\] M 186.4, m -99.7°C; b 128-129°/atm, 139°/760mm, d 0.811, n 1.4122. Dissolve in Et2O, wash with H2O, dry over CaCl2 and distil. [J Am Chem Soc 77 1685 1955; Collect Czech Chem Comm 24 3758 1959.]

Eosin B (Bluish, Eosin Scarlet, 4′,5′-dibromo-2′,7′-dinitrofluorescein disodium salt) \[548-24-3\] M 624.1, \(\lambda_{max} 514\text{nm}, \text{CI 45400.} \) Freed from inorganic halides by repeated crystallization from butan-1-ol.

Eosin Y (as di-Na salt) \[17372-87-1\] M 691.9. Dissolved in water and ppted by addition of dilute HCl. The ppt was washed with water, crystallized from ethanol, then dissolved in the minimum amount of dilute NaOH solution and evaporated to dryness on a water-bath. The purified disodium salt was then crystallized twice from ethanol [Parker and Hatchard Trans Faraday Soc 57 1894 1961].

Eosin YS (Eosin Yellowish, 2′,4′,5′,7′-tetrabromofluorescein di-Na salt) \[17372-87-1\] M 691.9, CI 45380. Dissolved in the minimum vol of H2O (1g/mL), filter and add EtOH until separation of salt is complete. Filter off, wash with abs EtOH, then Et2O and dry first in air, then at 100°. Used for staining blood cells and for estimating traces of Ag. [Selsted and Becker Anal Biochem 155 270 1986; El-Ghamry and Frei Anal Chem 40 1986 1968.]

Eriochrome Black T \[1787-61-7\] M 416.4, \(A_{1cm}^{\lambda_{max}} 656(620\text{nm})\) at pH 10, using the dimethylammonium salt, \(pK_{2}^{\text{acid}} 5.81, pK_{2}^{\text{base}} 11.55. \) The sodium salt (200g) was converted to the free acid by stirring with 500mL of 1.5M HCl, and, after several minutes, the slurry was filtered on a sintered-glass funnel. The process was repeated and the material was air dried after washing with acid. It was then desalted with *benzene for 12h in a Soxhlet extractor, then the *benzene was evaporated and the residue was air dried. A further desalting with 1.5M HCl (1L) was followed by crystallization from dimethylformamide (in which it is very soluble) by forming a saturated solution at the boiling point, and allowing to cool slowly. The crystalline dimethylammonium salt so obtained was washed with *benzene and treated repeatedly with dilute HCl to give the insoluble free acid which, after air drying, was dissolved in alcohol, filtered and evaporated. The final material was air dried, then dried in a vacuum desiccator over Mg(ClO4)2 [Diehl and Lindstrom, Anal Chem 31 414 1959]. Indicator for complexometry of alkaline earth metals.

Eriochrome Blue Black R (Palatine Chrome Black 6BN, Calcon, 3-hydroxy-4-(2-hydroxy-1-naphthylazo)naphthalene-1-sulfonic acid Na salt) \[2538-85-4\] M 416.4, \(pK_{2}^{\text{acid}} 7.0, pK_{2}^{\text{base}} 13.5. \) Freed from metallic impurities by three pptns from aqueous soln by addition of HCl. The ppted dye was dried at 60° under vacuum. Indicator for complexometry of Al, Fe, and Zr.

Ethoxycarbonylmethylene triphenylphosphonium bromide \[1530-45-6\] M 429.3, m 155-155.5°, 158°(dec). Wash with pet ether (b 40-50°) and recryst from CHCl3/Et2O and dry in high vac at 65°. [Isler et al. Helv Chim Acta 40 1242 1957; Wittig and Haag Chem Ber 88 1654, 1664 1955.]

(Ethoxycarbonylmethylene)triphenylphosphorane [ethyl (triphenylphosphoranylidene)acetate] \[1099-45-2\] M 348.4, m 116-117°, 128-130°. Cryst by dissolving in AcOH and adding pet ether (b 40-50°) to give colorless plates. UV \(\lambda_{max} (A_{1cm}^{\lambda_{max}}): 222nm (865)\) and 268nm (116) [Isler et al. Helv Chim Acta 40 1242 1957].

Ethylarsonic acid \[507-32-4\] M 154.0, m 99.5°, \(pK_{1} 4.72 (\text{As(OH)O}-), pK_{2} 8.00 [\text{AsO}_{2}^{2-}]. \) Cryst from ethanol.

2-Ethyl-1,2-benzisoxazolium tetrafluoroborate \[4611-62-5\] M 235.0, m 107-109°, 109.5-110.2°. Recryst from MeCN-EtOAc to give magnificent crystals. It is not hygroscopic but on long exposure to moisture it etches glass. It is light-sensitive and should be stored in brown glass bottles. UV (H2O), \(\lambda_{max} 258\text{nm} (e 13 100)\) and \(\lambda_{max} 297\text{nm} (e 2 900)\); IR (CH2Cl2): 1613 (C=N) and 1111-1000 (BF3) [UV, IR, NMR: Kemp and Woodward Tetrahedron 21 3019 1965].
Ethylene bis(diphenylphosphine) [1,2-bis(diphenylphosphino)ethane] [1663-45-2] M 398.4, m 139-140°. See 1,2-bis(diphenylphosphino)ethane (DIPHOS) on p. 402.

Ethylmercuric chloride [107-27-7] M 265.1, m 193-194°. Mercuric chloride can be removed by suspending ethylmercuric chloride in hot distilled water, filtering with suction in a sintered-glass crucible and drying. Then crystd from ethanol and sublimed under reduced pressure. It can also be crystd from water.

Ethylmercuric iodide [2440-42-8] M 356.6, m 186°. Crystd once from water (50mL/g).

Ethyl Orange (sodium 4,4'-diethylaminophenylazobenzenesulfonate) [62758-12-7] M 355.4, pK_est - 3.8. Recrystd twice from water.

Ethyl trimethylsilylacetate [4071-88-9] M 160.3, b 74.5°/41mm, 75.5°/42mm, 157°/730mm, d 0.8762, n 1.4149. Purified by distilling ca 10g of reagent through a 15cm, Vigreux column and then redistilling through a 21cm glass helices-packed column [J Am Chem Soc 75 994 1953]. Alternatively, dissolve in Et_2O, wash with H_2O, dilute Na_2CO_3, dry over Na_2SO_4, evaporate Et_2O and fractionally distil. [J Am Chem Soc 72 1935 1950.]

Ethynyl tributylstannane [994-89-8] M 315.1, b 76°/0.2mm, 130-135°/0.7mm, 200°/2mm, d 1.1113, n 1.4770. Purified by dissolving the reagent (ca 50g) in heptane (250mL), washing with H_2O (100mL), drying (MgSO_4), evaporating and distilling in a vacuum. It has IR v 3280 (S-H), 2950, 2850, 2005 (C=C), 1455, 1065 and 865 cm^-1. [J Org Chem 46 5221 1981; JAm Chem Soc 109 2138 1987; J Gen Chem USSR (Engl Edn) 37 1469 1967.]

Ethynyl trimethylsilane [1066-54-2] M 98.2, b 53°/atm, 52.5°/atm, d 0.71, n 1.3871. Distil through an efficient column. The IR has bands at 2041 (C=C) and 3289 (S-H) cm^-1. [Chem Ber 92 30 1959.]


Ferric acetylacetonate [14024-18-1] M 353.2, m 181.3-182.3°. Recrystd twice from benzene-pet ether m 181.3-182.3° corr [J Chem Soc 1256 1938]. Recrystd from EtOH or Et_2O, m 179° [Justus Liebigs Ann Chem 323 13 1902]. Recrystd from absolute EtOH, m 159.5° [Chem Ber 67 286 1934]. Dry for 1hr at 120°.


Ferric chloride (anhydrous) [17705-08-0] M 162.2, m >300°(dec). Sublimed at 200° in an atmosphere of chlorine. Stored in a weighing bottle inside a desiccator.
Ferric chloride (6H₂O) [10025-77-1] M 270.3, m 37°(dec), pK⁺ 2.83, pK²⁻ 4.59 (for hydrolysis of Fe³⁺). An aqueous soln, saturated at room temperature, was cooled to -20° for several hours. Pptn was slow, even with scratching and seeding, and it was generally necessary to stir overnight. The presence of free HCl retards the pptn [Linke J Phys Chem 60 91 1956].

Ferric nitrate (9H₂O) [7782-61-8] M 404.0, m 47°(dec). Cryst from aqueous solutions of moderately strong HNO₃ as the violet nonahydrate. With more concentrated aqueous solns (containing some HNO₃), the hexahydrate crysts out. The anhydrous salt is slightly deliquescent and decomposes at 47°.

Ferric perchlorate (9H₂O) [13537-24-1] M 516.3, pK²⁻ 5 -2.4 to -3.1 (for HClO₄). Crystd twice from conc HClO₄, the first time in the presence of a small amount of H₂O₂ to ensure that the iron is fully oxidised [Sullivan J Am Chem Soc 84 4256 1962]. Extreme care should be taken with this preparation because it is potentially DANGEROUS.

Ferric sulfate (xH₂O) [10028-22-5] M 399.9 + xH₂O. Dissolve in the minimum volume of dilute aqueous H₂SO₄ and allow to evaporate at room temp until crystals start to form. Do not concentrate by boiling off the H₂O as basic salts will be formed. Various hydrates are formed—the common ones are the dodeca and nona hydrates which are violet in colour. The anhydrous salt is colourless and very hygroscopic but dissolves in H₂O slowly unless ferrous sulfate is added.


Ferrous bromide [20049-65-4] M 215.7 + xH₂O, m 684°, d²⁵ 4.63. Crystn from air-free H₂O provides the hexahydrate as pale green to bluish-green rhombic prisms. On heating at 49° H₂O is lost and the tetrahydrate is formed. Further heating at 83° more H₂O is lost and the dihydrate is formed as a light yellow to dark brown hygroscopic powder. The ferrous iron in the aqueous solns of these salts readily oxidises to ferric iron. The salts should be stored over H₂SO₄ under N₂ in tightly closed containers. They have some solubility in EtOH. [Chem Ber 38 236 1904.]

Ferrous chloride (4H₂O) [13478-10-9] M 198.8, m 105°(dec), pK⁺ 6.7, pK²⁻ 9.3 (for aquo Fe²⁺). A 550mL round-bottomed Pyrex flask was connected, via a glass tube fitted with a medium porosity
sintered-glass disc, to a similar flask. To 240g of FeCl₂.4H₂O in the first flask was added conductivity water (200mL), 38% HCl (10mL), and pure electrolytic iron (8-10g). A stream of purified N₂ was passed through the assembly, escaping through a mercury trap. The salt was dissolved by heating which was continued until complete reduction had occurred. By inverting the apparatus and filtering (under N₂ pressure) through the sintered glass disc, unreacted iron was removed. After cooling and crystn, the unit was again inverted and the crystals of ferrous chloride were filtered free from mother liquor by applied N₂ pressure. Partial drying by overnight evacuation at room temperature gave a mixed hydrate which, on further evacuation on a water bath at 80°, lost water of hydration and its absorbed HCl (with vigorous effervescence) to give a white powder, FeCl₂.2H₂O [Gayer and Wootner J Am Chem Soc 78 3944 1956].

Ferrous chloride [7758-94-3] M 126.8, m 674°, b 1023°, d²₅ 3.16. Sublimes in a stream of HCl at ca 700°, or in H₂ below 300°. Its vapour pressure at 700° is 12mm. Anhydrous FeBr₂ can be obtained by carefully dehydrating the tetrahydrate in a stream of HBr and N₂, and it can be sublimed under N₂. White hygroscopic rhombohedral crystals with a green tint. They oxidise in air to FeCl₃ + Fe₂O₃. Sol in H₂O, EtOH Me₂CO but insol in Et₂O. The tetrahydrate is pale green to pale blue in colour and loses 2H₂O at 105-115°. The dihydrate loses H₂O at 120°. The ferrous iron in the aqueous solns of these salts readily oxidises to ferric iron. [Inorg Synth 6 172 1960; Handbook of Preparative Inorganic Chemistry (Ed Brauer) Vol II 1491 1965.]


Ferrous sulfate (7H₂O) [7782-63-0] M 278.0, m ~60°(dec). Crystd from 0.4M H₂SO₄.


Fluoroboric acid [16872-11-0] M 87.8, pK -4.9. Crystd several times from conductivity water.

Fluorotrimethylsilane (trimethylsilyl fluoride, TMSF) [420-56-4] M 92.2, m -74°, b 16°/760mm, 19°/730mm, dº 0.793. It is a FLAMMABLE gas which is purified by fractional distn through a column at low temperature and with the exclusion of air [Booth and Suttle J Am Chem Soc 68 2658 1946; Reid and Wilkins J Chem Soc 4029 1955].

Gallium [7440-55-3] M 69.7, m 29.8°. Dissolved in dilute HCl and extracted into Et₂O. Pptn with H₂S removed many metals, and a second extraction with Et₂O freed Ga more completely, except for Mo, Th(III) and Fe which were largely removed by pptn with NaOH. The soln was then electrolysed in 10% NaOH with a Pt anode and cathode (2-5A at 4-5V) to deposit Ga, In, Zn and Pb, from which Ga was obtained by fractional crystn of the melt [Hoffman J Res Nat Bur Stand 13 665 1934]. Also purified by heating to boiling in 0.5-1M HCl, then heating to 40° in water and pouring the molten Ga with water under vacuum onto a glass filter (30-50 μ pore size), to remove any unmelting metals or oxide film. The Ga was then fractionally crystd from the melt under water.

Gallium (III) Chloride [13450-90-3] M 176.1, m 77.8°, b 133°/100mm, 197.7°/700mm, d 2.47, pK₂ 2.91, pK₃ 3.70, pK₄ 4.42 (for Ga³⁺). Pure compound can be obtained by redistn in a stream of Cl₂ or Cl₂/N₂ followed by vacuum sublimation or zone refining. Colourless needles which give gallium dichloride [Ga(GaCl₄)] m 172.4° on heating. Dissolves in H₂O with liberation of heat. Soluble in Et₂O. [Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol I 846 1963.]

Gallium (III) nitrate (9H₂O) [63462-65-7] M 417.9, m ca 65°. Recrystd from H₂O (sol: 295g/100mL at 20°). White deliquescent colourless powder soluble in H₂O, absolute EtOH and Et₂O. Loses
HNO₃ upon heating at 40°. Addition of Et₂O to a warm ethanolic soln (40-50°) of Ga(NO₃)₃ 9H₂O precipitates Ga(OH)₂N0₃.Ga(OH)₃.2H₂O. If the salt has partly hydrolysed, dissolve in conc HNO₃, reflux, dilute with H₂O and concentrate on a sand bath. Wash several times by adding H₂O and evaporate until there is no odour of acid. Dilute the residue to a Ga concentration of 26g/100mL. At this concentration, spongy Ga(NO₃)₃.xH₂O separates from the viscous soln. After standing for several days the crystals are collected and dried in a stream of dry air first at room temp then at 40°. Dehydration is complete after 2 days. Recrystallise from H₂O and dry on a water pump at room temperature. [Z Naturforsch 20B 71 1965; Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol I 8561963.]

Gallium (III) sulfate [13494-91-2 (anhydr); 13780-42-2 (hydr)] M 427.6. Recrystn from H₂O gives the 16-18H₂O hydrate (sol at 20° is 170g/100mL). Alternatively dissolve in 50% H₂SO₄ and evaporate (60-70°), cool and ppte by adding EtOH/Et₂O. On heating at 165° it provides the anhydrous salt which is a white hygroscopic solid. [Z Naturforsch 20B 71 1965.]

Germanium [7440-56-4] M 72.6, m 937°, 925-975°, b 2700°, d 5.3. Copper contamination on the surface and in the bulk of single crystals of Ge can be removed by immersion in molten alkali cyanide under N₂. The Ge was placed in dry cyanide powder in a graphite holder in a quartz or porcelain boat. The boat was then inserted into a heated furnace which, after a suitable time, was left to cool to room temperature. At 750°, a 1mm thickness requires about 1min, whereas 0.5cm needs about half hour. The boat was removed and the samples were taken out with plastic-coated tweezers, carefully rinsed in hot water and dried in air [Wang J Phys Chem 60 45 1956].

Germanium (IV) oxide [1310-53-8] M 104.6, m 1080°(soluble form), d²₅ 6.239; m 1116°(insoluble form) d²₅ 4.228, pk₁²₅ 9.02, pk₂²₅ 12.82 (for germanic acid H₂GeO₃). The oxide (GeO₂) is usually prepared by hydrolysing redistd GeCl₄ and igniting in order to remove H₂O and chloride. It can be further purified by dissolving in hot H₂O (sol: 4gL cold) evaporating and drying the residual crystalline solid. When the soluble form (which is produced in H₂O at 355°) is heated for 10h it is converted to the insoluble form. This form is stable at temperatures up to 1033°, and fusion at 1080° for 4h causes complete devitrification and it reverts to the soluble form. [J Am Chem Soc 46 2358 1924, 47 1945 1925, 54 1953 1032.1

Germanium tetrachloride [10038-98-9] M 214.4, m -49.5°(α), -52.0°(β), b 83.1°/760mm, 86.5°/760mm corr, d²₅ 1.84. Traces of CL₂ and HCl can be removed from the liquid by blowing dry air through it for a few hours at room temperature or shake it with Hg or Hg₂Cl₂ and then fractionally distil in a vacuum. It decomposes on heating at 950°. It has a sharp penetrating odour and fumes in moist air to give a chalky coat of GeO₂. It is slowly hydrolysed by H₂O to give GeO₂. [J Am Chem Soc 44 306 1922.]

Germanium tetraethoxide [14165-55-0] M 252.8, m -72°; b 54.5°/5mm, 71-72°/11mm, 188-190°/72mm, d²₅ 1.1288. Distil through a 10cm Vigreux column under reduced pressure. Alternatively distil through a Fensche glass helices column fitted with a total condensation variable take-off stillhead. Fractionate under reduced pressure using a reflux ratio of 10:1. [J Am Chem Soc 75 718 1953; J Chem Soc 4916 1956.]

Glass powder (100-300 mesh). Washed with 10% HNO₃, water and dried.

Gold (III) bromide (gold tribromide) [10294-28-7] M 436.7, m 150°(dec). Purified by adding pure Br₂ to the dark powder, securely stopper the container, warm a little and shake while keeping away from light for ca 48h. Remove the stopper and place over NaOH until free Br₂ is no longer in the apparatus (48-60h). The bright yellow needles of the tribromide are stable over NaOH in the dark. It is sol in H₂O and in EtOH where it is slowly reduced. Keep in a cooled closed container and protect from light as decomposition causes gold to be formed. Aurobromic acid can be obtained by adding the calculated amount of conc HBr to AuBr₃ (actually Au₂Br₆) until all dissolves, whereby the acid crystallises out as HAuBr₄.5H₂O, deliquescent solid soluble in EtOH with m ca 27°, and store as above. [J Chem Soc 2410 1931, 217, 219 1935.]
Gold (III) chloride (hydrate) \([16903-35-8]\) M 339.8 + xH₂O, m 229°, b 354°(dec), d 3.9. Obtained as a dark red crystalline mass by dissolving Au in aqua regia and evaporating. When sublimed at 180° the crystals are ruby red. The anhydrous salt is hygroscopic sol in H₂O but sparingly soluble in EtOH and Et₂O. Aurochloric acid is formed when AuCl₃ is dissolved in HCl. [J Am Chem Soc 35 553 1913; Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol II 1056 1965.]

Gold (I) cyanide \([506-65-0]\) M 223.0, m dec on heating. The lemon yellow powder is sparingly soluble in H₂O and EtOH but soluble in aqueous NH₃. It is obtained by heating H[Au(CN)₂] at 110°. Wash well with H₂O and EtOH and dry at 110°. It has an IR band at ν 2239 cm⁻¹ typical for C=N stretching vibration. [Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol II 1064 1965.]

CARE: may evolve HCN.

Gold (I) iodide \([10294-31-2]\) M 323.9, m 120°(dec), d 8.25. It has been prepared by heating gold and iodine in a tube at 120° for 4 months. Since it decomposes to Au and I₂ in the presence of UV light and heat then the main impurity is Au. The salt is therefore purified by heating at 120° with I₂ for several weeks. The crystals should be kept dry and in a cool place in the dark. [ZNaturforsch 11B 604 1956.]

Gold (III) oxide hydrate \([1303-58-8]\) M 441.9 + xH₂O, evolves O₂ at 110°, pK₂15 <11.7, pK₂13.36, pK₂15 >15.3 [for Au(OH)₃]. Most probable impurities are Cl⁻ ions. Dissolve in strong boiling KOH soln (ca 5M) and precipitate (care) with excess of 3N H₂SO₄. Then shake and centrifuge, resuspend in H₂O and repeat wash several times until free from SO₄ and Cl ions. This gives a wet oxide which is dried in air, and dec to Au in sunlight. It is best to keep it wet as it decomposes on drying (analyse wet sample). Store away from light in the presence of H₂O vapour. It evolves O₂ at 110°. It is insoluble in H₂O but soluble in HCl and conc HNO₃. [J Am Chem Soc 49 1221 1927.]

Graphite \([7782-42-5]\). Treated with hot 1:1 HCl. Filtered, washed, dried, powdered and heated in an evacuated quartz tube at 1000° until a high vacuum was obtained. Cooled and stored in an atmosphere of helium [Craig, Van Voorhis and Bartell J Phys Chem 60 1225 1956].


Helium \([7440-59-7]\) M 4.0. Dried by passage through a column of Linde 5A molecular sieves and CaSO₄, then passed through an activated-charcoal trap cooled in liquid N₂, to adsorb N₂, argon, xenon and krypton. Passed over CuO pellets at 300° to remove hydrogen and hydrocarbons, over Ca chips at 600° to remove oxygen, and then over titanium chips at 700° to remove N₂ [Arnold and Smith J Chem Soc, Faraday Trans 2 7786 1981].


Hexachlorocyclotriphosphazene \([940-71-6]\) M 347.7, m 113-114°, 113-115°. See phosphonitrilic chloride trimmer on p. 450.

Hexachloroplatinic acid hydrate (H₂PtCl₆, chloroplatinic acid, platinum IV chloride seuton) \([16941-12-1]\) M 409.8 + H₂O, m 60°(deliquescent solid). If it is to be purified, or regenerated from Pt recovered from catalytic hydrogenations, it was dissolved in aqua regia followed by evaporation to dryness and dissolution in the minimum vol of H₂O. Then the aqueous solution was treated with saturated ammonium chloride until all the ammonium hexachloroplatinate separated. The (NH₄)_2PtCl₆ was filtered off and dried at 100°. Ignite the salt to give Pt sponge, dissolve the Pt sponge in aqua regia, boil to
dryness, dissolve in concentrated HCl, boil to dryness again and repeat the process. Protect from light. [Hickers

Hexaethylsiloxane [924-49-0] M 246.5, b 114-115°/16mm, 235.5°/760mm, d 0.8443, n 1.4330. Distil in a vacuum, but can be distilled at atmospheric pressure without decomposition. It is characterised by completely dissolving in conc H2SO4. [J Chem Soc 3077 1950.]

2,2,4,4,6,6-Hexamethylcyclotrisiloxane [1009-93-4] M 219.5, m -10°, b 81-82°/19mm, 111-112°/85mm, 188°/760mm, d 0.9196, n 1.448. Purified by fractional distillation at atmospheric pressure until the temperature reaches 200°. The residue in the flask is mostly octamethylcyclotetrasilazane. [J Chem Soc 3077 1950.]

Hexamethyldisilane [1450-14-2] M 164.4, m 9-12°, b 113.1°/750mm, d 0.7272, n 1.4229. Most likely impurity is trimethylchlorosilane (cf boiling point). Wash with H2O, cold conc H2SO4, H2O again then aqueous NaHCO3, dry over CaSO4 and fractionate at atmospheric pressure. [J Chem Soc 281 1958.]

Grossly impure sample (25% impurities) was purified by repeated spinning band distn. This lowered the impurity level to 500 ppm. The main impurity was identified as 1-hydroxypentamethyldisilane. [J Am Chem Soc 70 3888 1948.]

Hexamethyldisilazane (HMDS) [999-97-3] M 161.4, b 125-125.6°/atm, 126°/760mm, d 0.7747, n 1.407. Possible impurity is MesSiCl. Wash well with pet ether and fractionate through a vacuum jacketed column packed with Helipac using a reflux ratio of 10:1. [J Org Chem 23 50 1958.]


Hexamethylphosphorous triamide (HMPT) [1608-26-0] M 163.2, f 7.2°, b 68-70°/1mm, 235°/760mm, d 1.024, n 1.460. The industrial synthesis is usually by treatment of POCl3 with excess of dimethylamine in isopropyl ether. Impurities are water, dimethylamine and its hydrochloride. It is purified by refluxing over BaO or CaO at about 4mm pressure in an atmosphere of nitrogen for several hours, then dist from sodium at the same pressure. The middle fraction (b ca 90°) is collected, refluxed over sodium under reduced pressure under nitrogen and distd. It is kept in the dark under nitrogen, and stored in solid CO2. Can also be stored over 4A molecular sieves. Alternatively, it is distd under vacuum from CaH2 at 60° and crystd twice in a cold room at 0°, seeding the liquid with crystals obtained by cooling in liquid nitrogen. After about two-thirds frozen, the remaining liquid is drained off [Fujinaga, Izutsu and Sakara Pure Appl Chem 44 117 1975]. For tests of purity see Fujinaga et al. in Purification of Solvents, Coetzee Ed., Pergamon Press, Oxford, 1982. For efficiency of desiccants in drying HMPT see Burfield and Smithers [J Org Chem 43 3966 1978; Sammes et al. J Chem Soc, Faraday Trans 2 8 281 1986]. CARCINOGEN.

Hexamethylphosphoramic triamide (HMPA) [680-31-9] M 179.2, f 7.2°, b 68-70°/1mm, 235°/760mm, d 1.024, n 1.460. The industrial synthesis is usually by treatment of POCl3 with excess of dimethylamine in isopropyl ether. Impurities are water, dimethylamine and its hydrochloride. It is purified by refluxing over BaO or CaO at about 4mm pressure in an atmosphere of nitrogen for several hours, then dist from sodium at the same pressure. The middle fraction (b ca 90°) is collected, refluxed over sodium under reduced pressure under nitrogen and distd. It is kept in the dark under nitrogen, and stored in solid CO2. Can also be stored over 4A molecular sieves. Alternatively, it is distd under vacuum from CaH2 at 60° and crystd twice in a cold room at 0°, seeding the liquid with crystals obtained by cooling in liquid nitrogen. After about two-thirds frozen, the remaining liquid is drained off [Fujinaga, Izutsu and Sakara Pure Appl Chem 44 117 1975]. For tests of purity see Fujinaga et al. in Purification of Solvents, Coetzee Ed., Pergamon Press, Oxford, 1982. For efficiency of desiccants in drying HMPT see Burfield and Smithers [J Org Chem 43 3966 1978; Sammes et al. J Chem Soc, Faraday Trans 2 8 281 1986]. CARCINOGEN.

Hexamethylenebismethane (HMPT) [1608-26-0] M 163.2, f 7.2°, b 49-51°/12mm, 162-164°/12mm, d 0.899, n 1.466. It may contain more than 1% of phosphoric triamide. The yellow oil is first distd at atm press then under reduced press and stored under N2. It is air sensitive, TOXIC, should not be inhaled and is absorbed through the skin. [Mark Org Synth Coll Vol V 602 1973.]

Hexaminecobalt(III) chloride [10534-89-1] M 267.5. Crystd from warm water (8mL/g) by cooling. [Bjerrum and McReynolds Inorg Synth 2 217 1946.]

Hexarhodium hexadecacarbonyl [28407-51-4] M 1065.6, m 220° (dec, in air), d 2.87. Slowly loses CO when heated in air; may be regenerated by heating at 80-200°C in the presence of CO at 200atm pressure for 15h, preferably in the presence of Cu. Forms black crystals which are insoluble in hexane. It has bands at 2073, 2026 and 1800 cm⁻¹ in the IR. [Z Anorg Allg Chem 251 96 1963; J Am Chem Soc 85 1202 1963; Tetrahedron Lett 22 1783 1981.]

Hydrazine (anhydrous) [302-01-2] M 32.1, f 1.5-2.0°, b 47°/26mm, 56°/71mm, 113-113.5°/atm, n 1.470, d 1.91, pK₂ -0.88, pK₅ 8.11. Hydrazine hydrate is dried by refluxing with an equal weight of KOH pellets for 3h, then distilled from fresh NaOH or BaO in a current of dry N₂. [Kovack et al. J Am Chem Soc 107 7360 1985.]

Hydrazine dihydrochloride [5341-61-7] M 105.0, m 198°, d 1.42. Crystd from aqueous EtOH and dried under vacuum over CaSO₄.

Hydrazine monohydrochloride [2644-70-4] M 68.5, m 89°. Prepared by dropwise addition of cold conc HC₁ to cold liquid hydrazine in equimolar amounts. The crystals were harvested from water and were twice recrystd from absolute MeOH and dried under vacuum. [Kovack et al. J Am Chem Soc 107 7360 1985.]

Hydriodic acid [10034-85-2] M 127.9, b 127° (aq azeotrope), d 1.701, pK₂ 8.56. Iodine can be removed from aqueous HI, probably as the amine hydrogen triiodide, by three successive extractions using a 4% soln of Amberlite LA-2 (a long-chain aliphatic amine) in CCl₄, toluene or pet ether (10mL per 100mL of acid). [Davidson and Jameson Chem Ind (London) 1686 1963.] Extraction with tributyl phosphate in CHCl₃ or other organic solvents is also suitable. Alternatively, a De-acidite FF anion-exchange resin column in the OH⁻-form using 2M NaOH, then into its I⁻-form by passing dilute KI soln, can be used. Passage of an HI solution under CO₂ through such a column removes polyiodide. The column can be regenerated with NaOH. [Irving and Wilson Chem Ind (London) 653 1964.] The earlier method was to reflux with red phosphorus and distil in a stream of N₂. The colourless product was stored in ampoules in the dark [Bradbury J Am Chem Soc 74 2709 1952; Z Inorg Synth 1 157 1939]. Fumes in moist air. HARMFUL VAPOURS.

Hydrobromic acid [10035-10-6] M 80.9, b 125° (aq azeotrope, 47.5% HBr), d 1.38 (34% HBr), pK₂ 8.69. A soln of aqueous HBr ca 48% (w/w, constant boiling) was distilled twice with a little red phosphorus, and the middle half of the distillate was taken. (The azeotrope at 760mm contains 47.8% (w/w) HBr.) [Hetzer, Robinson and Bates J Phys Chem 66 1423 1962.] Free bromine can be removed by Irvine and Wilson's method for HI (see above), except that the column is regenerated by washing with an ethanolic solution of aniline or styrene. Hydrobromic acid can also be purified by aerating with H₂S, distilling and collecting the fraction boiling at 125-127°. [Inorg Synth 1 155 1939.] HARMFUL VAPOURS.

Hydrochloric acid [7647-01-0] M 36.5, b 108.6° (aq azeotrope, 20.2% HCl), d 1.09 (20%), pK₂ 6.1. Readily purified by fractional distillation as constant boiling point acid, following dilution with H₂O. The constant-boiling fraction contains 1 mole of HCl in the following weights of distillate at the stated pressures: 179.555g (730mm), 179.766g (740mm), 179.979 (750mm), 180.193 (760mm), 180.407 (770mm) [Foulk and Hollingsworth J Am Chem Soc 45 1220 1923..] HARMFUL VAPOURS.

Hydrofluoric acid [7664-39-3] M 20.0, b 112.2° (aq azeotrope, 38.2% HF), d 1.15 (47-53% HF), pK₂ 3.21. Freed from lead (Pb ca 0.002ppm) by co-precipitation with SrF₂, by addition of 10mL of 10% SrCl₂ soln per kilogram of the conc acid. After the ppt has settled, the supernatant is decanted through a filter in a hard-rubber or paraffin lined-glass vessel [Rosenqvist Am J Sci 240 358 1942]. Pure aqueous HF solutions (up to 25M) can be prepared by isothermal distn in polyethylene, polypropylene or platinum apparatus [Kwestroo and Visser Analyst 90 297 1965]. HIGHLY TOXIC.

Hydrogen [1333-74-0] M 2.0, m -259.1°, -252.9°. Usually purified by passage through suitable absorption train. Carbon dioxide is removed with KOH pellets, soda-lime or NaOH pellets. Oxygen is removed with a "De-oxo" unit or by passage over Cu heated to 450-500°C on Kieselguhr at 250°C. Passage over a mixture of MnO₂ and CuO (Hopcalite) oxidises any CO to CO₂ (which is removed as above). Hydrogen can be dried by passage through dried silica-alumina at -195°C, through a dry-ice trap followed by a liquid-N₂ trap.
packed with glass wool, through CaCl$_2$ tubes, or through Mg(ClO$_4$)$_2$ or P$_2$O$_5$. Other purification steps include passage through a hot palladium thimble [Masson *J Am Chem Soc* 74 4731 1952], through an activated-charcoal trap at -195°, and through non-absorbent cotton-wool filter or small glass spheres coated with a thin layer of silicone grease. *Potentially VERY EXPLOSIVE in air.*

**Hydrogen bromide (anhydrous) [10035-10-6] M 80.9.** Dried by passage through Mg(ClO$_4$)$_2$ towers. This procedure is **hazardous**, see Stoss and Zimmermann [*Ind Eng Chem* 17 70 1939]. Shaken with mercury, distd through a -78° trap and condensed at -195°/10$^{-5}$mm. Fumes in moist air. **HARMFUL VAPOURS.**

**Hydrogen chloride [7647-01-0] M 36.5.** Passed through conc H$_2$SO$_4$, then over activated charcoal and silica gel. Fumes in moist air. Hydrogen chloride in gas cylinder include ethylene, 1,1-dichloroethane and ethyl chloride. The latter two may be removed by fractionating the HCl through a trap cooled to -112°. Ethylene is difficult to remove. **Fumes in moist air.** **HARMFUL VAPOURS.**

**Hydrogen cyanide (anhydrous) [74-90-8] M 27.0, b 25.7°, pK$_{\text{aq acid}}$ 9.21 (aq acid).** Prepared from NaCN and H$_2$SO$_4$, and dried by passage through H$_2$SO$_4$ and over CaCl$_2$, then distilled in a vacuum system and degassed at 77°K before use [Arnold and Smith *J Chem Soc, Faraday Trans 2* 77 861 1981]. Cylinder HCN may contain stabilisers against explosive polymerisation, together with small amounts of H$_3$PO$_4$, H$_2$SO$_4$, SO$_2$, and water. It can be purified by distn over P$_2$O$_5$, then frozen in Pyrex bottles at Dry-ice temperature for storage. **EXTREMELY POISONOUS.**

**Hydrogen fluoride (anhydrous) [7664-39-3] M 20.0, b 19.4°.** Can be purified by trap-to-trap distn, followed by drying over CoF$_2$ at room temperature and further distn. Alternatively, it can be absorbed on NaF to form NaHF$_2$ which is then heated under vacuum at 150° to remove volatile impurities. The HF is regenerated by heating at 300° and stored with CoF$_2$ in a nickel vessel, being distilled as required. (Water content ca 0.01%.) To avoid contact with base metal, use can be made of nickel, polychlorotrifluoroethylene and gold-lined fittings [Hyman, Kilpatrick and Katz *J Am Chem Soc* 79 3688 1957]. **HIGHLY TOXIC.**

**Hydrogen iodide (anhydrous) [10034-85-2] M 127.9, b -35.5°.** After removal of free iodine from aqueous HI, the solution is frozen, then covered with P$_2$O$_5$ and allowed to melt under vacuum. The gas evolved is dried by passage through P$_2$O$_5$ on glass wool. It can be freed from iodine contamination by repeated fractional distillation at low temperatures. Fumes in moist air. **HARMFUL VAPOURS.**

**Hydrogen ionophore II (ETH 1907) (4-nonadecylpyridine - Proton ionophore) [70268-36-9] M 345.6, b 180°/0.07mm, pK$_{\text{aet}}$~ 6.0.** Dissolve the waxy solid (ca 60g) in CHC$_3$ (200mL), wash with H$_2$O (3 x 200mL), dry and evaporate to dryness then distil in vacuum. A waxy solid is formed on cooling the distillate. UV: 257nm (ε 1.86 x 10$^3$ M$^{-1}$cm$^{-1}$), 308nm (ε 1.7 x 10$^2$ M$^{-1}$cm$^{-1}$). [IR, NMR UV: *Inorg Chem* 18 2160 1979.]

**Hydrogen ionophore III (N,N-dioctadecyl methylamine) [4088-22-6] M 536.0, m 40°, 44-46°, 48-49°, b 252-259°, pK$_{\text{aet}}$~ 10.** It can be distd at high vacuum; but dissolving in *C$_6$H$_6$, filtering and evaporating gives a waxy solid suitable for electrode use. It recrystallises from Me$_2$CO. [Chem Ber 69 60 1936; *Talanta* 34 435 1987.]

**Hydrogen ionophore IV ETH 1778 (octadecyl isonicotinate) [103225-02-1] M 375.6, m 57.5°, pK$_{\text{aet}}$~ 3.5.** Dissolve in Et$_2$O and wash 3 times with H$_2$O. Dry, evaporate, and recrystallise the residue from EtOAc/hexane (4:1). [Anal Chem 58 2285 1986.]

**Hydrogen peroxide [7722-84-1] M 34.0, d 1.110, pK$_{\text{a}}$ 11.65.** The 30% material has been steam distilled using distilled water. Gross and Taylor [*J Am Chem Soc* 72 2075 1950] made 90% H$_2$O$_2$ approximately 0.001M in NaOH and then distilled under its own vapour pressure, keeping the temperature below 40°, the receiver being cooled with a Dry-ice/isopropyl alcohol mush. The 98% material has been rendered anhydrous by repeated fractional crystallisation in all-quartz vessels. **EXPLOSIVE IN CONTACT WITH ORGANIC MATERIAL.**
Hydrogen sulfide [7783-06-4] M 34.1, b -59.6°, pK_H^+ 7.05, pK_OH^- 12.89. Washed, then passed through a train of flasks containing saturated Ba(OH)_2 (2x), water (2x), and dilute HCl [Goates et al. J Am Chem Soc 73 707 1951]. HIGHLY POISONOUS.


Hydroxylamine Crystd from n-butanol at -10°, collected by vacuum filtration and washed with cold diethyl ether. Harmful vapours.

Hydroxylamine hydrochloride [5470-11-1] M 69.5, m 151°. Crystallised from aqueous 75% ethanol or boiling methanol, and dried under vacuum over CaSO_4 or P_2O_5. Has also been dissolved in a minimum of water and saturated with HCl; after three such crysts it was dried under vacuum over CaCl_2 and NaOH.

Hydroxylamine sulfate [10039-54-0] M 164.1, m 170°(dec). Crystallised from boiling water (1.6mL/g) by cooling to 0°.

Hydroxylamine-O-sulfonic acid [2950-43-8] M 113.1, m 210-211°, 215°(dec), pK 1.48. Stir the solid vigorously with anhydrous Et_2O and filter off using large volumes of dry Et_2O. Drain dry at the pump for 5min and then for 1-14h in a vacuum. Store in a vacuum desiccator/conc H_2SO_4. Determine the purity by oxidation of iodide to I_2. Must be stored in a dry atmosphere at 0-4°. It decompose slowly in H_2O at 25° and more rapidly above this temperature. [Inorg Synth 5 122 1957.]

Hydroxynaphthol Blue tri-Na salt [63451-35-4] M 620.5, m dec on heating, pK_Est <0. Crude material was treated with hot EtOH to remove soluble impurities, then dissolved in 20% aqueous MeOH and chromatographed on a cellulose powder column with propanol:EtOH:water (5:5:4) as eluent. The upper of three zones was eluted to give the pure dye which was ppted as the monosodium salt trihydrate by adding conc HCl to the concentrated eluate [Ito and Ueno Analyst 95 583 1970].

4-Hydroxy-3-nitrobenzenearsonic acid [121-19-7] M 263.0. See 2-nitrophenol-4-arsonic acid on p. 446.

Hydroxyurea [127-07-1] M 76.1, m 70-72° (unstable form), m 133-136°, 141° (stable form), pK 10.6. Recrystallise from absolute EtOH to remove soluble impurities, then dissolved in 20% aqueous MeOH and chromatographed on a cellulose powder column with propanol:EtOH:water (5:5:4) as eluent. The upper of three zones was eluted to give the pure dye which was ppted as the monosodium salt trihydrate by adding conc HCl to the concentrated eluate [Ito and Ueno Analyst 95 583 1970].

Hypophosphorous acid (Phosphinic acid) [6303-21-5] M 66.0, m 26.5°, d_4^3 1.217, 1.13 and 1.04 for 50, 30-32, and 10% aq solns resp, pK_2 1.31 (H_3PO_2). Phosphorous acid is a common contaminant of commercial 50% hypophosphorous acid. Jenkins and Jones [J Am Chem Soc 74 1353 1952] purified this material by evaporating about 600mL in a 1L flask at 40°, under reduced pressure (in N_2), to a volume of about 300mL. After the soh was cooled, it was transferred to a wide-mouthed Erlenmeyer flask which was stoppered and left in a Drierite/acetone bath for several hours to freeze (if necessary, with scratching of the wall). When the flask was then left at ca 5° for 12h, about 30-40% of it liquefied, and again filtered. This process was repeated, then the solid was stored over Mg(ClO_4)_2 in a vacuum desiccator in the cold. Subsequent crysts from n-butanol by dissolving it at room temperature and then cooling in an ice-salt bath at -20° did not appear to purify it further. The free acid forms deliquescent crystals m 26.5°, and is soluble in H_2O and EtOH. The NaH_2PO_2 salt can be purified through an anion exchange resin [Z Anorg Allg Chem 260 267 1949].

Indigocarmine (2-[1,3-dihydro-3-oxo-5-sulfo-2H-indol-2-ylidene]-2,3-dihydro-3-oxo-1H-indole-5-sulfonic acid di-Na salt) [860-22-0] M 466.4, pK_1 2.8, pK_2 12.3. It's
solubility in H₂O is 1g/100mL at 25°. Could be purified by dissolving in H₂O, filtering and adding EtOH to cause the salt to separate. Wash the solid with EtOH, Et₂O and dry in vacuo. [Vöhrander and Schubert Chem Ber 34 1860 1901; UV: Smit et al. Anal Chem 27 1159 1955; Preisler et al. J Am Chem Soc 81 1991 1959.]

**Indium** [7440-74-6] M 114.8, m 156.6°, b 2000°, d 7.31. Before use, the metal surface can be cleaned with dilute HNO₃, followed by a thorough washing with water and an alcohol rinse.

**Indium (III) chloride** [10025-82-8] M 211.2, m 586°, d 4.0, pK₁ 3.54, pK₂ 4.28, pK₃ 5.16 (for aquo In³⁺). The anhydrous salt forms yellow deliquescent crystals which can be sublimed at 600° in the presence of Cl₂/N₂ (1:10) (does not melt). It is resublimed in the presence of Cl₂/N₂ (1:10) and finally heated to 150° to expel excess Cl₂. It is soluble in H₂O and should be stored in a tightly closed container. [J Am Chem Soc 55 1943 1933, Smit et al. Anal Chem 27 1159 1955; Preisler et al. J Am Chem Soc 81 1991 1959.]

**Indium (III) oxide** [1312-43-2] M 277.6, d 7.18, m sublimes at 850°. Wash with H₂O and dry below 850°. Volatilises at 850° and dissolves in hot mineral acids to form salts. Store away from light because it darkens due to formation of In.


**Indium (III) sulfate (5H₂O)** [17069-79-3] M 607.9, d 3.44. Dissolve in strong H₂SO₄ and slowly evaporate at ca 50°. Wash crystals with glacial AcOH and then heat in a furnace at a temperature of 450-500° for 6h. Sol in H₂O is 5%. The pentahydrate is converted to an anhydrous hygroscopic powder on heating at 500° for 6h; but heating above this temperature over N₂ yields the oxide sulfate. Evaporation of neutral aqueous solutions provides basic sulfates. [J Am Chem Soc 55 1943 1993, 58 2126 1933.]

**Iodic acid** [7782-68-5] M 175.9, m 118°(dec), d 4.628, pK₂ 0.79. Dissolve in the minimum volume of hot dilute HNO₃, filter and evaporate in a vacuum desiccator until crystals are formed. Collect crystals and wash with a little cold H₂O and dry in the dark. Soluble in H₂O: 269g/100mL at 20° and 295g/100mL at 40°. Soluble in dilute EtOH and darkens on exposure to light. It is converted to HIO₃·H₂O on heating at 70°, but at 220° complete conversion to HIO₃ occurs. [J Am Chem Soc 42 1636 1920, 53 44 1931.]

**Iodine** [7553-56-2] M 253.8, m 113.6°. Usually purified by vacuum sublimation. Preliminary purifications include grinding with 25% by weight of KI, blending with 10% BaO and subliming; subliming with CaO; grinding to a powder and treating with successive portions of H₂O to remove dissolved salts, then drying; and crystn from benzene. Barrer and Wasilewski [Trans Faraday Soc 57 1140 1961] dissolved I₂ in conc KI and distilled it, then steam distilled three times, washing with distilled H₂O. Organic material was removed by sublimation in a current of O₂ over platinum at about 700°, the iodine being finally sublimed under vacuum. HARMFUL VAPOURS.

**Iodine monobromide** [7789-33-5] M 206.8, m 42°. Purified by repeated fractional crystallisation from its melt.

**Iodine monochloride** [7790-99-0] M 162.4, m 27.2°. Purified by repeated fractional crystallisation from its melt.

**Iodine pentafluoride** [7783-66-6] M 221.9, m -8.0°, b 97°. Rogers et al. [J Am Chem Soc 76 4843 1954] removed dissolved iodine from IF₅ by agitating with a mixture of dry air and CIF₂ in a Fluorothene beaker using a magnetic stirrer. The mixture was transferred to a still and the more volatile impurities were pumped off as the pressure was reduced below 40mm. The still was gradually heated (kept at 40mm) to remove the CIF₂ before IF₅ distilled. Stevens [J Org Chem 26 3451 1961] pumped IF₅ under vacuum from its cylinder, trapping it at -78°, then allowing it to melt in a stream of dry N₂. HARMFUL VAPOURS.

**Iodine trichloride** [865-44-1] M 233.3, m 33°, b 77°(dec). Purified by sublimation at room temperature.
Iodomethyl trimethylsilane \([4206-67-1]\) M 214.1, b 139.5°/744mm, d 1.44, \(n_D^{25} 1.4917\). It is slightly violet in colour wash with aqueous 1% sodium metabisulfite, H2O, dry over Na2SO4 and fractionally distil at atmospheric pressure. [J Am Chem Soc 68 481 1946.]

Iodotrimethylsilane (trimethylsilyl iodide, TMSI) \([16029-98-4]\) M 200.1, b 106.8°/742mm, 107°/760mm, d 1.47. Add a little antimony powder and fractionate with this powder in the still. Stabilise with 1% wt of Cu powder. [J Am Chem Soc 68 481 1946.]

Iridium \([7439-88-5]\) M 192.2, m 2450°, b -4500°, d 22.65. It is a silver white hard solid which oxidises on the surface in air. Scrape the outer tarnished layer until silver clear and store under paraffin. Stable to acids but dissolves in aqua regia. [Chem Rev 32 277 1934.]

Iridium (IV) chloride hydrate (hexachloroiridic acid) \([16454-81-8]\) M 334.0+H2O. If it contains nitrogen then repeatedly concentrate a conc HCl solution until free from nitrogen, and dry free from HCl in a vac over CaO until crystals are formed. The solid is very hygroscopic. [J Am Chem Soc 53 884 1931; Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol II 1592 1965.]

Iron (wire) \([7439-89-6]\) M 55.9, m 1535°. Cleaned in conc HCl, rinsed in de-ionised water, then reagent grade acetone and dried under vacuum.

Iron enneacarbonyl (di-iron nonacarbonyl) \([15321-51-4]\) M 363.7, m 100°(dec). Wash with EtOH and Et2O and dry in air. Sublimes at 35° at high vacuum. Dark yellow plates stable for several days when kept in small amounts. Large amounts, especially when placed in a desiccator spontaneously ignite in a period of one day. It decomposes in moist air. It is insoluble in hydrocarbon solvents but forms complexes with several organic compounds. [J Am Chem Soc 72 1107 1950; Chem Ber 60 1424 1927.]

Iron pentacarbonyl (pentacarbonyl iron) \([13463-40-6]\) M 195.9, m -20°, b 102.8°/749mm, 103°/760mm, n 1.520, d 1.490. It is a pale yellow viscous liq which is PYROPHORIC and readily absorbed by the skin. HIGHLY TOXIC (protect from light and air). It should be purified in a vacuum line by distilling and collecting in a trap at -96° (toluene-Dry ice slush). It has been distd at atm pressure (use a very efficient fume cupboard). At 180°/atm it decomp to give Fe and CO. In UV light in pet ether it forms Fe2(CO)+ [Hagen et al. Znorg Chem 17 1369 1978; Ewens et al. Trans Faraday Soc 35 681 1939.]

Isopropyldimethyl chlorosilane \([3634-56-8]\) M 140.7, b 109.8-110.0°/738mm, d 0.88, n 1.4158. Probable impurity is Me3SiCl (b 56.9°/783mm) which can be removed by efficient fractional distillation. [J Am Chem Soc 76 801 1954.]

\((2,3-O-\text{Isopropylidene})-2,3\text{-dihydroxy-1,4-bis-(diphenylphosphino)}\text{-butane} (\text{DIOP}) \) \([4R,5S\text{-}(-)\text{-}32305-98-9; 4S,5R\text{-}(+)\text{-}37002-48-5]\) M 498.5, m 88-90°, \([\alpha]_D^{19} \text{(-) and (+)}\text{ 26}°\) (c 2.3, CHCl3), pK\text{H}~4.5. It has been recrystd from \(\text{C}_6\text{H}_6\text{-pet ether. After 2 recrystns from EtOH it was pure by TLC on silica gel using Me}_2\text{CO-hexane as solvent. [Kagan and Dang J Am Chem Soc 94 6429 1972.]}

Lanthanide shift reagents see p. 277 in Chapter 4.

Lanthanum \([7439-91-0]\) M 138.9, m 920°, b 3470°, d 6.16. White metal that slowly tarnishes in air due to oxidation. Slowly decomposed by H2O in the cold and more rapidly on heating to form the
hydroxide. The metal is cleaned by scraping off the tarnished areas until the shiny metal is revealed and stored under oil or paraffin. It burns in air at 450°.

**Lanthanum triacetate**  [917-70-4]  M 316.0, \( pK_a^{25} 9.06 \) (for aquo La\(^{3+}\)). Boil with redistilled \( \text{Ac}_2\text{O} \) for 10 min (does not dissolve and is a white solid). Cool, filter, wash with \( \text{Ac}_2\text{O} \) and keep in a vacuum desiccator (NaOH) till free from solvent. [J Indian Chem Soc 33 877 1956.]

\( N\)-\( \text{Lauroyl-N-methyltaurine sodium salt} \) (sodium \( N\)-decanoyl-\( N\)-methyl-2-aminoethane sulfonate)  [4337-75-1]  M 343.5, \( pK_a^{10.1} \). Prepared from methyldecanoate (at 180° under \( \text{N}_2 \)) or decanoyl chloride and sodium \( N\)-methylthane sulfonate and purified by dissolving in \( \text{H}_2\text{O} \) and precipitating by addition of \( \text{Et}_2\text{O} \). Decomposes on heating. [Desseigne and Mathian Mém Services Chim Etat Paris 31 359 1944, Chem Abstr 41 705 1947.]

**Lead II acetate**  [301-04-2 (anhyd); 6080-56-4 (\( 3\text{H}_2\text{O} \))]  M 325.3, \( m 280°, pK_a^{10.1} \) (for \( \text{Pb}^{2+} \)), \( pK_a^{5.8} \) (\( \text{PbO}_2^{2-} \)). Crystallised twice from anhydrous acetic acid and dried under vacuum for 24 h at 100°.


**Lead (II) bromide**  [7758-95-4]  M 278.1, \( m 501° \). Crystallised from distilled water at 100° (33 mL/g) after filtering through sintered-glass and adding a few drops of HCl, by cooling. After three crystns the solid was dried under vacuum or under anhydrous HCl vapour by heating slowly to 400°.

**Lead diethyl dithiocarbamate**  [17549-30-3]  M 503.7, \( pK_a^{25} 3.36 \) (for \( N, N\)-diethyl dithiocarbamate). Wash with \( \text{H}_2\text{O} \) and dry at 60-70°, or dissolve in the min vol of \( \text{CH}_3\text{Cl}_2 \) and add the same vol of EtOH. Collect the solid that separates and dry as before. Alternatively, recryst by slow evaporation of a \( \text{CH}_3\text{Cl}_2 \) soln at 70-80°. Filter the crystals, wash with \( \text{H}_2\text{O} \) until all \( \text{Pb}^{2+} \) ions are eluted (check by adding chromate) and then dry at 60-70° for at least 10 h. [Justus Liebigs Ann Chem 49 1146 1977.]

**Lead (II) formate**  [811-54-4]  M 297.3, \( m 190° \). Crystd from aqueous formic acid.

**Lead (II) iodide**  [10101-63-0]  M 461.0, \( m 402° \). Crystd from a large volume of water.

**Lead (II) nitrate**  [10099-74-8]  M 331.2, \( m 470° \). Ppted twice from hot (60°) conc aqueous soln by adding \( \text{HNO}_3 \). The ppt was sucked dry in a sintered-glass funnel, then transferred to a crystallising dish which was covered by a clock glass and left in an electric oven at 110° for several hours [Beck, Singh and Wynne-Jones Trans Faraday Soc 55 331 1959]. After 2 recrystns of ACS grade no metals above 0.001 ppm were detected.

**Lead tetraacetate**  [546-67-8]  M 443.4, \( m 175-180°, pK_a^{1.8}, pK_a^{5.2}, pK_a^{5.2}, pK_a^{6.7} \). Dissolved in hot glacial acetic acid, any lead oxide being removed by filtration. White crystals of lead tetraacetate separated on cooling. Stored in a vacuum desiccator over \( \text{P}_2\text{O}_5 \) and KOH for 24 h before use.

**Lissamine Green B** \( 1\text{-}[\text{-bis-(4,4'-dimethylaminophenyl)methyl}-2-hydroxyanaphthalene-3,6-disulfonic acid sodium salt, Acid Green 50] \)  [3087-16-9]  M 576.6, \( m >200°(\text{dec}) \), Cl 44090, \( \lambda_{\text{max}} 633\text{nm} \). Crystd from EtOH/water (1:1, v/v).
Lissapol C (mainly sodium salt of 9-octadecene-1- sulfate) [2425-51-6]. Refluxed with 95% EtOH, then filtered to remove insoluble inorganic electrolytes. The alcohol solution was then concentrated and the residue was poured into dry acetone. The ppt was filtered off, washed in acetone and dried under vacuum. [Biswa and Mukerji J Phys Chem 64 1 1960].

Lissapol LS (mainly sodium salt of anisidine sulfate) [28903-20-0]. Refluxed with 95% EtOH, then filtered to remove insoluble inorganic electrolytes. The alcohol solution was then concentrated and the residue was poured into dry acetone. The ppt was filtered off, washed in acetone and dried under vacuum. [Biswa and Mukerji J Phys Chem 64 1 1960].

Lithium (metal) [7439-93-2] M 6.9, m 180.5°, b 1342°, d 0.534. After washing with pet ether to remove storage oil, lithium was fused at 400° and then forced through a 10-micron stainless-steel filter with argon pressure. It was again melted in a dry-box, skimmed, and poured into an iron distillation pot. After heating under vacuum to 500°, cooling and returning to the dry-box for a further cleaning of its surface, the lithium was distd at 600° using an all-iron distn apparatus [Gun and Green J Am Chem Soc 80 4782 1958].

Lithium acetate (2H2O) [546-89-4] M 102.0, m 54-56°. Crystallised from EtOH (5mL/g) by partial evaporation.

Lithium aluminium hydride [16853-85-3] M 37.9, m 125°(dec). Extracted with Et2O, and, after filtering, the solvent was removed under vacuum. The residue was dried at 60° for 3h, under high vacuum [Ruff J Am Chem Soc 83 1788 1961]. IGNITES in the presence of a small amount of water and reacts EXPLOSIVELY.

Lithium amide [7782-89-0] M 23.0, m 380-400°, d17.5 1.178. Purified by heating at 400° while NH3 is passed over it in the upper of two crucibles (the upper crucible is perforated). The LiNH2 will drip into the lower crucible through the holes in the upper crucible. The product is cooled in a stream of NH3. Protect it from air and moisture, store under N2 in a clear glass bottle sealed with paraffin. Store small quantities so that all material is used once the bottle is opened. If the colour of the amide is yellow it should be destroyed as it is likely to have oxidised and to EXPLODE. On heating above 450° it is decomposed to Li2NH which is stable up to 750-800°. [Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol 1 463 1963; Inorg Synth 2 135 1953.]

Lithium benzoate [553-54-8] M 128.1. from EtOH (13mL/g) by partial evaporation.

Lithium borohydride [16949-15-8] M 21.8, mCrystd 268°, b 380°(dec), d 0.66. Crystd from Et2O, and pumped free of ether at 90-100° during 2h [Schaeffer, Roscoe and Stewart J Am Chem Soc 78 729 1956].

Lithium bromide [7550-35-8] M 86.8, m 550°. Crystd several times from water or EtOH, then dried under high vacuum for 2 days at room temperature, followed by drying at 100°.

Lithium carbonate [554-13-2] M 73.9, m 552°, 618°. Crystd from water. Its solubility decreases as the temperature is raised.

Lithium chloride [7447-41-8] M 42.4, m 600°, 723°. Crystd from water (1mL/g) or MeOH and dried for several hours at 130°. Other metal ions can be removed by preliminary crystallisation from hot aqueous 0.01M disodium EDTA. Has also been crystallised from conc HCl, fused in an atmosphere of dry HCl gas, cooled under dry N2 and pulvrised in a dry-box. Kolthoff and Bruckenstein [J Am Chem Soc 74 2529 1952] ppid with ammonium carbonate, washed with Li2CO3 five times by decantation and finally with suction, then dissolved in HCl. The LiCl solution was evaporated slowly with continuous stirring in a large evaporating dish, the dry powder being stored (while still hot) in a desiccator over CaCl2.

Lithium diisopropylamide [4111-54-0] M 107.1, b 82-84°/atm, 84%/atm, d22 0.722, flash point -6°. It is purified by refluxing over Na wire or NaH for 30min and then distilled into a receiver under
N₂. Because of the low boiling point of the amine a dispersion of NaH in mineral oil can be used directly in this purification without prior removal of the oil. It is HIGHLY FLAMMABLE, and is decomposed by air and moisture. [Org Synth 50 67 1970.]

Lithium dodecylsulfate [2044-56-6] M 272.3. Recrystd twice from absolute EtOH and dried under vacuum.

Lithium fluoride [7789-24-4] M 25.9, m 842°, 848°, b 1676°, 1681°, d 2.640. Possible impurities are Li₂CO₃, H₂O and HF. These can be removed by calcining at red heat, then pulverised with a Pt pestle and stored in a paraffin bottle. Solubility in H₂O is 0.27% at 18°. It volatilises between 1100-1200°. [Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol I 235 1963.]

Lithium formate (H₂O) [6108-23-2 (H₂O); 556-63-8 (anhydr)] M 70.0, d 1.46. Crystd from hot water (0.5mL/g) by chilling.

Lithium hydride. [7580-67-8] M 7.95, m 680°, d 0.76-0.77. It should be a white powder otherwise replace it. It darkens rapidly on exposure to air and is decomposed by H₂O to give H₂ and LiOH, and reacts with lower alcohols. One gram in H₂O liberates 2.8L of H₂ (Could be explosive).

Lithium hydroxide (H₂O) [1310-66-3 (H₂O); 1310-65-2 (anhydr)] M 42.0, m 471°, d 1.51, pK₂5 13.82. Crystd from hot water (3mL/g) as the monohydrate. Dehydrated at 150° in a stream of CO₂-free air.


Lithium iodide [10377-51-2] M 133.8, m 469°, b 1171°, d 1.51, pK₂5 13.82. Crystd from hot water (3mL/g) by cooling in CaCl₂-ice, or from acetone. Dried under vacuum over P₂O₅ for 1h at 60° and then at 120°.

Lithium methylate (lithium methoxide) [865-34-9] M 38.0. Most probable impurity is LiOH due to hydrolysis by moisture. It is important to keep the sample dry. It can be dried by keeping in a vacuum at 60-80° under dry N₂ using an oil pump for a few hours. Store under N₂ in the cold. It should not have bands above 3000cm⁻¹; IR has vKBr 1078, 2790, 2840 and 2930cm⁻¹. [J Org Chem 21 156 1956.]

Lithium nitrate [7790-69-4] M 68.9, m 253°, d 2.38. Crystd from water or EtOH. Dried at 180° for several days by repeated melting under vacuum. If it is crystallised from water keeping the temperature above 70°, formation of trihydrate is avoided. The anhydrous salt is dried at 120° and stored in a vac desiccator over CaSO₄. After 99% salt was recrystd 3 times it contained: metal (ppm) Ca (1.6), K (1.1), Mo (0.4), Na (2.2).

Lithium nitrite (H₂O) [13568-33-7] M 68.9, m 253°, d 2.38. Crystd from water or EtOH. Dried at 180° for several days by repeated melting under vacuum. If it is crystallised from water keeping the temperature above 70°, formation of trihydrate is avoided. The anhydrous salt is dried at 120° and stored in a vac desiccator over CaSO₄. After 99% salt was recrystd 3 times it contained: metal (ppm) Ca (1.6), K (1.1), Mo (0.4), Na (2.2).

Lithium perchlorate [7791-03-9] M 106.4, pK₂5 -2.4 to -3.1 (for HClO₄). Crystd from water or 50% aq MeOH. Rendered anhydrous by heating the trihydrate at 170-180° in an air oven. It can then be recrystd twice from acetonitrile and again dried under vacuum [Mohammad and Kosower J Am Chem Soc 93 2713 1971].

Lithium salicylate [552-38-5] M 144.1. Crystd from EtOH (2mL/g) by partial evaporation.

Lithium sulfate (anhydrous) [10377-48-7] M 109.9, loses H₂O at 130° and m 859°, d 2.21. Crystd from H₂O (4mL/g) by partial evaporation.
50°. Wash the residue with dry Et₂O, and pass dry N₂ gas over the solid and finally heat in an oven at 80-90°. Solubility in Et₂O: 1.9(1.3) g in 100 mL at 25°, in THF: 71 g in 100 mL at 25°. It is hygroscopic and is an IRRITANT. [J Am Chem Soc 74 5211 1952, 75 1753 1953.]

Lithium thiocyanate (lithium rhodanide) [556-65-0] M 65.0, pK₂ 1.85 (for HSCN). It crystallises from H₂O as the dihydrate but on drying at 38-42° it gives the monohydrate. It can be purified by allowing an aqueous soln to crystallise in a vac over P₂O₅. The crystals are collected, dried out in vacuum at 80°/P₂O₅ in a stream of pure N₂ at 110°. [J Chem Soc 1245 1936.]

Lithium trimethylsilanolate (trimethylsilanol Li salt) [2004-14-0] M 96.1, m 120°(dec in air). Wash with Et₂O and pet ether. Sublimes at 180°/1mm as fine transparent needles. [J Org Chem 17 1555 1952.]

Magnesium [7439-95-4] M 24.3, m 651°, b 1100°, d 1.739. Slowly oxidises in moist air and tarnishes. If dark in colour do not use. Shiny solid should be degreased by washing with dry Et₂O, dry and keep in a N₂ atmosphere. It can be activated by adding a crystal of I₂ in the Et₂O before drying and storing.

Magnesium acetate [142-72-3 (anhyd); 16674-78-5 (4H₂O)] M 214.5, m 80°. Crystd from anhydrous acetic acid, then dried under vacuum for 24 h at 100°.

Magnesium benzoate (3H₂O) [553-70-8] M 320.6, m ~200°. Crystd from water (6 mL/g) between 100° and 0°.

Magnesium bromide (anhydrous) [7789-48-2] M 184.1, m 711°, d 3.72. Crystd from EtOH.

Magnesium chloride (6H₂O) [7791-18-6] M 203.3, m ~100°(dec), pK⁺ 10.3, pK⁻ 12.2 (for Mg⁺ hydrolysis). Crystd from hot water (0.5 mL/g) by cooling.

Magnesium dodecylsulfate [3097-08-3] M 555.1. Recrystd three times from EtOH and dried in a vacuum.

Magnesium ethylate (magnesium ethoxide) [2414-98-4] M 114.4. Dissolve ca 1 g of solid in 12.8 mL of absolute EtOH and 20 mL of dry xylene and reflux in a dry atmosphere (use CaCl₂ in a drying tube at the top of the condenser). Add 10 mL of absolute EtOH and cool. Filter solid under dry N₂ and dry in a vacuum. Alternatively dissolve in absolute EtOH and pass through molecular sieves (40 mesh) under N₂, evapor under N₂, and store in a tightly stoppered container. [J Am Chem Soc 68 889 1946.]

Magnesium D-gluconate [3632-91-5] M 414.6, [α]₂θ 20 546 +13.5°, [α]₂θ 20 D +11.3° (c 1, H₂O). Cryst from dilute EtOH to give ca trihydrate, and then dry at 98° in high vacuum. Insol in EtOH and solubility in H₂O is 16% at 25°.

Magnesium iodate (4H₂O) [7790-32-1] M 446.2. Crystd from water (5 mL/g) between 100° and 0°.

Magnesium iodide [10377-58-9] M 278.1, m 634°. Crystd from water (1.2 mL/g) by partial evapn in a desiccator.

Magnesium ionophore I (ETH 1117), (N,N'-diheptyl-N,N'-dimethyl-1,4-butanediamide) [75513-72-3] M 340.6. Purified by flash chromatography (at 40 kPa) on silica and eluting with EtOH-hexane (4:1). IR has v(CHCl₃) 1630 cm⁻¹. [Helv Chim Acta 63 2271 1980.] It is a good magnesium selectophore compared with Na, K and Ca [Anal Chem 52 2400 1980].
Magnesium ionophore II (ETH 5214), \([N,N''\text{-octamethylene\text{-bis}}(N'\text{-heptyl-}N''\text{-methylmethylene})]\) \[119110-37-1\] M 538.8. Reagent (ca 700mg) can be purified by flash chromatography on Silica Gel 60 (30g) and eluting with CH\(_2\)Cl\(_2\)-Me\(_2\)CO (4:1). [Anal Chem 61 574 1989.]

Magnesium lactate \[18917-37-1\] M 113.4. Crystd from water (6mL/g) between 100\(^\circ\) to 0\(^\circ\).

Magnesium nitrate (6H\(_2\)O) \[13446-18-9\] M 256.4, m ~95\(^\circ\)(dec). Crystd from water (2.5mL/g) by partial evapn in a desiccator. After 2 recrystns ACS grade has: metal (ppm) Ca (6.2), Fe (8.4), K (2), Mo (0.6), Na (0.8), Se (0.02).

Magnesium perchlorate (Anhydrone, Dehydrite) \[10034-81-8\] (anhydr) M 259.2, m >250\(^\circ\), pK\(_{25}\) -2.4 to -3.1 (for HClO\(_4\)). Crystd from water to give the hexahydrate M 331.3 \[13346-19-0\]. Coll, Nauman and West [J Am Chem Soc 81 1284 1959] removed traces of unspecified contaminants by washing with small portions of Et\(_2\)O and drying in a vac (CARE). The anhydrous salt is commercially available as an ACS reagent, and is as efficient a dehydrating agent as P\(_2\)O\(_5\) and is known as "Dehydrite" or "Anhydrone". [Smith et al. J Am Chem Soc 44 2255 1922 and Ind Eng Chem 16 20 1924.] Hygroscopic, Keep in a tightly closed container. EXPLOSIVE in contact with organic materials, and is a SKIN IRRITANT.

Magnesium succinate \[556-32-1\] M 141.4. Crystd from water (0.5mL/g) between 100\(^\circ\) and 0\(^\circ\).

Magnesium sulfate (anhydrous) \[7487-88-9\] M 120.4, m 1127\(^\circ\). Crystd from warm H\(_2\)O (1mL/g) by cooling. Dry heptahydrate at ~250\(^\circ\) until it loses 25\% of its wt. Store in a sealed container.

Magnesium trifluoromethanesulfonate \[60871-83-2\] M 322.4, m >300\(^\circ\). Wash with CH\(_2\)Cl\(_2\) and dry at 125\(^\circ\)/2h and 3mmHg. [Tetrahedron Lett 24 169 1983.]

Magon [3-hydroxy-4-(hydroxyphenylazo)-2-naphthoyl-2,4-dimethylanilide; Xylidyl Blue II] \[523-67-1\] M 411.5, m 246-247\(^\circ\). Suspend in H\(_2\)O and add aqueous NaOH until it dissolves, filter and acidify with dil HCl. Collect the dye, dissolve in hot EtOH (sol is 100mg/L at 20\(^\circ\)).

Manganese (III) acetate (2H\(_2\)O) \[19513-05-4\] M 268.1, pK\(_{25}\) 0.06 (for Mn\(^{3+}\) hydrolysis). Wash the acetate with AcOH then thoroughly with Et\(_2\)O and dry in air to obtain the dihydrate. The anhydrous salt can be made by stirring vigorously a mixt of the hydrated acetate (ca 6g) and Ac\(_2\)O (22.5mL) and heat carefully (if necessary) until the mixture is clear. It is set aside overnight for the material to crystallise. Filter the solid, wash with Ac\(_2\)O and dry over P\(_2\)O\(_5\). The dihydrate can also be obtained from the divalent acetate by adding 500mL of Ac\(_2\)O and 48g of the hydrated acetate and refluxing for 20min, then add slowly 8.0g of K\(_2\)MnO\(_4\). After refluxing for an additional 30min, the mixture was cooled to room temperature and 85mL of H\(_2\)O added. It should be noted that larger amounts of H\(_2\)O change the yield and nature of the manganese acetate and the yields of reactions that use this reagent, e.g. formation of lactones from olefines. The Mn(OAc)\(_2\).2H\(_2\)O is then filtered off after 16h, washed with cold AcOH and air dried. [J Am Chem Soc 90 5903, 5905 1968, Heiba et al. 91 138 1969.]

Alternatively dissolve the salt (30g) in glacial acetic acid (200mL) by heating and filter. If crystals do not appear, the glass container should be rubbed with a glass rod to induce crystn which occurs within 1h. If not, allow to stand for a few days. Filter the cinnamon brown crystals which have a silkly lustre and dry over CaO. Keep away from moisture as it is decomposed by cold H\(_2\)O. [Lux in Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol II, p 1469 1963; Williams and Hunter Can J Chem 54 3830 1976.]

Manganese (II) acetylacetone \[14024-58-9\] M 253.2, m ~250\(^\circ\). Purify by stirring 16g of reagent for a few min with 100mL absolute EtOH and filter by suction as rapidly as possible through coarse filter paper. Sufficient EtOH is added to the filtrate to make up for the loss of EtOH and to redissolve any solid that separates. Water (15mL) is added to the filtrate and the solution is evaporated with a stream of N\(_2\) until reduced to half its vol. Cool for a few min and filter off the yellow crystals, dry under a stream of N\(_2\), then in a
vacuum at room temp for 6-8h. These conditions are important for obtaining the dihydrate. A vacuum to
several mm of Hg or much lower pressure for several days produces the anhydrous complex. The degree of
hydration can be established by determining the loss in weight of 100g of sample after heating for 4h at 100°
and <20mmHg. The theoretical loss in weight for 2H₂O is 12.5%. Material sublimes at 200°/2mm. It is
soluble in heptane, MeOH, EtOH or °C₆H₆ at 30O.

**Manganese decacarbonyl Mn₂(CO)₁₀ [10170-69-1] M 390.0, m 151-152°, 154-155°(sealed
tube), δ₂⁵ 1.75. Golden yellow crystals which in the absence of CO begin to decompose at 110°, and on
further heating yield a metallic mirror. In the presence of 3000psi of CO it does not decompose on heating to
250°. It is soluble in common organic solvents, insoluble in H₂O, not very stable in air, to heat or UV light.
Dissolves in a lot of °C₆H₆ and can be crystallised from it. It distils with steam at 92-100°. It can be purified
by sublimation under reduced pressure (<0.5mm) at room temperature to give well formed golden yellow
crystals. If the sample is orange coloured this sublimation leads to a mixture of golden-yellow and dark red
crystals of the carbonyl and carbonyl iodide respectively which can be separated by hand picking under a
microscope. Separate resublimations provide the pure compounds. POISONOUS [J Am Chem Soc 76
3831 1954, 80 6167 1958, 82 1325 1960].

**Manganous acetate (4H₂O) [6156-78-1 (4H₂O); 638-38-0 (anhydr)] M 245.1, m 80°, δ 1.59, pK₂⁵
10.59 (for Mn²⁺ hydrolysis). Crystd from water acidified with acetic acid.

**Manganous bromide (anhydrous) [13446-03-2] M 214.8, m 695°; 4H₂O [10031-20-6] M
286.8, m 64°(dec). Rose-red deliquescent crystals soluble in EtOH. The H₂O is removed by heating at 100°
then in HBr gas at 725° or dry in an atmosphere of N₂ at 200°.

**Manganous chloride (4H₂O) [13446-34-9; 7773-01-5 (anhydr)] M 197.9, m 58°, 87.5°, δ 2.01.
Crystd from water (0.3mL/g) by cooling.

Crystd from EtOH.


**Manganous sulfate (H₂O) [10034-96-5 (H₂O); 15244-36-7 (xH₂O)] M 169.0, δ 2.75. Crystd from water
(0.9mL/g) at 54-55° by evaporating about two-thirds of the water. Dehydr at >400°.

2-Mercaptopyridine N-oxide sodium salt (pyridinethione or pyrithione sodium salt) [3811-
73-2] M 149.1, m ~250°(dec), pK₁ ~1.95, pK₂ 4.65. When recrystd from water it assayed as 98.7%
based on AgNO₃ titration [Krivis et al. Anal Chem 35 966 1963, see also Krivis et al. Anal Chem 48 1001
1976; and Barton and Crich J Chem Soc. Perkin Trans I 1603, 1613 1986].

**Mercuric acetate [1600-27-7] M 318.7, pK₂⁵ 2.47, pK₂⁵ 3.49 (for Hg²⁺ hydrolysis). Crystd from
acetic acid. POISONOUS.

**Mercuric bromide [7789-47-1] M 360.4, m 238.1°. Crystd from hot saturated ethanolic soln, dried
and kept at 100° for several hours under vacuum, then sublimed. POISONOUS.

**Mercuric chloride [7487-94-7] M 271.5, m 276°, b 304°, δ 5.6. Crystd twice from distilled water,
dried at 70° and sublimed under high vacuum. POISONOUS.

**Mercuric cyanide [592-04-1] M 252.6, m 320°(dec), δ 4.00. Crystd from water. POISONOUS.

**Mercuric iodide (red) [7774-29-0] M 454.4, m 259°(yellow >130°), b ~350°(subl), δ 6.3.
Crystd from MeOH or EtOH, and washed repeatedly with distilled water. Has also been mixed thoroughly with
excess 0.001M iodine solution, filtered, washed with cold distilled water, rinsed with EtOH and Et₂O, and dried
in air. POISONOUS.
Mercuric oxide (yellow) \([21908-53-2]\) M 216.6, m 500°(dec). Dissolved in HClO₄ and ppted with NaOH soln.

Mercuric thiocyanate \([592-85-8]\) M 316.8, m 165°(dec), pK²⁺ 1.85 (for HSCN). Recryst from H₂O, and can form various crystal forms depending on conditions. Solubility in H₂O is 0.069% at 25°, but is more soluble at higher temps. Decomposes to Hg above 165°. Poisonous. \([J Phys Chem 35 1128 1931; Chem Ber 68 919 1935]\)

Mercurous nitrate \((2H₂O)\) \([7782-86-7 (2H₂O); 7783-34-8 (H₂O); 10415-75-5 (anhydr)\) M 561.2, m 70°(dec), d 4.78, pK²⁺ 2.68 (for Hg²⁺ hydrolysis). Solubility in H₂O containing 1% HNO₃ is 7.7%. Recrystd from a warm saturated soln of dilute HNO₃ and cool to room temp slowly to give elongated prisms. Rapid cooling gives plates. Colourless crystals to be stored in the dark. Poisonous. \([J Chem Soc 1312 1956]\)

Mercurous sulfate \([7783-36-0]\) M 497.3, d 7.56. Recrystallise from dilute H₂SO₄, and dry in a vacuum under N₂ and store in the dark. Solubility in H₂O is 0.6% at 25°. Poisonous.

Mercury \([7439-97-6]\) M 200.6, m -38.9°, b 126°/1mm, 184°/10mm, 261°/100 mm, 356.9°/ atm, d 13.534. After air had been bubbled through mercury for several hours to oxidise metallic impurities, it was filtered to remove coarser particles of oxide and dirt, then sprayed through a 4-ft column containing 10% HNO₃. It was washed with distilled water, dried with filter paper and distilled under vacuum.

Mercury(I₁) bis(cyclopentadieny1) \([18263-08-6]\) M 330.8. Purified by low-temp recrystn from Et₂O.

Mercury dibromofluorescein \(\{\text{mercurochrome, merobromin, } 2',7'-\text{dibromo-4'-\{hydroxy-mercurio\}-fluorescein di-Na salt}\}\) \([129-16-8]\) M 804.8, m>300°. The Na salt is dissolved in the minimum vol of H₂O, or the free acid suspended in H₂O and dilute NaOH added to cause it to dissolve, filter and acidify with dilute HCl. Collect the ppt wash with H₂O by centrifugation and dry in vacuum. The di Na salt can be purified by dissolving in the minimum volume of H₂O and ppted by adding EtOH, filter, wash with EtOH or Me₂CO and dry in a vacuum. Solubility in 95% EtOH is 2% and in MeOH it is 16%. \([J Am Chem Soc 42 2355 1920]\)

Mercury orange \([1-\{4-chloromercurophenylazo\}-2-naphthol\] \([3076-91-3]\) M 483.3, m 291.5-293°(corr) with bleaching. Wash several times with boiling 50% EtOH and recrystallise from 1-butanol (0.9g/L of boiling alcohol). Fine needles insoluble in H₂O but slightly soluble in cold alcohols, CHCl₃ and soluble in aqueous alkalis. \([J Am Chem Soc 70 3522 1948]\)


Metanil Yellow \(\{3[\{4-phenylamino\}phenylazo]-benzenesulfonic acid\}\) \([587-98-4]\) M 375.4, pKᵢ 0. Salted out from water three times with sodium acetate, then repeatedly extracted with EtOH [McGrew and Schneider, J Am Chem Soc 72 2547 1950].

(Methoxycarbonylmethyl)triphenylphosphorane \(\{\text{methyl (triphenylphosphoranylidene)-acetate}\}\) \([2605-67-6]\) M 334.4, m 162-163°, 169-171°. Cryst by dissolving in AcOH and adding pet ether (b 40-50°) to give colorless plates. UV λmax (Å⁻¹m): 222nm (865) and 268nm (116) \([Isler et al. Helv Chim Acta 40 1242 1957]\).

Methoxycarbonylmethyltriphenylphosphonium bromide \([1779-58-4]\) M 415.3, m 163°, 165-170°(dec). Wash with pet ether (b 40-50°) and recryst from CHCl₃/Et₂O and dry in high vac at 65°. \([Isler et al. Helv Chim Acta 40 1242 1957; Wittig and Haag Chem Ber 88 1654, 1664 1955]\)
Methoxymethyl trimethylsilane (trimethylsilylmethyl methyl ether) [14704-14-4] M 118.3, b 838°/740 mm, d 0.758, n 13878. Forms an azeotrope with MeOH (b 60°). If it contains MeOH (check IR for bands above 3000 cm⁻¹) then wash with H₂O and fractionate. A possible impurity could be chloromethyl trimethylsilane (b 97°/740 mm).

1-Methoxy-2-methyl-1-trimethylsiloxypropene (dimethyl ketene methyl trimethylsilyl acetal) [31469-15-5] M 174.3, b 121-122°/0.35 mm, 125-126°/0.4 mm, 148-150°/atm, d 0.86. Add Et₂O, wash with cold H₂O, dry (Na₂SO₄), filter, evaporate Et₂O, and distil oily residue in a vacuum.

Methylarsonic acid [124-58-3] M 137.9, m 161°, pH 3.47. Crystd from abs EtOH.

Methyl dichlorosilane (dichloro methylsilane) [75-54-7] M 115.0, m -92.5°, b 41°/748 mm, 40.9°/760 mm, 40-45°/atm, d 1.105. Impurities are generally other chloromethyl silanes. Distilled through a conventional Stedman column of 20 theoretical plates or more. [Stedman column. A plain tube containing a series of wire-gauze discs stamped into flat, truncated cones and welded together, alternatively base-to-base and edge-to-edge, with a flat disc across each base. Each cone has a hole, alternately arranged, near its base, vapour and liquid being brought into intimate contact on the gauze surfaces (Stedman Can J Res B 15 383 1937). It should be protected from H₂O by storing over P₂O₅.

Methylmercuric chloride [115-09-3] M 251.1, m 167°. Crystd from absolute EtOH (20 mL/g).

Methyl Orange (sodium 4,4'-dimethylaminophenylazobenzenesulfonate) [547-58-0] M 327.3, pH 3.47. Crystd twice from hot water, then washed with a little EtOH followed by diethyl ether. Indicator: pH 3.1 (red) and pH 4.4 (yellow).

Methylphenyl dichlorosilane (dichloro methyl phenylsilane) [149-74-6] M 191.1, b 114-115°/50 mm, 202-205°/atm, d 1.17. Purified by fractionation using an efficient column. It hydrolyses ca ten times more slowly than methyltrichlorosilane and ca sixty times more slowly than phenyltrichlorosilane. [J Phys Chem 61 1591 1957].

Methylphosphonic acid [993-13-5] M 96.0, m 104-106°, 105-107°, 108°, pH 2.12, pH 2.4. If it tests for Cl⁻, add H₂O and evaporate to dryness; repeat several times till free from Cl⁻. The residue solidifies to a wax-like solid. Alternatively, dissolve the acid in the minimum volume of H₂O, add charcoal, warm, filter and evaporate to dryness in a vacuum over P₂O₅. [J Am Chem Soc 75 3379 1953.] The di-Na salt is prepared from 24 g of acid in 50 mL of dry EtOH and a solution of 23 g Na dissolved in 400 mL EtOH is added. A white ppt is formed but the mixture is refluxed for 30 min to complete the reaction. Filter off and recrystallise from 50% EtOH. Dry crystals in a vacuum desiccator. [J Chem Soc 3292 1952.]

Methylphosphonic dichloride [676-97-1] M 132.9, m 33°, 33-37°, b 53-54°/10 mm, 64-67°/20.5 mm, 86°/44 mm, 162°/760 mm, d 1.4382. Fractionally redistilled until the purity as checked by hydrolysis and acidimetry for Cl⁻ is correct and should solidify on cooling. [J Chem Soc 3437 1952; J Am Chem Soc 75 3379 1952; for IR see Can J Chem 34 1611 1956.]

Methyl Thymol Blue, sodium salt [1945-77-3] M 844.8, Ε 1.89 x 10⁴ at 435 nm, pH 5.5. Starting material for synthesis is Thymol Blue. Purified as for Xylenol Orange on p. 387 in Chapter 4.
Methyl trichlorosilane [75-79-6] M 149.5, b 13.7°/101mm, 64.3°/710.8mm, 65.5°/745mm, 66.1°/atm, d 1.263, n 1.4110. If very pure distil before use. Purity checked by \( ^{29}\text{Si} \) nmr, \( \delta \) in MeCN is 13.14 with respect to Measi. Possible contaminants are other silanes which can be removed by fractional distillation through a Stedman column of >72 theoretical plates with total reflux and 0.35% take-off (see p. 441). The apparatus is under N\(_2\) at a rate of 12 bubbles/min fed into the line using an Hg manometer to control the pressure. Sensitive to H\(_2\)O.

Methyl triethoxysilane [2031-67-6] M 178.31, b 142-144.5°/742mm, 141°/765mm, 141.5°/775mm, d 0.8911, n 1.3820. Repeated fractionation in a stream of N\(_2\) through a 3' Heligrid packed Todd column (see p. 174). Hydrolysed by H\(_2\)O and yields cyclic polysiloxanes on hydrolysis in the presence of acid in \( ^{13}\text{C}_6\text{H}_6 \). [J Am Chem Soc 77 1292, 1390 1955.1

Methyl trimethoxysilane [1185-55-3] M 136.2, b 102°/760mm, d 1.3687, n 1.3711. Likely impurities are 1,3-dimethyltetrarnethoxy disiloxane (b 31°/lmm) and cyclic polysiloxanes, see methyl triethoxysilane. [J Org Chem 26 1400 1952, 20 250 1955.

Methyl triphenylphosphonium iodide [I 7579-99-61 M 452.2, m 146°. Gently heat the impure iodide with good grade Me\(_2\)CO The saturated solution obtained is decanted rapidly from undissolved salt and treated with an equal volume of dry Et\(_2\)O. The iodide separates as beautiful flat needles which are collected by centrifugation, washed several times with dry Et\(_2\)O, and dried in a vacuum over P\(_2\)O\(_5\). For this recrystn it is essential to minimise the time of contact with Me\(_2\)CO and to work rapidly and with rigorous exclusion of moisture. If the crude material is to be used, it should be stored under dry Et\(_2\)O, and dried and weighed in vacuo immediately before use. [J Chem Soc Perkin Trans 1 982 1974; J Chem Soc 224 1953.]


N-Methyl-N-trimethylsilyl trifluoroacetamide [24589-78-4] M 199.3, b 78-79°/130mm. Fractionate through a 40mm Vigreux column. Usually it contains ca 1% of methyl trifluoroacetamide and 1% of other impurities which can be removed by gas chromatography or fractionating using a spinning band column. [J Chromatogr 42 103 1969, 103 91 1975.]
with metal filings (20 theoretical plates) at atmospheric pressure. [Izv Akad Nauk SSSR Ser Khim 1474 1957 and 767 1958.]

Milling Red SWB [1-[4-[4-[4-toluenesulfonyloxy]phenylazo](3,3'dimethyl-1,1'-biphenyl)-4'-azo]-2-hydroxynaphthalene-6,8-disulfonic acid di-Na salt, Acid Red 114] [6459-94-5] M 830.8, m dec >250\(^\circ\), CI 23635, \(\lambda_{\text{max}} \approx 514\text{nm}\). Salted out three times with sodium acetate, then repeatedly extracted with EtOH. [McGrew and Schneider J Am Chem Soc 72 2547 1950.] See Solochrome Violet R on p. 352 in Chapter 4.


Molybdenum trichloride (molybdenum IV oxide, MoO\(_3\)) [1313-27-5] M 143.9, m 795\(^\circ\), d 4.5. Crystd from water (50mL/g) between 70\(^\circ\) and 90\(^\circ\).

Monocalcium phosphate (2H\(_2\)O) (monobasic) [7789-77-7 (2H\(_2\)O); 7757-93-9 (anhydr)] M 154.1, m 200\(^\circ\)(dec), loses H\(_2\)O at 100\(^\circ\), d 2.2. Crystd from a near-saturated soln in 50% aqueous reagent grade phosphoric acid at 100\(^\circ\) by filtering through fritted glass and cooling to room temperature. The crystals were filtered off and this process was repeated three times using fresh acid. For the final crystn the solution was cooled slowly with constant stirring to give thin plate crystals that were filtered off on fritted glass, washed free of acid with anhydrous acetone and dried in a vacuum desiccator [Egan, Wakefield and Elmore, JAm Chem Soc 78 1811 1956].

Monoperoxyphthalic acid magnesium salt 6H\(_2\)O. (MMPP) [84665-66-7] M 494.7, m -93\(^\circ\)(dec). MMPP is a safer reagent than m-chloroperbenzoic acid because it is not as explosive and has advantages of solubility. It is sol in H\(_2\)O, low mol wt alcohols, i-PrOH and DMF. The product of reaction, Mg phthalate, is sol in H\(_2\)O. It has been used in aq phase to oxidise compds in e.g. CHCl\(_3\) and using a phase transfer catalyst e.g. methyltrioctylammonium chloride [Brougham Synthesis 1015 1987]. The oxidising activity can be checked (as for perbenzoic acid in Silbert et al. Org Synth Coll Vol V 906 1973), and if found to be low it would be best to prepare afresh from phthalic anhydride (1mol), H\(_2\)O\(_2\) (1mol) and MgO at 20-25\(^\circ\) to give MMPP. [Hignett, European Pat Appl 27 693 1981, Chem Abstr 95 168810 1981.]

Naphthalene Scarlet Red 4R [1-(4-sulfonaphthalene-1-azo)-2-hydroxynaphthalene-6,8-disulfonic acid tri-Na salt, New Coccine, Acid Red 18] [2611-82-7] M 604.5, m >250\(^\circ\)(dec), CI 16255, \(\lambda_{\text{max}} 506\text{nm}\). Dissolved in the minimum quantity of boiling water, filtered and enough EtOH was added to ppte ca 80% of the dye. This process was repeated until a soln of the dye in aqueous 20% pyridine had a constant extinction coefficient.

Naphthol Yellow S (citronin A, flavianic acid sodium salt, 8-hydroxy-5,7-dinitro-2-naphthalene sulfonic acid disodium salt) [846-70-8] M 358.2, m dec on heating. Greenish yellow powder soluble in H\(_2\)O. The free sulfonic acid can be recrystd from dil HCl (m 150\(^\circ\)) or AcOH-EtOAc (m 148-149.5\(^\circ\)). The disodium salt is then obtained by dissolving the acid in two equivalents of aqueous NaOH
and evaporating to dryness and drying the residue in a vacuum desiccator. The sodium salt can be recrystd from the minimum volume of H2O or from EtOH [Dermer and Dermer J Am Chem Soc 61 3302 1939].


1,2-Naphthyl phosphate disodium salt [2183-17-7] M 268.1, pK_{H1} 0.97, pK_{H2} 5.85 (for free acid). The free acid has m 157-158° (from Me$_2$CO/*C&j). The free acid is crystd several times by adding 20 parts of boiling *C$_6$H$_6$ to a hot solution of 1 part of free acid and 1.2 parts of Me$_2$CO. It has m 157-158°. [J Am Chem Soc 77 4002 1955.] The monosodium salt was ppted from a soln of the acid phosphate in MeOH by addition of an equivalent of MeONa in MeOH. [J Am Chem Soc 72 624 1950.]

2-Naphthyl phosphate monosodium salt [14463-68-4] M 246.1, m 203-205°, pK_{H1} 1.25, pK_{H2} 5.83 (for free acid). Recrystd from H2O (10mL) containing NaCl (0.4g). The salt is collected by centrifugation and dried in a vac desiccator, m 203-205° (partially resolidifies and melts at 244°). Crystd from MeOH (m 222-223°). The free acid is crystd several times by addn of 2.5 parts of hot CHCl$_3$ to a hot soln of the free acid (1 part) in Me$_2$CO (1.3 parts), m 177-178°. [J Am Chem Soc. 73 5292 1951, 77 4002 1955.]

Neodymium chloride 6H$_2$O [13477-89-9] M 358.7, m 124°, pK_{H1} 8.43 (for Nd$^{3+}$ hydrolysis). Forms large purple prisms from conc solns of dilute HCl. Soluble in H$_2$O (2.46 parts in 1 part of H$_2$O) and EtOH.

Neodymium nitrate (6H$_2$O) [16454-60-7] M 438.4, m 70-72°. Crystallises with 5 and 6 molecules of H$_2$O from conc solutions in dilute HNO$_3$ by slow evaporation; 1 part is soluble in 10 parts of H$_2$O.


Neon [7440-01-9] M 20.2. Passed through a copper coil packed with 60/80 mesh 13X molecular sieves which is cooled in liquid N$_2$, or through a column of Ascarite (NaOH-coated silica adsorbent).


New Methylene Blue N (2,8-dimethyl-3,6-bis(ethylamino)phenothazinium chloride 0.5 ZnCl$_2$) [6586-05-6] M 416.1, m >200°(dec), pK$_1$ 3.54, pK$_2$ 4.82. Crystd from *benzene/MeOH (3:1).

Nickel (II) acetate (4H$_2$O) [6018-89-9] M 248.9, d 1.744, pK_{H1} 8.94 (from Ni$^{2+}$ hydrolysis). Recryst from aqueous AcOH as the green tetrahydrate. Soluble in 6 parts of H$_2$O. It forms lower hydrates and should be kept in a well closed container. [Z Anorg Allg Chem 343 92 1966.]

Nickel (II) acetylacetonate [3264-82-2] M 256.9, m 229-230°, b 220-235°/11mm, d$^1$ 1.655. Wash the green solid with H$_2$O, dry in a vacuum desiccator and recrystallise from MeOH. [J Phys Chem 62 440 1958.] The complex can be conveniently dehydrated by azeotropic distn with toluene and the crystals may be isolated by concentrating the toluene solution. [J Am Chem Soc 76 1970 1954.]

Nickel bromide [13462-88-9] M 218.5, m 963°(loses H$_2$O at ~ 200°). Crystd from dilute HBr (0.5mL/g) by partial evaporation in a desiccator.
Nickel chloride (6H₂O) [7791-20-0 (6H₂O); 69098-15-3 (xH₂O); 7718-54-9 (anhydr)] M 237.7. Crystd from dilute HCl.

Nickel nitrate (6H₂O) [13478-00-7] M 290.8, m 57°. Crystd from water (0.3mL/g) by partial evaporation in a desiccator.


Nickel (II) phthalocyanine [14055-02-8] M 571.3, m >300°. Wash well with H₂O and boiling EtOH and sublime at high vacuum in a slight stream of CO₂. A special apparatus is used (see reference) with the phthalocyanine being heated to red heat. The sublimate is made of needles with an extremely bright red lustre. The powder is dull greenish blue in colour. [J Chem Soc 1719 1936.]

Nickel sulfate (7H₂O) [1010-98-1] M 280.9, m loses 5H₂O at 100°, anhydr m at ~280°. Crystd from warm water (0.25mL/g) by cooling.


Niobium (V) chloride [10026-12-7] M 270.2, m 204.7-209.5°, b ~250°(begins to sublimate at 125°), d 2.75. Yellow very deliquescent crystals which decompose in moist air to give HCl. Should be kept in a dry box flushed with N₂ in the presence of P₂O₅. Wash with CCl₄ and dry over P₂O₅. The yellow crystals usually contain a few small dirty white pellets among the yellow needles. These should be easily picked out. Upon grinding in a dry box, however, they turn yellow. NbCl₃ has been sublimed and fractionated in an electric furnace. [Znorg Synth 7 163 1963; J Chem Soc suppl 233 1949.]

Nitric acid [7697-37-2] M 63.0, m -42°, b 83°, d₂₅ 1.5027, [Constant boiling acid has composition 68% HNO₃ + 32% H₂O, b 120.5°, d 1.41], pK₂₅ -1.27 (1.19). Obtained colourless (approx. 92%) by direct distn of fuming HNO₃ under reduced pressure at 40-50° with an air leak at the head of the fractionating column. Stored in a desiccator kept in a refrigerator. Nitrite-free HNO₃ can be obtained by vac distn from urea.

Nitric oxide [10102-43-9] M 30.0, b -151.8°. Bubbling through 10M NaOH removes NO₂. It can also be freed from NO₂ by passage through a column of Ascarite followed by a column of silica gel held at -197ºK. The gas is dried with solid NaOH pellets or by passing through silica gel cooled at -78º, followed by fractional distillation from a liquid N₂ trap. This purification does not eliminate nitrous oxide. Other gas scrubbers sometimes used include one containing conc H₂SO₄ and another containing mercury. It is freed from traces of N₂ by a freeze and thaw method. TOXIC.


Nitrogen [7727-37-9] M 28.0, b -195.8°. Cylinder N₂ can be freed from oxygen by passage through Fieser's soln which comprises 2g sodium anthraquinone-2-sulfonate and 15g sodium hydrosulfite dissolved in 100mL of 20% KOH [Fieser, J Am Chem Soc 46 2639 1924] followed by scrubbing with saturated lead acetate soln (to remove any H₂S generated by the Fieser soln), conc H₂SO₄ (to remove moisture), then soda-lime (to remove any H₂SO₄ and CO₂). Alternatively, after passage through Fieser's solution, N₂ can be dried by washing with a soln of the metal ketyl from benzophenone and Na wire in absolute diethyl ether. [If ether vapour in N₂ is undesirable, the ketyl from liquid Na-K alloy under xylene can be used.]

Another method for removing O₂ is to pass the nitrogen through a long tightly packed column of Cu turnings, the surface of which is constantly renewed by scrubbing it with ammonia (sg 0.880) soln. The gas is then
passed through a column packed with glass beads moistened with conc H₂SO₄ (to remove ammonia), through a column of packed KOH pellets (to remove H₂SO₄ and to dry the N₂), and finally through a glass trap packed with chemically clean glass wool immersed in liquid N₂. Nitrogen has also been purified by passage over Cu wool at 723°K and Cu(II) oxide [prepared by heating Cu(NO₃)₂·6H₂O at 903°K for 24h] and then into a cold trap at 77°K.

A typical dry purification method consists of a mercury bubbler (as trap), followed by a small column of silver and gold turnings to remove any mercury vapour, towers containing anhydrous CaSO₄, dry molecular sieves or Mg(ClO₄)₂, a tube filled with fine Cu turnings and heated to 400° by an electric furnace, a tower containing soda-lime, and finally a plug of glass wool as filter. Variations include tubes of silica gel, traps containing activated charcoal cooled in a Dry-ice bath, copper on Kieselguhr heated to 250°, and Cu and Fe filings at 400°.

2-Nitrophenol-4-arsonic acid (4-hydroxy-3-nitrophenylarsonic acid) [121-19-7] M 263.0, pKₑ₁(1)~ 4.4 As(O)-(OH)-(O⁻), pKₑ₂(2)~ 7.4 (phenolic OH), pKₑ₃(3)~ 7.7 (As(O)-2(O⁻)). Crystd from water.

1-Nitroso-2-naphthol-3,6-disulfonic acid, di-Na salt, hydrate (Nitroso-R-salt) [525-05-3] M 377.3, m >300°, pKₑ₁(1)<0 (SO₃⁻), pKₑ₂(2)~7 (OH). Purified by dissolution in aqueous alkali and precipitation by addition of HCl.

Nitrosyl chloride [2696-92-6] M 65.5, b -5.5°. Fractionally distilled at atmospheric pressure in an all-glass, low temperature still, taking the fraction boiling at -4° and storing it in sealed tubes.

Nitrous oxide [10024-97-2] M 44.0, b -88.5°. Washed with conc alkaline pyrogallol solution, to remove O₂, CO₂, and NO₂, then dried by passage through columns of P₂O₅ or Drierite, and collected in a dry trap cooled in liquid N₂. Further purified by freeze-pump-thaw and distn cycles under vacuum [Ryan and Freeman J Phys Chem 81 1455 1977].

Nuclear Fast Red (1-amino-2,4-dihydroxy-5,10-anthraquinone-3-sulfonic acid Na Salt) [6409-77-4] M 357.3, m >290°(dec), λₑ₉ 518nm. A soln of 5g of the dye in 250mL of warm 50% EtOH was cooled to 15° for 36h, then filtered on a Buchner funnel, washed with EtOH until the washings were colourless, then with 100mL of diethyl ether and dried over P₂O₅. [Kingsley and Robnett Anal Chem 33 552 1961.]

Octadecyl isonicotinate see hydrogen ionophore IV, ETH 1778 on p. 430.

Octadecyl trichlorosilane [112-04-9] M 387.9, b 159-162°/13mm, 185-199°/2-3mm, d₋₄ 0.98. Purified by fractional distillation. [J Am Chem Soc 69 2916 1947.]


Octamethyl cyclotetrasiloxane [556-67-7] M 296.6, m 17-19°, 17.58°, 18.5°, b 74°/20mm, 176.4°/760mm, d₋₄ 3.09451, n₁₋₆ 1.3968. Solid has two forms, m 16.30° and 17.65°. Dry over CaH₂ and distil. Further fractionation can be effected by repeated partial freezing and discarding the liquid phase. [J Am Chem Soc 76 399 1954, 75 6313 1953.]

Octamethyl trisiloxane [107-51-7] M 236.5, m -80°, b 151.7°/747mm, 153°/760mm. Distil twice, the middle fraction from the first distillation is again distilled, and the middle fraction of the second distillation is used. [J Am Chem Soc 68 358, 691 1946, J Chem Soc 1908 1953.]

Octaphenyl cyclotetrasiloxane [546-56-5] M 793.2, m 201-202°, 203-204°, b 330-340°/1mm. Recryst from AcOH, EtOAc, C₆H₆ or C₆H₄/ηEtOH. It forms two stable polymorphs and both
forms as well as the mixture melt at 200-201°. There is a metastable form which melts at 187-189°. \[J\text{\ Am Chem Soc} 67 2173 1945, 69 488 1947.\]

Octyl trichlorosilane \(\{5283-66-9\}\) M 247.7, b 96.5°/10mm, 112°/15mm, 119°/28mm, 229°/760mm, d 1.0744, n 1.4453. Purified by repeated fractionation using a 15-20 theoretical plates glass column packed with glass helices. This can be done more efficiently using a spinning band column. The purity can be checked by analysing for Cl \([\text{ca} 0.5\text{-g of sample is dissolved in 25mL of MeOH, diluted with H}_2\text{O and titrated with standard alkali.}}\ [J\text{\ Am Chem Soc} 68 475 1946, 80 1737 1958.\]

Orange I \([\text{tropaeolin 000 Nr1, 4-(4-hydroxy-1-naphthylazo)benzenesulfonic acid sodium salt}]\) \(\{523-44-4\}\) M 350.3, m >260°(dec). Purified by dissolving in the minimum volume of H\(_2\)O, adding, with stirring, a large excess of EtOH. The salt separates as orange needles. It is collected by centrifugation or filtration, washed with absolute EtOH (2x) in the same way and dried in a vacuum desiccator over KOH. The free acid can be recrystallised from EtOH. \[\text{Chem Ber 64 86 1931.}\]

Orange II \([\text{tropaeolin 000 Nr2, 4-(2-hydroxy-1-naphthylazo)benzenesulfonic acid sodium salt}]\) \(\{633-96-5\}\) M 350.3. Purification is as for Orange I. The solubility in H\(_2\)O is 40gL at 25°. \[\text{Helv Chim Acta 35 2579 1952.}\]

Orange G \([1\text{-phenylazo-2-naphthol-6,8-disulfonic acid di-Na salt}]\) \(\{1936-15-8\}\) M 452.4, pK\(_{\text{rat}}\)-9. Recryst from 75% EtOH, dry for 3h at 110° and keep in a vacuum desiccator over H\(_2\)SO\(_4\). The free acid crystallises from EtOH or conc HCl in deep red needles with a green reflex. \[\text{J Am Chem Soc 68 2483 1946, J Chem Soc 292 1938.}\]

Orange RO \([\text{acid orange 8, 1,8-[bis(4-n-propyl-3-sulfophenyl-1-amino)anthra-9,10-quinone di-Na salt}]\) \(\{5850-86-2\}\) M 364.4, CI 15575, \(\lambda_{\max}\) 490nm. Salted out three times with sodium acetate, then repeatedly extracted with EtOH.

Osmium tetroxide (osmic acid) \(\{20816-12-0\}\) M 524.2, m 40.6°, b 59.4°/60mm, 71.5°/100mm, 109.3°/400mm, 130°/760mm, d 5.10, pK\(_1\)^{<7.2}, pK\(_2\)^{<12.2}, pK\(_3\)^{<13.95}, pK\(_4\)^{<14.17} (H\(_4\)OsO\(_4\)). It is VERY TOXIC and should be manipulated in a very efficient fume cupboard. It attacks the eyes severely \(\text{(use also face protection)}\) and is a good oxidising agent. It is volatile and has a high vapour pressure (11mm) at room temp. It sublimes and dists well below its boiling point. It is sol in C\(_6\)H\(_6\), H\(_2\)O (7.24% at 25°), CCl\(_4\) (375% at 25°), EtOH and Et\(_2\)O. It is estimated by dissolving a sample in a glass stoppered flask containing 25mL of a solution of KI (previously saturated with CO\(_2\)) and acidified with 0.35M HCl. After gentle shaking in the dark for 30min, the solution is diluted to 200mL with distilled H\(_2\)O satd with CO\(_2\) and titrated with standard thiosulfate using Starch indicator. This method is not as good as the gravimetric method. Hydrazine hydrochloride (0.1 to 0.3g) is dissolved in 3M HCl (10mL) in a glass stoppered bottle. After warming to 55-65°, a weighed sample of OsO\(_4\) solution is introduced, and the mixture is digested on a water bath for 1h. The mixture is transferred to a weighed glazed crucible and evaporated to dryness on a hot plate. A stream of H\(_2\) is started through the crucible and the crucible is heated over a burner for 20-30 min. The stream of H\(_2\) is continued until the crucible in cooled to room temperature, and then the H\(_2\) is displaced by CO\(_2\) in order to avoid rapid combustion of H\(_2\). Finally the crucible is weighed. \[\text{Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol II 1603 1965; J Am Chem Soc 60 1822 1938.}\]

§ Available commercially on a polymer support.
Oxygen [7782-44-7] M 32.00, m -182.96°, d_{183} 1.149, d_{-252*5} 1.426. Purified by passage over finely divided platinum at 673°K and Cu(II) oxide (see under nitrogen) at 973°, then condensed in liquid N_{2}-cooled trap. **HIGHLY EXPLOSIVE in contact with organic matter.**

**Palladium (II) acetate** [3375-31-3] M 244.5, m 205°dec, pk_{1}^{25} 1.0, pk_{2}^{5} 1.2 (for Pd_{2}^{2+}). Recrystd from CHCl_{3} as purple crystals. It can be washed with AcOH and H_{2}O and dried in air. Large crystals can be obtained by dissolving in C_{6}H_{6} and allowing to evaporate slowly at room temp. It forms green adducts with nitrogen donors, dissolved in KI soln but is insoluble in aqueous saturated NaCl, and NaOAc. Soluble in HCl to form PdCl_{4}^{2-}. [Chem Ind (London) 544 1964; J Chem Soc 658 1970.]

**Palladium (II) acetyl acetone** [14024-61-4] M 304.6. Recrystd from C_{6}H_{6}-pet ether and sublimed in vacuo. It is soluble in heptane, C_{6}H_{6} (1.2% at 20°, 2.2 at 40°), toluene (0.56% at 20°, 1.4% at 40°) and acetylacetone (1.2% at 20°, 0.05% at 40°). [J Inorg Nucl Chem 5 295 1957/8; Inorg Synth 5 105 1957.]

**Palladium (II) chloride** [7647-10-1] M 177.3, m 678-680°. The anhydrous salt is insoluble in H_{2}O and dissolves in HCl with difficulty. The dihydrate forms red hygroscopic crystals that are readily reduced to Pd. Dissolve in conc HCl through which dry Cl_{2} was bubbled. Filter this solution which contains H_{2}PdCl_{4} and H_{2}PdCl_{6} and on evaporation yields a residue of pure PdCl_{2}. [Handbook of Preparative Inorganic Chemistry (Ed Brauer) Vol 2 1582 1965; Org Synth Coll Vol III 685 1955.]

**Palladium (II) cyanide** [2035-66-7] M 158.1. A yellow solid, wash well with H_{2}O and dry in air. [Inorg Chem 2 245 1946]. **POISONOUS.**

**Palladium (II) trifluoroacetate** [42196-31-6] M 332.4, m 210°(dec). Suspend in trifluoroacetic acid and evaporate on a steam bath a couple of times. The residue is then dried in vacuum (40-80°) to a brown powder. [J Chem Soc 3632 1965; J Am Chem Soc 102 3572 1980.]

**Pentafluorophenyl dimethylchlorosilane (Flophemesyl chloride)** [20082-71-7] M 260.7, b 89-90°/10mm, d_{4}^{a} 1.403, n_{D}^{I} 1.447. If goes turbid on cooling due to separation of some LiCl. then dissolve in Et_{2}O, filter and fractionate. [J Chromatogr 89 225 1974, 132 548 1977.]

**Perchloric acid** [7601-90-3] M 100.5, d 1.665, pk_{1}^{25} -2.4 to -3.1 (HClO_{4}). The 72% acid has been purified by double distn from silver oxide under vacuum: this frees the acid from metal contamination. Anhydrous acid can be obtained by adding gradually 400-500mL of oleum (20% fuming H_{2}SO_{4}) to 100-120mL of 72% HClO_{4} in a reaction flask cooled in an ice-bath. The pressure is reduced to 1mm (or less), with the reaction mixture at 20-25°. The temperature is gradually raised during 2h to 85°, the distillate being collected in a receiver cooled in Dry-ice. For further details of the distillation apparatus [see Smith J Am Chem Soc 75 184 1953]. **HIGHLY EXPLOSIVE, a strong protective screen should be used at all times.**

**Phenylnarsonic acid (benzenearsonic acid)** [98-05-5] M 202.2, m 155-158°(dec), pk_{1}^{25} 3.65, pk_{2}^{5} 8.77. Crystd from H_{2}O (3ml/Jg) between 90° and 0°.

**Phenyloboric acid (benzenoboronic acid)** [98-80-6] M 121.9, m -43°, 215-216° (anhydride), 217-220°, pk_{1}^{25} 8.83. It recrystallises from H_{2}O, but can convert spontaneously to benzenoboronic anhydride or phenylboroxide on standing in dry air. Possible impurity is dibenzeneborinic acid which can be removed by washing with pet ether. Heating in an oven at 110°/760mm 1h converts it to the anhydride m 214-216°. Its solubility in H_{2}O is 1.1% at 0° and 2.5% at 25° and in EtOH it is 1.0% (w/v). [Gilman and Moore J Am Chem Soc 80 3609 1958.]

If the acid is required, not the anhydride, the acid (from recrystallisation in H_{2}O) is dried in a slow stream of air saturated with H_{2}O. The anhydride is converted to the acid by recrystallisation from H_{2}O. The acid gradually dehydrates to the anhydride if left in air at room temperature with 30-40% relative humidity. The melting point is usually that of the anhydride because the acid dehydrates before it melts [Washburn et al. Org Synth Coll Vol IV 68 1963].
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**Toxic and Moisture Sensitive.**

1,2-Phenylenephosphorochloridate (2-chloro-1,3,2-benzodioxaphosphole-2-oxide) [1499-17-8] M 190.5, m 52°, 58-59°, 59-61°, b 80-81°/1-2mm, 118°/10mm, 122°/12mm, 125°/16mm, 155°/33mm. Distil in a vacuum, sets to a colourless solid. It is soluble in pet ether, benzene and slightly soluble in Et2O. [J Chem Soc (C) 2092 1970; Justus Liebigs Ann Chem 454 109 1927.]

**Phenylmercuric hydroxide** [100-57-2] M 294.7, m 195-203°. Crystd from dilute aqueous NaOH.

**Phenylmercuric nitrate** [8003-05-2] M 634.4, m 178-188°. Crystd from water.

**Phenylphosphinic acid** [benzene phosphinic acid, PhPH(O)(OH)] [1779-48-2] M 142.1, m 70°, 71°, 83-85°, 86°, pK\textsubscript{a} 7.15. Cryst from H2O (sol 7.7% at 25°). Purified by placing the solid in a flask covered with dry Et2O, and allowed to stand for 1 day with intermittent shaking. Et2O was decanted off and the process repeated. After filtration, excess Et2O was removed in vacuum. [Justus Liebigs Ann Chem 181 265 1876; Anal Chem 29 109 1957; NMR: J Am Chem Soc 78 5715 1956; IR: Anal Chem 23 853 1951.]

**Phenylphosphonic acid** [121-70-0] M 141.1, m 71°, pK\textsubscript{a} < 0, pK\textsubscript{b} 2.1. Crystd from hot H2O.


**Phenylphosphinous acid** [PhP(OH)\textsubscript{2}] [644-97-3] M 179.0, b 68-70°/1mm, 224-226°/atm, d\textsubscript{4} 1.9317, n\textsubscript{D} 1.5962. Vacuum distilled by fractionating through a 20cm column packed with glass helices (better use a spinning band column) [J Am Chem Soc 73 755 1951; NMR: J Am Chem Soc 78 3557 1956; IR: Anal Chem 23 853 1951.]

It forms a yellow Ni complex: Ni(C\textsubscript{6}H\textsubscript{5}Cl\textsubscript{2}P)\textsubscript{4} (m 91-92°, from H2O)[J Am Chem Soc 79 3681 1957] and a yellow complex with molybdenum carbonyl: Mo(CO)\textsubscript{3} (C\textsubscript{6}H\textsubscript{5}Cl\textsubscript{2}P) (m 106-110° dec) [J Chem Soc 2323 1959].

**Phenyl phosphoro chloride** (diphenyl phosphoryl chloride) [2524-64-3] M 268.6, b 141°/1mm, 194°/13mm, 314-316°/272mm, d\textsubscript{4} 1.2960, n\textsubscript{D} 1.5490. Fractionally distd in a good vac, better use a spinning band column. [J Am Chem Soc 81 3023 1959; IR: J Chem Soc 475, 481 1952.]

**Phenyl phosphoryl dichloride** [770-12-7] M 211.0, m -10°, b 103-104°/2mm, 110-111°/10mm, 130-134°/21mm, 241-243°/atm, d\textsubscript{4} 1.4160, n\textsubscript{D} 1.5216. Fractionally distilled under as good a vacuum as possible using an efficient fractionating column or a spinning band column. It should be redistilled if the IR is not very good [IR: J Chem Soc 475, 481 1952; J Am Chem Soc 60 750 1938, 80 727 1958].

**Harmful Vapours.**

**Phenylthio trimethylsilane** (trimethyl phenylthio silane) [4551-15-9] M 182.4, b 95-99°/12mm, d\textsubscript{4} 0.97. Purification is as for phenyl trimethyl silylmethyl sulfide on p. 450.
Phenyl trimethoxysilane (trimethoxysilyl benzene) \[2996-92-1\] M 198.3, b 103\(^{\circ}\)/20mm, 130.5-131\(^{\circ}\)/45mm, \(d_4^{15} 1.022\), \(n_0^D 1.4698\). Fractionate through an efficient column but note that it forms an azeotrope with MeOH which is a likely impurity. [\textit{J Am Chem Soc} 75 2712 1953; \textit{J Gen Chem USSR} (Engl Transl) 25 1079 1955.]

Phenyl trimethylsilane (trimethylphenylsilane) \[768-32-1\] M 150.3, b 67.3\(^{\circ}\)/20mm, 98-99\(^{\circ}\)/80mm, 170.6\(^{\circ}\)/738mm, \(d_4^{25} 0.8646\). See trimethylphenylsilane on p. 489.

Phenyl trimethylsilylmethyl sulfide [(phenylthiomethyl)trimethylsilane] \[7873-08-4\] M 196.4, b 48\(^{\circ}\)/0.04mm, 113-115\(^{\circ}\)/12mm, 158.6\(^{\circ}\)/738mm, \(d_4^{10} 0.9671\), \(n_0^0 1.5380\). If the sample is suspect then add H\(_2\)O, wash with 10\% aqueous NaOH, H\(_2\)O again, dry (anhydrous CaCl\(_2\)) and fractionally distil through a 2ft column packed with glass helices. [\textit{J Am Chem Soc} 76 3713 1954.]

Phosgene \[75-44-5\] M 98.9, b 8.2\(^{\circ}\)/756mm. Dried with Linde 4A molecular sieves, degassed and distilled under vacuum. This should be done in a closed system such as a vacuum line. HIGHLY TOXIC, should not be inhaled. If it is inhaled operator should lie still and be made to breathe ammonia vapour which reacts with phosgene to give urea.

Phosphine \[7803-51-2\] M 34.0, m -133\(^{\circ}\), b -87.7\(^{\circ}\), pK \(14\), pK\(_b\) 28. Best purified in a gas line (in a vacuum) in an efficient fume cupboard. It is spontaneously flammable, has a strong odour of decayed fish and is POISONOUS. The gas is distilled through solid KOH towers (two), through a Dry ice-acetone trap (-78\(^{\circ}\), to remove H\(_2\)O, and P\(_2\)H\(_4\) which causes spontaneous ignition with O\(_2\)), then through two liquid N\(_2\) traps (-196\(^{\circ}\)), followed by distillation into a -126\(^{\circ}\) trap (Dry ice-methylcyclohexane slush), allowed to warm in the gas line and then seal in ampoules preferably under N\(_2\). IR: \(v 2327\) (m), 1121 (m) and 900 (m) cm\(^{-1}\). [Klement in \textit{Handbook of Preparative Inorganic Chemistry} (Ed. Brauer) Vol I, pp. 525-530 1963; Gokhale and Jolly \textit{Inorg Synth} 9 56 1967. PH\(_3\) has also been absorbed into a soln of cuprous chloride in hydrochloric acid (when CuCl.PH\(_3\) is formed). PH\(_3\) gas is released when the soln is heated and the gas is purified by passage through KOH pellets and over then P\(_2\)O\(_5\). The solubility is 0.26mL/1 mL of H\(_2\)O at 20\(^{\circ}\) and a crystalline hydrate is formed on releasing the pressure on an aq soln.

Phosphonitrilic chloride (tetramer) \[1832-07-1\] M 463.9. Purified by zone melting, then crystd from pet ether (b 40-60\(^{\circ}\)) or n-hexane. [van der Huizen et al. \textit{J Chem Soc, Dalton Trans} 1317 1986.]


Phosphoric acid \[7664-38-2\] M 98.0, m 42.3\(^{\circ}\), pK\(_1^{25}\) 2.15, pK\(_2^{25}\) 7.21, pK\(_3^{25}\) 12.33. Pyrophosphate can be removed from phosphoric acid by diluting with distilled H\(_2\)O and refluxing overnight. By cooling to 11\(^{\circ}\) and seeding with crystals obtained by cooling a few millilitres in a Dry-ice-acetone bath, 85\% orthophosphoric acid crystallises as H\(_3\)PO\(_4\). The crystals are separated using a sintered glass filter. It has pK\(_1^{25}\) values of 2.15, 7.20 and 12.37 in H\(_2\)O.

Phosphorus (red) \[7723-14-0\] M 31.0, m 590\(^{\circ}\)/43atm, ignites at 200\(^{\circ}\), d 2.34. Boiled for 15min with distilled H\(_2\)O, allowed to settle and washed several times with boiling H\(_2\)O. Transferred to a Büchner funnel, washed with hot H\(_2\)O until the washings are neutral, then dried at 100\(^{\circ}\) and stored in a desiccator.

Phosphorus (white) \[7723-14-0\] M 31.0, m 590, d 1.82. Purified by melting under dilute H\(_2\)SO\(_4\)* dichromate (possible carcinogen) mixture and allowed to stand for several days in the dark at room temperature. It remains liquid, and the initial milky appearance due to insoluble, oxidisable material gradually disappears. The phosphorus can then be distilled under vacuum in the dark [Holmes \textit{Trans Faraday Soc} 58 1916]
Other methods include extraction with dry CS₂ followed by evaporation of the solvent, or washing with 6M HNO₃, then H₂O, and drying under vacuum. **POISONOUS.**

**Phosphorus oxychloride** [10025-87-3] M 153.3, b 105.5⁰, n 1.461, d 1.675. Distilled under reduced pressure to separate from the bulk of the HCl and the phosphoric acid, the middle fraction being distilled into ampoules containing a little purified mercury. These ampoules are sealed and stored in the dark for 4-6 weeks with occasional shaking to facilitate reaction of any free chloride with the mercury. The POCl₃ is then again fractionally distd and stored in sealed ampoules in the dark until used [Herber *J Am Chem Soc* 82 792 1960]. Lewis and Sowerby [J Chem Soc 336 1957] refluxed their distilled POCl₃ with Na wire for 4h, then removed the Na and again distilled. Use Na only with almost pure POCl₃ to avoid explosions. **HARMFUL VAPOURS.**

**Phosphorus pentabromide** [7789-69-7] M 430.6, m <100⁰, b 106⁰(dec). Dissolved in pure nitrobenzene at 60⁰, filtering off any insoluble residue on to sintered glass, then crystallised by cooling. Washed with dry Et₂O and removed the ether in a current of dry N₂. (All manipulations should be performed in a dry-box.) [Harris and Payne *J Chem Soc* 3732 1958]. Fumes in moist air because of hydrolysis. **HARMFUL VAPOURS.**

**Phosphorus pentachloride** [10026-13-8] M 208.2, m 179-180⁰(sublimes). Sublimed at 160-170⁰ in an atmosphere of chlorine. The excess chlorine was then displaced by dry N₂ gas. All subsequent manipulations were performed in a dry-box [Downs and Johnson *J Am Chem Soc* 77 2098 1955]. Fumes in moist air. **HARMFUL VAPOURS.**

**Phosphorus pentasulfide** [1314-80-3] M 444.5, m 277-283⁰. Purified by extraction and crystallisation with CS₂, using a Soxhlet extractor. Liberates H₂S in moist air. **HARMFUL VAPOURS and attacks skin.**

**Phosphorus pentoxide** [1314-56-3] M 141.9, m 562⁰, b 605⁰. Sublimed at 250⁰ under vacuum into glass ampoules. Fumes in moist air and reacts violently with water. **HARMFUL VAPOURS and attacks skin.**

**Phosphorus sesquisulfide** P₄S₃ [1314-85-8] M 220.1, m 172⁰. Extracted with CS₂, filtered and evapd to dryness. Placed in H₂O, and steam was passed through for an hour. The H₂O was then removed, the solid was dried, followed by crystallisation from CS₂ [Rogers and Gross *J Am Chem Soc* 74 5294 1952].

**Phosphorus sulfochloride (phosphorus thiochloride)** [13455-01-1] M 411.7, m 61⁰. Decomposes in moist air and must be kept in a desiccator over CaCl₂. It is crystallised from sulfur-free CS₂ otherwise the m decreases to ca 55⁰. It is best prepared freshly. [J Am Chem Soc 49 301 1927; *Handbook of Preparative Inorganic Chemistry* (Ed. Brauer) vol I 541 1963.] **HARMFUL VAPOURS.**
12-Phosphotungstic acid \( \text{[12501-23-4]} \) \( \text{M 2880.2, m \text{-96}^\circ} \). A few drops of \text{conc HNO}_3 were added to \( 100 \text{g} \) of phosphotungstic acid dissolved in \( 75 \text{mL} \) of water, in a separating funnel, and the soln was extracted with diethylether. The lowest of the three layers, which contained a phosphotungstic acid-ether complex, was separated, washed several times with \( 2 \text{M HCl} \), then with water and again extracted with ether. Evaporation of the ether, under vacuum with mild heating on a water bath gave crystals which were dried under vacuum and ground [Matijevic and Kerker, \textit{J Am Chem Soc} \textit{81} 1307 1959].

**Phthalocyanine** [574-93-6] \( \text{M 514.6} \). Purified by sublimation (two to three times) in an argon flow at 300-400Pa. Similarly for the Cu(II), Ni(II), Pb(II), VO(II) and Zn(II) phthalocyanine complexes.

**Platinum (II) acetylacetone** [15170-57-7] \( \text{M 393.3, m 249-252}^\circ \). Recrystd from \( \text{C}_6\text{H}_6 \) as yellow crystals and dried in air or in a vacuum desiccator. [Chem Ber \textit{34} 2584 1901.]

**Platinum (II) chloride** [10025-65-7] \( \text{M 266.0, d 5.87} \). It is purified by heating at \( 450^\circ \) in a stream of \( \text{Cl}_2 \) for \( 2 \text{h} \). Some sublimation occurs because the \( \text{PtCl}_2 \) sublimes completely at \( 560^\circ \) as red (almost black) needles. This sublimate can be combined to the bulk chloride and while still at \( ca 450^\circ \) it should be transferred to a container and cooled in a desiccator. A probable impurity is \( \text{PtCl}_4 \). To test for this add a few drops of \( \text{H}_2\text{O} \) (in which \( \text{PtCl}_4 \) is soluble) to the salt, filter and add an equal volume of saturated aqueous \( \text{NH}_4\text{Cl} \) to the filtrate. If no ppt is formed within \( 1 \text{min} \) then the product is pure. If a ppt appears then the whole material should be washed with small volumes of \( \text{H}_2\text{O} \) until the soluble \( \text{PtCl}_4 \) is removed. The purified \( \text{PtCl}_2 \) is partly dried by suction and then dried in a vacuum desiccator over \( \text{P}_2\text{O}_5 \). It is insoluble in \( \text{H}_2\text{O} \) but soluble in \( \text{HCl} \) to form chloroplatinic acid (\( \text{H}_2\text{PtCl}_4 \)) by disproportionation. [Inorg Synth \textit{6} 209 1960.]

**Polystyrenesulfonic acid sodium salt** \( (-\text{CH}_2\text{CH(C}_6\text{H}_4\text{SO}_3\text{Na})-) \) [25704-18-1]. Purified by repeated pptn of the sodium salt from aqueous soln by \( \text{MeOH} \), with subsequent conversion to the free acid by passage through an Amberlite IR-120 ion-exchange resin. [Kotin and Nagasawa \textit{J Am Chem Soc} \textit{83} 1026 1961.] Recrystd from \( \text{EtOH} \). Also purified by passage through cation and anion exchange resins in series (Rexyn 101 cation exchange resin and Rexyn 203 anion exchange resin), then titrated with \( \text{NaOH} \) to \( \text{pH} 7 \). The sodium form of polystyrenesulfonic acid pptd by addition of 2-propanol. Dried in a vac oven at \( 80^\circ \) for \( 24 \text{h} \), finally increasing to \( 120^\circ \) prior to use. [Kowblansky and Ander \textit{J Phys Chem} \textit{80} 297 1976.]

**Pontacyl Carmine 2G** (Acid Red 1, Amido Naphthol Red G, Azophloxine, 1-acetamido-8-hydroxy-7-phenylazonaphthalene-3,7-disulfonic acid di-Na salt) [3734-67-6] \( \text{M 510.4, CI 18050, h}_\text{max} 532\text{nm} \). Salted out three times with sodium acetate, then repeatedly extracted with \( \text{EtOH} \). See Solochrome Violet R on p. 352 in Chapter 4. [McGrew and Schneider \textit{J Am Chem Soc} \textit{72} 2547 1950.]

**Pontacyl Light Yellow GX** [Acid Yellow 17, 1-(2,5-dichloro-4-sulfophenyl]-3-methyl-4-(4-sulfophenylazo)-5-hydroxypyrazole di-Na Salt] [6359-98-4] \( \text{M 551.3, CI 18965, h}_\text{max} 400\text{nm} \). Purification as for Pontacyl Carmine 2G above.

**Potassium (metal)** [7440-09-7] \( \text{M 39.1, m 62.3}^\circ, \text{d 0.89} \). Oil was removed from the surface of the metal by immersion in \( n \)-hexane and pure \( \text{Et}_2\text{O} \) for long periods. The surface oxide was next removed by scraping under ether, and the potassium was melted under vacuum. It was then allowed to flow through metal constrictions into tubes that could be sealed, followed by distillation under vacuum in the absence of mercury vapour (see Sodium). EXPLOSIVE IN WATER.

**Potassium acetate** [127-08-2] \( \text{M 98.2, m 292}^\circ, \text{d 1.57, pK}^{15} 16 \) (for aquo \( \text{K}^+ \)). Crystd three times from water-ethanol (1:1) dried to constant weight in a vacuum oven, or crystd from anhydrus acetic acid and pumped dry under vacuum for 30h at \( 100^\circ \).

**Potassium 4-aminobenzoate** [138-84-1] \( \text{M 175.2} \). Crystd from \( \text{EtOH} \).

**Potassium antimonyltartrate** (\( \text{H}_2\text{O} \)) [28300-74-5] \( \text{M 333.9, }\text{[a]}_{D}^{100} +141^\circ \) \( \text{c 2, H}_2\text{O} \). Crystd from water (3mL/g) between 100\(^\circ\) and 0\(^\circ\). Dried at 100\(^\circ\).
Potassium benzoate [582-25-2] M 160.2. Crystd from water (1mL/g) between 100° and 0°.

Potassium bicarbonate [298-14-6] M 100.1. Crystd from water at 65-70° (1.25mL/g) by filtering, then cooling to 15°. During all operations, CO₂ is passed through the stirred mixture. The crystals, sucked dry at the pump, are washed with distilled water, dried in air and then over H₂SO₄ in an atmosphere of CO₂.

Potassium bisulfate [7646-93-7] M 136.2, m 214°. Crystd from H₂O(1mL/g) between 100° and 0°.


Potassium bromate [7758-01-2] M 167.0, m 350°(dec at 370°), d 3.27. Crystd from distilled H₂O(2mL/g) between 100° and 0°. To remove bromide contamination, a 5% soln in distilled H₂O, cooled to 10°, has been bubbled with gaseous chlorine for 2h, then filtered and extracted with reagent grade CCl₄ until colourless and odourless. After evaporating the aqueous phase to about half its volume, it was cooled again slowly to about 10°. The crystalline KBrO₃ was separated, washed with 95% EtOH and vacuum dried [Boyd, Cobble and Wexler J Am Chem Soc 74 237 1952]. Another way to remove Br⁻ ions was by stirring several times in MeOH and then dried at 150° [Field and Boyd J Phys Chem 89 3767 1985].

Potassium bromide [7758-02-3] M 119.0, m 734°, d 2.75. Crystd from water between 100° and 0°. Washed with 95% EtOH, followed by Et₂O. Dried in air, then heated at 115° for lh, pulverised and heated in a vacuum oven at 130° for 4h. Has also been crystd from aqueous 30% EtOH, or EtOH, and dried over P₂O₅ under vacuum before heating in an oven.

Potassium tert-butoxide [865-47-4] M 112.2. It sublimes at 220°/1 Torr. Last traces of tert-BuOH are removed by heating at 150-160°/2mm for 1h. It is best prepared fresh; likely impurities are tert-BuOH, KOH and K₂CO₃ depending on exposure to air. Its solubility at 25°-26° in hexane, toluene, Et₂O, and THF is 0.27%, 2.27%, 4.34% and 25.0% respectively. [J Am Chem Soc 78 5938, 4364 1956].

Potassium carbonate [584-08-7] M 138.2, m 898°, d 2.3. Crystd from water between 100° and 0°. After 2 recrystns tech grade had B, Li and Fe at 1.0, 0.04 and 0.01 ppm resp.

Potassium chlorate [3811-04-9] M 122.6, m 368°. Crystd from water (1.8mL/g) between 100° and 0°, and the crystals are filtered onto sintered glass.

Potassium chloride [7447-40-7] M 74.6, m 771°, d 1.98. Dissolved in conductivity water, filtered, and saturated with chlorine (generated from conc HCl and KMnO₄). Excess chlorine was boiled off, and the KCl was pptd by HCl (generated by dropping conc HCl into conc H₂SO₄). The ppte was washed with water, dissolved in conductivity water at 90-95°, and crystd by cooling to about -5°. The crystals were drained at the centrifuge, dried in a vacuum desiccator at room temperature, then fused in a platinum dish under N₂, cooled and stored in desiccator. Potassium chloride has also been sublimed in a stream of prepurified N₂ gas and collected by electrostatic discharge [Craig and McIntosh Can J Chem 30 448 1952].

Potassium chromate [7789-00-6] M 194.2, m 975°, d 2.72, pK²⁺ 0.74, pK²⁺ 6.49 (for H₂CrO₄). Crystd from conductivity water (0.6g/mL at 20°), and dried between 135° and 170°.

Potassium cobalticyanide [13963-58-1] M 332.4, m dec on heating, d 1.91. Crystd from water to remove traces of HCN.

Potassium cyanate [590-28-3] M 81.1, d 2.05, pK²⁻ 3.46 (for HCNO). Common impurities include ammonia and bicarbonate ion (from hydrolysis). Purified by preparing a saturated aqueous solution at
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50°, neutralising with acetic acid, filtering, adding two volumes of EtOH and keeping for 3-4h in an ice bath. (More EtOH can lead to co-precipitation of KHCO₃.) Filtered, washed with EtOH and dried rapidly in a vacuum desiccator (P₂O₅). The process is repeated [Vanderzee and Meyers J Chem Soc 65 153 1961].

Potassium cyanide [151-50-8] M 65.1, m 634°, d 1.52. A saturated solution in H₂O-ethanol (1:3) at 60° was filtered and cooled to room temperature. Absolute EtOH was added, with stirring, until crystallisation ceased. The solution was then allowed to cool to room temperature (during 2-3h) then the crystals were filtered off, washed with absolute EtOH, and dried, first at 70-80° for 2-3h, then at 105° for 2h [Brown, Adisesh and Taylor J Phys Chem 66 2426 1962]. Also purified by vacuum melting and zone refining. HIGHLY POISONOUS.

Potassium dichromate [7778-50-9] M 294.2, m 398°(dec), d 2.68. Crystd from water (1mL/g) between 100° and 0° and dried under vacuum at 156°. (Possible CARCINOGEN).


Potassium dihydrogen phosphate [7778-77-0] M 136.1. Dissolved in boiling distilled water (2mL/g), kept on a boiling water-bath for several hours, then filtered through paper pulp to remove any turbidity. Cooled rapidly with constant stirring, and the crystals were separated on to hardened filter paper, using suction, washed twice with ice-cold water, once with 50% EtOH, and dried at 105°. Alternative crystals are from water, then 50% EtOH, and again water, or from conc aqueous solution by addition of EtOH. Freed from traces of Cu by extracting its aqueous solution with diphenylthiocarbazone in CCl₄, followed by repeated extraction with CCl₄ to remove traces of diphenylthiocarbazone.

Potassium dithionate [13455-20-4] M 238.3, pK⁻¹ 3.4, pK₂ 0.49 (for dithionic acid). Crystd from water (1.5mL/g) between 100° and 0°.

Potassium ethylxanthate [140-89-6] M 160.3, m > 215°(dec). Crystd from absolute EtOH, ligroin-ethanol or acetone by addition of Et₂O. Washed with ether, then dried in a desiccator.


Potassium ferrocyanide (3H₂O) [16921-30-5] M 486.0, m 250°(dec). Crystd from water (20mL/g) between 100° and 0°.
Potassium hexacyanochromate (III) \((3\text{H}_2\text{O})\) \([13601-11-1]\) M 418.5. Crystd from water.

Potassium hexafluorophosphate \([17084-13-8]\) M 184.1, \(pK_{2}^{+} 0.5, pK_{2}^{-} 5.12\) (for fluorophosphoric acid \(\text{H}_2\text{PO}_3\text{F}\)). Crystd from alkaline aqueous solution, using polyethylene vessels, or from 95% EtOH, and dried in a vacuum desiccator over KOH.

Potassium hexafluorozirconate \((\text{K}_2\text{ZrF}_6)\) \([16923-95-8]\) M 283.4, d 3.48. Recrystd from hot water (solubility is 0.78% at 20° and 25% at 100°).

Potassium hexafluorophosphate \([7789-29-9]\) M 78.1. Crystd from water.

Potassium hexafluoroacetate \([18404-47-2]\) M 248.2, m 188°(dec). Crystd from water.

Potassium hydrogen malate \([4675-64-3]\) M 172.2. A saturated aqueous solution at 60° was decolorised with activated charcoal, and filtered. The filtrate was cooled in water-ice bath and the salt was ppted by addition of EtOH. After being crystallised five times from ethanol-water mixtures, it was dried overnight at 130° in air [Eden and Bates \(J\ Res\ Nat\ Bur\ Stand\ 62\ 161\ 1959\)].

Potassium hydrogen oxalate \((\text{H}_2\text{O})\) \([127-95-7]\) M 137.1. Crystd from water by dissolving 20g in 100mL water at 60° containing 4g of potassium oxalate, filtering and allowing to cool to 25°. The crystals, after washing three or four times with water, are allowed to dry in air.

Potassium hydrogen phthalate \([877-24-7]\) M 204.2. Crystd first from a dilute aqueous solution of \(\text{K}_2\text{CO}_3\), then \(\text{H}_2\text{O}(3\text{mL/g})\) between 100° and 0°. Before being used as a standard in volumetric analysis, analytical grade potassium hydrogen phthalate should be dried at 120° for 2h, then allowed to cool in a desiccator.

Potassium hydrogen d-tartrate \([868-14-4]\) M 188.2, \(\alpha\)\(^{20}\) +37.5° (c 10, \(\text{NaOH}\)). Crystd from water (17mL/g) between 100° and 0°. Dried at 110°.

Potassium hydroxide (solution) \([1310-58-3]\) M 56.1, \(pK_{2}^{+} 16\) (for aquo \(\text{K}^{+}\)). Its carbonate content can be reduced by rinsing KOH sticks rapidly with water prior to dissolving them in boiled out distilled water. Alternatively, a slight excess of saturated \(\text{BaCl}_2\) or \(\text{Ba(OH)}_2\) can be added to the soln which, after shaking well, is left so that the \(\text{BaCO}_3\) ppt will separate out. Davies and Nancollas [Nature 165 237 1950] rendered KOH solutions carbonate free by ion exchange using a column of Amberlite IR-100 in the OH\(^-\) form.

Potassium iodate \([7758-05-6]\) M 214.0, \(pK_{2}^{+} 0.80\) (for \(\text{HIO}_3\)). Crystd twice from distilled water (3mL/g) between 100° and 0°, dried for 2h at 140° and cooled in a desiccator. Analytical reagent grade material dried in this way is suitable for use as an analytical standard.

Potassium iodide \([7681-11-0]\) M 166.0, \(pK_{2}^{+} -8.56\) (for \(\text{HI}\)). Crystd from distilled water (0.5mL/g) by filtering the near-boiling soln and cooling. To minimise oxidation to iodine, the crysn can be carried out under \(\text{N}_2\) and the salt is dried under vacuum over \(\text{P}_2\text{O}_5\) at 70-100°. Before drying, the crystals can be washed with EtOH or with acetone followed by pet ether. Has also been recrystallised from water/ethanol. After 2 recrystns ACS/USP grade had Li and Sb at <0.02 and <0.01 ppm resp.

Potassium ionophore I (valinomycin) \([2001-95-8]\) M 111.3, m 186-187°, 190°, \(\alpha\)\(^{20}\) +31.0° (c 1.6, \(\text{C}_6\text{H}_6\)). See valinomycin on p. 573 in Chapter 6.

Potassium isooamyl xanthate \([61792-26-5]\) M 202.4, \(pK 1.82\) (\(pK_0 2.8\) free acid). Crystd twice from acetone-diethyl ether. Dried in a desiccator for two days and stored under refrigeration.

Potassium laurate \([10124-65-9]\) M 338.4. Recrystd three times from EtOH [Neto and Helene \(J\ Phys\ Chem\ 91\ 1466\ 1987\)].
Potassium nickel sulfate (6H₂O) [13842-46-1] M 437.1. Crystd from H₂O (1.7mL/g) between 75° and 0°.

Potassium nitrate [7757-79-1] M 101.1, m 334°. Crystd from hot H₂O (0.5mL/g) by cooling (cf KNO₂ below). Dried for 12 h under vacuum at 70°. After 2 recrystns tech grade had < 0.001 ppm of metals.

Potassium nitrite [7758-09-0] M 85.1, m 350° (dec), pK substance 3.20 (for HNO₂). A saturated solution at 0° can be warmed and partially evaporated under vacuum, the crystals so obtained being filtered from the warm solution. (This procedure is designed to reduce the level of nitrate impurity and is based on the effects of temperature on solubility. The solubility of KNO₃ in water is 13g/100mL at 0°, 247g/100mL at 100°; for KNO₂ the corresponding figures are 280g/100mL and 413g/100mL.)

Potassium nitrosodisulfonate (Fremy's Salt) [14293-70-0] M 268.3. Yellow needles (dimeric) which dissolve in H₂O to give the violet monomeric free radical. Purified by dissolving (-12g) in 2M KOH (600mL) at 45°, filtering the blue soln and keeping it in a refrigerator overnight. The golden yellow crystals (log) are filtd off, washed with MeOH (3x), then Et₂O and stored in a glass container in a vac over KOH. It is stable indefinitely when dry. [Cram and Reeves J Org Chem 80 3094 1958; Schenk Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol I p. 505 1963.]

Potassium nonafluorobutane sulfonate [29420-49-3] M 338.2. Wash with H₂O and dry in vacuum. The K salt when distilled with 100% H₂SO₄ gives the free acid which can be distilled (b 105°/22mm, 210°-212°/760mm) and then converted to the K salt. [J Chem Soc 2640 1957.]

Potassium oleate [143-18-0] M 320.6. Crystd from EtOH (1mL/g).

Potassium osmate (VI) dihydrate [19718-36-6] M 368.4. Hygroscopic POISONOUS crystals which are soluble in H₂O but insol in EtOH and Et₂O. It decomposes slowly in H₂O to form the tetroxide which attacks the eyes. The solid should be kept dry and in this form it is relatively safe. [Synthesis 610 1972.]


Potassium perchlorate [7778-74-7] M 138.6, m 400 (dec), d 2.52, pK substance 25 -2.4 to -3.1 (for HClO₄). Crystd from boiling water (5mL/g) by cooling. Dried under vacuum at 105°.

Potassium periodate (potassium metaperiodate) [7790-21-8] M 230.0, m 582°, d 3.62. Crystd from distilled water.

Potassium permanganate [7722-64-7] M 158.0, m 240 (dec), d 2.7, pK substance 25 -2.25 (for HMnO₄). Crystd from hot water (4mL/g at 65°), then dried in a vacuum desiccator over CaSO₄. Phillips and Taylor [J Chem Soc 4242 1962] cooled an aqueous solution of KMnO₄, saturated at 60°, to room temperature in the dark, and filtered through a No.4 porosity sintered-glass filter funnel. The solution was allowed to evaporate in air in the dark for 12 h, and the supernatant liquid was decanted from the crystals, which were dried as quickly as possible with filter paper.

Potassium peroxydisulfate (potassium persulfate) [7727-21-1] M 270.3. Crystd twice from distilled water (10mL/g) and dried at 50° in a vacuum desiccator.

Potassium peroxymonosulfate (Oxone, potassium monopersulfate triple salt; 2KHSO₅.KHSO₄.K₂SO₄) [37222-66-5, triple salt] [70693-62-8] M 614.8. This is a stable form of Caro's acid and should contain >4.7% of active oxygen. It can be used in EtOH/H₂O and EtOH/AcOH/H₂O solutions. If active oxygen is too low it is best prepared afresh from 1mole of KHSO₅, 0.5mole of KHSO₄ and 0.5mole of K₂SO₄. [Kennedy and Stock J Org Chem 25 1901 1960; Stephenson US Patent 2,802,722 1957.] A rapid prepn of Caro's acid is made by stirring finely powdered potassium persulfate (M 270.3) into ice cold conc H₂SO₄ (7mL) and when homogeneous add ice (40-50g). It is stable for several days if kept cold.
Keep away from organic matter as it is a STRONG OXIDANT. A detailed prepn of Caro's acid (hypersulfuric acid, H$_2$SO$_5$, [7722-86-3]) in crystalline form m -45° from H$_2$O$_2$ and chlorosulfonic acid was described by Fehér in *Handbook of Preparative Inorganic Chemistry* (Ed. Brauer) Vol I p. 388 1963.

Potassium perrhenate (KReO$_4$) [10466-65-6] M 289.3, pK$_{25}$ -1.25 (for HReO$_4$). Crystd from water (7mL/g), then fused in a platinum crucible in air at 750°.

Potassium phenol-4-sulfonate (4-hydroxybenzene-1-sulfonic acid K salt) [30145-40-5] M 212.3. Crystd several times from distilled water at 90°, after treatment with charcoal, by cooling to ca 100°. Dried at 90-100°.

Potassium phthalimide (phthalimide K salt) [1074-82-4] M 185.2, m >300°. The solid may contain phthalimide and K$_2$CO$_3$ from hydrolysis. If too much hydrolysis has occurred (this can be checked by extraction with cold Me$_2$CO in which the salt is insoluble, evaporation of the Me$_2$CO and weighing the residue) it would be better to prepare it afresh. If little hydrolysis had occurred then recryst from a large volume of EtOH, and wash solid with a little Me$_2$CO and dry in a continuous vacuum to constant weight. [Salzerg and Supriawski *Org Synth Coll* Vol I 119 1941; Raman and IR: Hase *J Mol Struct* 48 33 1978; Dykman *Chem Ind (London)* 40 1972; IR, NMR: Assaf et al. *Bull Soc Chim Fr* 11-167 1979.]

Potassium picrate [573-83-1] M 267.2. Crystd from water or 95% EtOH, and dried at room temperature in vacuum. It is soluble in 200 parts of cold water and 4 parts of boiling water. THE DRY SOLID EXPLODES WHEN STRUCK OR HEATED.

Potassium propionate [327-62-8] M 112.2. Crystd from water (30mL/g) or 95% EtOH.


Potassium (VI) ruthenate [34432-70-4] M 243.3. Dissolve in H$_2$O and evaporate until crystals are formed. The crystals are iridescent green prisms which appear red as thin films. Possible impurity is RuO$_4$; in this case wash with CCl$_4$ (which dissolves RuO$_4$). The concn of an aqueous solution of RuO$_4$ (orange colour) can be estimated from the absorbance at 385nm (ε 1030 M$^{-1}$ cm$^{-1}$), or at 460nm (ε 1820 M$^{-1}$ cm$^{-1}$). [Can J Chem 50 3741 1972; J Am Chem Soc 74 5012 1952; *Handbook of Preparative Inorganic Chemistry* (Ed. Brauer) Vol II 1600 1965].

Potassium selenocyanate [3425-46-5] M 144.1. Dissolved in acetone, filtered and ppted by adding Et$_2$O.

Potassium sodium tartrate (4H$_2$O) [6381-59-5 (4H$_2$O); 304-59-6 (R,R)] M 282.3. Crystd from distilled water (1.5mL/g) by cooling to 0°.

Potassium sulfate [7778-80-5] M 174.3, m 1069°, d 2.67 Crystd from distilled water (4mL/g at 20°; 8mL/g at 100°) between 100° and 0°.

Potassium d-tartrate (H$_2$O) [921-53-9 , 6381-59-5] M 235.3, m loses H$_2$O at 150°, d 1.98. Crystd from distilled water (solubility: 0.4mL/g at 100°; 0.5mL/g at 14°).

Potassium tetrachloroplatinate(II) [10025-99-7] M 415.1, m 500°(dec). Crystd from aqueous 0.75M HCl (20mL/g) between 100° and 0°. Washed with ice-cold water and dried.

Potassium tetracyanopalladate (II) 3H$_2$O [10025-98-6] M 377.4. All operations should be carried out in an efficient fume cupboard - Cyanide is very POISONOUS Dissolve the complex (ca 5g) in a solution of KCN (4g) in H$_2$O (75mL) with warming and stirring and evaporate hot till crystals appear. Cool, filter off the crystals and wash with a few drops of cold H$_2$O. Further concentration of the mother liquors provides more crystals. The complex is recrystallised from H$_2$O as the colourless trihydrate. It effloresces in
dry air and dehydrates at 100° to the monohydrate. The anhydrous salt is obtained by heating at 200°, but at higher temperatures it decomposes to (CN)₂, Pd and KCN. [Inorg Synth 2 245 1946.]

**Potassium tetrafluoroborate (potassium borofluoride) [14075-53-7] M 125.9, m 530°, d₄³⁰ 2.505, pK₂⁵ -4.9 (for HBF₄).** Cryst from H₂O (sol % (temp): 0.3 (30°), 0.45 (20°), 1.4 (40°), 6.27 (100°), and dry under vacuum. Non-hygroscopic salt. A 10% solution is transparent blue at 100°, green at 90° and yellow at 60°. [Chem Ber 65 555 1932; Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol 1 223 1963.]

**Potassium tetraoxalate (2H₂O) [oxalic acid hemipotassium salt] [13446-67-8; 127-96-8 (anhydr)] M 254.2.** Cryst from water below 50°. Dried below 60° at atmospheric pressure.

**Potassium tetraphenylborate [32444-41-5] M 358.3.** Ppted from a soln of KCl acidified with dilute HCl, then crystallised twice from acetone, washed thoroughly with water and dried at 100°. [Findeis and de Vries Anal Chem 28 1899 1956.] It has also been recrystd several times from conductivity water.

**Potassium thiocyanate [333-20-0] M 97.2, m 172°, pK₂⁵ -1.85 (for HSCN).** Crystd from H₂O if much chloride ion is present in the salt, otherwise from EtOH or MeOH (optionally by addition of Et₂O). Filtered on a Büchner funnel without paper, and dried in a desiccator at room temperature before being heated for 1h at 150°, with a final 10-20min at 200° to remove the last traces of solvent [Kolthoff and Lingane J Am Chem Soc 57 126 1935]. Stored in the dark.

**Potassium thiosulfate hydrate [13446-67-8; 10294-66-3 (75% aq soln)] M 190.3, pK₂⁵ 0.6, pK₅ 1.74 (for H₂S₂O₃).** Crystd from warm water (0.5mL/g) by cooling in an ice-salt mixture.

**Potassium thiosulphate [28519-50-8] M 226.4.** Recrystallise from absolute EtOH and dry at 130°. In wet EtOH the monohydrate can be obtained. [J Gen Chem USSR (Engl Transl) 28 1345 1958.]

**Potassium tungstate (ortho 2H₂O) [37349-36-3; 7790-60-5] M 362.1, m 921°, d 3.12, pK₂⁵ 2.20, pK₅ 3.70 (for H₂WO₄).** Cryst from hot water (0.7mL/g).


**Praseodymium trichloride (6H₂O) [10361-79-2] M 355.4, pK₂⁵ 8.55 (for Pr³⁺ hydrol).** Its 1M soln in 6M HCl was passed twice through a Dowex-1 anion-exchange column. The eluate was evaporated in a vac desiccator to about half its vol and allowed to crystallise [Katzin and Gulyas J Phys Chem 66 494 1962].

**Propargyl triphenyl phosphonium bromide [2091-46-5] M 381.4, m 179°.** Recrystallises from 2-propanol as white plates. Also crystallises from EtOH, m 156-158°. IR has ν 1440, 1110cm⁻¹ (P-C str). [Justus Liebig's Ann Chem 682 62 1965; J Org Chem 42 200 1977].
Propenyloxy trimethylsilane \[1833-53-0]\(\) M 130.3, b 93-95°/atm, d 0.786. Purified by fractional distillation using a very efficient column at atmospheric pressure. Usually contains 5% of hexamethyldisiloxane which boils at 99-101°, but is generally non-reactive and need not be removed. [J Am Chem Soc 71 5091 1952.] It has been distilled under N2 through a 15cm column filled with glass helices. Fraction b 99-104° is further purified by gas chromatography through a Carbowax column (Autoprep A 700) at a column temperature of 87°, retention time is 9.5min. [J Organometal Chem 1 476 1963-4.]

1-Propenyltrimethylsilane (cis and trans mixture) \[17680-01-2]\(\) M 114.3, b 85-88°, n\(\)\(^\text{D}\) 1.4121. Dissolve (~20g) in THF (200mL), shake with H2O (2x 300 mL), dry (Na2SO4) and fractionate. This is a mixture of cis and trans isomers which can be separated by gas chromatography on an AgNO3 column (for prep: see Seyferth and Vaughan J Organomet Chem I 138 1963) at 25° with He as carrier gas at 9psi. The cis-isomer has \(\)\(n_\text{D}^25\) 1.4105 and the trans-isomer has \(\)\(n_\text{D}^25\) 1.4062. [Seyferth et al. Pure Appl Chem 13 159 1966.]

Pyridinium chlorochromate \[26299-14-9]\(\) M 215.6, m 205°(dec). Dry in a vacuum for 1h. It is not hygroscopic and can be stored for extended periods at room temp without change. If very suspect it can be readily prepared. [Tetrahedron Lett 2647 1975; Synthesis 245 1982.]

Available commercially on a polymer support.

Pyridinium dichromate \[20039-37-6]\(\) M 376.2, m 145-148°, 152-153°. Dissolve in the minimum volume of H2O and add 5 volumes of cold Me2CO and cool to -20°. After 3h the orange crystals are collected, washed with a little cold Me2CO and dried in a vacuum. It is soluble in dimethylformamide (0.9g/mL at 25°), and in H2O, and has a characteristic IR with v 930, 875, 765 and 730cm\(^{-1}\). [Tetrahedron Lett 399 1979; Chem Ind (London) 1594 1969.] (Possible carcinogen).

Available commercially on a polymer support.

3-(2-Pyridyl)-5,6-diphenyl-1,2,4-triazine-p,p'-disulfonic acid, monosodium salt (H2O) \[63451-29-6]\(\) M 510.5. Purified by recrystn from water or by dissolving in the minimum volume of water, followed by addition of EtOH to ppte the pure salt.

Pyrocatechol Violet (tetraphenolictriphenylmethanesulfonic acid Na salt) \[115-41-3]\(\) M 386.4, \(\varepsilon\) 1.4 x 10\(^4\) at 445nm in acetate buffer pH 5.2-5.4, \(\text{pK}_{\text{eq}}(1)>0\) (SO\(_3\)H), \(\text{pK}_{\text{eq}}(2)=9.4, \text{pK}_{\text{eq}}(3)=13\). It was recrystd from glacial acetic acid. Very hygroscopic. Indicator standard for metal complex titrations. [Mustafin et al. Zh Anal Khim 22 1808 1967.]

Pyrogallol Red (tetraphenolic xanthyliumphenylsulfonate) \[32638-88-3]\(\) M 418.4, m >300°(dec), \(\varepsilon\) 4.3 x 10\(^4\) at 542nm, pH 7.9-8.6, pK as above. Recrystd from aqueous alkaline solution (Na2CO3 or NaOH) by precipitation on acidification [Suk Collect Czech Chem Commun 31 3127 1966].

Pyronin B [di-(3,6-bis(diethylamino)xanthylium chloride) diFeCl\(_3\) complex] \[2150-48-3]\(\) M 358.9 (Fe free), m 176-178° (diFe complex), CI 45010, \(\lambda_{\text{max}}\) 555nm, \(\text{pK}_{\text{f5}}\) 7.7. Crystd from EtOH. Forms Fe stain.

Quinolinium chlorochromate \[108703-35-1]\(\) M 265.6, m 127-130°. A yellow-brown solid which is stable in air for long periods. If it has deteriorated or been kept for too long, it is best to prepare it freshly. Add freshly distilled quinoline (13mL) to a mixture of chromic acid (CrO\(_3\)) (10g) and ~5M HCl (11mL of conc HCl and 10mL of H2O) at 0°. A yellow-brown solid separates, it is filtered off on a sintered glass funnel, dried for 1h in a vacuum, and can be stored for extended periods without serious loss in activity. It is a good oxidant for primary alcohol in CH\(_2\)Cl\(_2\). [Singh et al. Chem Ind (London) 751 1986; method of Corey and Suggs Tetrahedron Lett 2647 1975.]
Reinecke salt  see ammonium reineckate on p. 394.

Resorufin  (7-hydroxy-3H-phenoxazine-3-one Na salt)  {635-78-9}  M 213.2, \( pK_1^{10} 6.93, pK_2^{10} 9.26, pK_3^{10} 10.0 \). Washed with water and recrystd from EtOH several times.

Rhodium (II) acetate dimer (2H\_2O) \{15956-28-2\}  M 478.0. Dissolve 5g in boiling MeOH (ca 600mL) and filter. Concentrate to 400mL and chill overnight at ca 0° to give dark green crystals of the MeOH adduct. Concen of the mother liquors gives a further crop of [Rh(OAc)\_2]\_2.2MeOH. The adduct is then heated at 45° in vacuum for 2h (all MeOH is lost) to leave the emerald green crystals of the acetate. [J Chem Soc (A) 3322 1970.] Alternatively dissolve in glacial AcOH and reflux for a few hs to give an emerald green soln. Evaporate most of the AcOH on a steam bath then heat the residue at 120°/1h. Extract the residue with boiling Me\_2CO. Filter, concentrate to half its volume and keep at Oo/18h. Collect the crystals, wash with ice cold Me\_2CO and dry at 110°. It is soluble in most organic solvents with which it forms adducts including NMe\_3 and Me\_2S and give solutions with different colours varying from green to orange and red. [UV: Inorg Synth 2 960 1963.]

Rhodium (III) chloride \{10049-07-7\}  M 209.3, m >100°(dec), b 717°. Probable impurities are KCl and HCl. Wash solid well with small volumes of H\_2O to remove excess KCl and KOH and dissolve in the minimum volume of conc HCl. Evaporate to dryness on a steam bath until odour of HCl is lost - do not try to dry further as it begins to decompose above 100° to the oxide and HCl. It is not soluble in H\_2O but soluble in alkalis or CN solns and forms double salts with alkali chlorides. [Inorg Synth 7 214 1963.]

Rhodizonic acid sodium salt (5,6-dihydroxycyclohex-5-ene-1,2,3,4-tetraone di-Na salt) \{523-21-7\}  M 214.0, \( pK_1^{10} 4.1 (4.25), pK_2^{10} 4.5 (4.72) \). The free acid, obtained by acidifiying and extracting with Et\_2O, drying (MgSO\_4), filtering, evaporating and distilling in vacuum (b 155-160°/14mm). The free acid solidifies on cooling and the colourless crystals can be recrystd from tetrahydrofuran-pet ether or \*C\_6H\_6. It forms a dihydrate m 130-140°. The pure di Na salt is formed by dissolving in 2 equivs of NaOH and evaporating in a vacuum. It forms violet crystals which give an orange soln in H\_2O that is unstable for extended periods even at 0°, and should be prepared freshly before use. Salts of rhodizonic acid cannot be purified by recrystn without great loss due to conversion to croconate, so that the original material must be prepared pure. It can be washed with NaOAc soln then EtOH to remove excess NaOAc dried under vacuum and stored in the dark. [UV and tautomerism: Schwarzenbach and Suter Helv Chim Acta 24 617 1941; Polarography: Preissler and Berger J Am Chem Soc 64 67 1942; Souchay and Taibouet J Chim Phys 49 C108 1952.]

Rose Bengal [Acid Red 94. 4,5,6,7-tetrachloro-2',4',5',7'-tetradiodofluorescein di-Na or di-K salt] [di-Na salt 632-69-9] M 1017.7 (di-Na salt) [di-K salt 11121-48-5] M 1049.8 (di-K salt). This biological stain can be purified by chromatography on silica TLC using a 35:65 mix of EtOH/acetone as eluent.

Rubidium bromide \{7789-39-1\}  M 165.4, m 682°, b 1340°, d 3.35. A white crystalline powder which crystallises from H\_2O (solubility: 50% in cold and 67% in boiling H\_2O to give a neutral soln). Also cryst from near-boiling water (0.5mL/g) by cooling to 0°.

Rubidium chlorate \{13446-71-4\}  M 168.9, d 3.19. Cryst from water (1.6mL/g) by cooling to 100°.

Rubidium chloride \{7791-11-9\}  M 120.9, m 715°, d 2.80. Cryst from water (0.7mL/g) by cooling to 0° from 100°.

Rubidium nitrate \{13126-12-0\}  M 147.5, m 305°, d 3.11. Cryst from hot water (0.25mL/g) by cooling to room temperature.
Purification of Inorganic and Metal-Organic Chemicals

Rubidium perchlorate [13510-42-4] M 184.9, d 2.80, pK$_2^{50}$ -2.4 to -3.1 (for HClO$_4$). Cryst from hot water (1.6mL/g) by cooling to 0°.

Rubidium sulfate [7748-54-2] M 267.0, m 1050°, d 6.31. Cryst from water (1.2mL/g) between 100° and 0°.


Ruthenium (III) chloride (2H$_2$O) (β-form) [14898-67-0] M 207.4 + H$_2$O, m >500°(dec), d 3.11, pK$_{25}^{25}$ 3.40 (for aquo Rh$_3^{3+}$ hydrolysis). Dissolve in H$_2$O, filter and concentrate to crystallise in the absence of air to avoid oxidation. Evaporate the solution in a stream of HCl gas while being heated just below its boiling point until a syrup is formed and finally to dryness at 80-100° and dried in a vacuum over H$_2$SO$_4$. When heated at 700° in the presence of Cl$_2$ the insoluble α-form is obtained. [Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol II pp. 1598 1965; J Org Chem 46 3936 1981.]

Ruthenium (IV) oxide [12036-10-1] M 133.1, m 6.97. Freed from nitrates by boiling in distilled water and filtering. A more complete purification is based on fusion in a KOH-KNO$_3$ mix to form the soluble ruthenate and perruthenate salts. The melt is dissolved in water, and filtered, then acetone is added to reduce the ruthenates to the insoluble hydrate oxide which, after making a slurry with paper pulp, is filtered and ignited in air to form the anhydrous oxide [Campbell, Ortner and Anderson Anal Chem 33 58 1961.]

Ruthenocene [bis-(cyclopentadienyl)ruthenium] [128713-4] M 231.2, m 195.5°, 199-210°. Sublime in high vacuum at 120°. Yellow crystals which can be recrystallised from CCl$_4$ as transparent plates. [J Am Chem Soc 74 6146 1952.]

Samarium (II) iodide [32248-43-4] M 404.2, m 520°, b 1580. Possible impurity is SmI$_3$ from which it is made. If present, grind solid to a powder and heat in a stream of pure H$_2$. The temperature (~ 500-600°) should be below the m (~ 628°) of SmI$_3$, since the molten compounds react very slowly. [Wetzel in Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol II pp. 1149, 1150 1965.]

Selenious acid [7783-00-8] M 129.0, m 70°(dec), d 3.0, pK$_1^{25}$ 2.62, pK$_2^{25}$ 8.32 (H$_2$SeO$_3$). Cryst from water. On heating it loses water and SeO$_2$ sublimes.

Selenium [7782-49-2] M 79.0, m 217.4°, d 4.81. Dissolved in small portions in hot conc HNO$_3$ (2mL/g) filtered and evaporated to dryness to give selenious acid which was then dissolved in conc HCl. Passage of SO$_2$ into the solution pted selenium (but not tellurium) which was filtered off and washed with conc HCl. This purification process was repeated. The selenium was then converted twice to the selenocyanate by treating with a 10% excess of 3M aqueous KCN, heating for half an hour on a sand-bath and filtering. Addition of an equal weight of crushed ice to the cold solution, followed by an excess of cold, conc HCl, with stirring (in a well ventilated fume hood because HCN is evolved) pted selenium powder, which, after washing with water until colourless, and then with MeOH, was heated in an oven at 105°, then by fusion for 2h under vacuum. It was cooled, crushed and stored in a desiccator [Tideswell and McCullough J Am Chem Soc 78 3036 1956].

Selenium dioxide [7446-08-4] M 111.0, m 340°. Purified by sublimation, or by solution in HNO$_3$, pptn of selenium which, after standing for several hours or boiling, is filtered off, then re-oxidised by HNO$_3$ and cautiously evaporated to dryness below 200°. The dioxide is dissolved in water and again evaporated to dryness.

Selenopyronine [85051-91-8] M 365.8, λ$_{max}$ 571nm (ε 81,000). Purified as the hydrochloride from hydrochloric acid [Fanghanel et al. J Phys Chem 91 3700 1987].
Selenourea \([630-10-4]\) M 123.0, m 214-215\(^{\circ}\)C (dec). Recrystd from water under nitrogen.

Silica \([7631-86-9\text{(colloidal); 112945-52-5\text{(fumed)}]}\). Purification of silica for high technology applications uses isopiestic vapour distillation from conc volatile acids and is absorbed in high purity water. The impurities remain behind. Preliminary cleaning to remove surface contaminants uses dip etching in HF or a mixture of HCl, H\(\text{2}O\)\(_2\) and deionised water [Phelan and Powell Analyst 109 1299 1984].

Silica gel \([63231-67-4; 112926-00-8]\). Before use as a drying agent, silica gel is heated in an oven, then cooled in a desiccator. Conditions in the literature range from heating at 110\(^{\circ}\)C for 15h to 250\(^{\circ}\)C for 2-3h. Silica gel has been purified by washing with hot acid (in one case successively with aqua regia, conc H\(\text{N}O_3\), then conc HCl; in another case digested overnight with hot conc H\(\text{2}SO_4\)), followed by exhaustive washing with distilled water (one week in a Soxhlet apparatus has also been used), and prolonged oven drying. Alternatively, silica gel has been extracted with acetone until all soluble material was removed, then dried in a current of air, washed with distilled water and oven dried. Silica gel has also been washed successively with water, M HCl, water, and acetone, then activated at 110\(^{\circ}\)C for 15h.

Silicon monoxide \([10097-28-6]\) M 44.1, m > 1700\(^{\circ}\)C, d 2.18. Purified by sublimation in a porcelain tube in a furnace at 1250\(^{\circ}\)C (4h) in a high vacuum (10\(^{-4}\)mm) in a stream of N\(_2\). It is obtained as brownish black scales. [Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol I 696 1963.]

Silicon tetraacetate \([562-90-3]\) M 264.3, m 110-111\(^{\circ}\), b 148\(^{\circ}/5-6\)mm, p\(K_a\)\(^{25}\) 9.7, p\(K_a\)\(^{15}\) 11.9 (for H\(_4\)SiO\(_4\) free acid). It can be crystallised from mixtures of CCl\(_4\) and pet ether or Et\(_2\)O, or from acetic anhydride and then dried in a vacuum desiccator over KOH. Ac\(_2\)O adheres to the crystals and is removed first by drying at room temp then at 100\(^{\circ}\)C for several hours. It is soluble in Me\(_2\)CO, is very hygroscopic and effervesces with H\(_2\)O. It decomposes at 160-170\(^{\circ}\). [Z Obshch Khim (Engl Transl) 27 985 1957; Handbook of Preparative Inorganic Chemistry (Ed. Bruer) Vol I 701 1965.]

Silicon tetrachloride \([10026-04-7]\) M 169.9, m -70\(^{\circ}\), b 57.6\(^{\circ}\), d 1.483. Distd under vacuum and stored in sealed ampoules under N\(_2\). Very sensitive to moisture.

12-Silicotungstic acid (tungstosilicic acid; H\(_4\)SiW\(_{12}O_{40}\)) \([12027-43-9]\) M 2914.5. Extracted with diethyl ether from a solution acidified with HCl. The diethyl ether was evaporated under vacuum, and the free acid was crystallised twice [Matijevic and Kerker J Phys Chem 62 1271 1958].

Silver (metal) \([7440-22-4]\) M 107.9, m 961.9\(^{\circ}\), b 2212\(^{\circ}\), d 10.5. For purification by electrolysis, see Craig et al. [J Res Nat Bur Stand 64A 381 1960].

Silver acetate \([563-63-3]\) M 166.9, p\(K_a\)\(^{25}\) >11.1 (for aquo Ag\(^+\) hydrolysis). Shaken with acetic acid for three days, the process being repeated with fresh acid, the solid then being dried in a vacuum oven at 40\(^{\circ}\) for 48h. Has also been recrystallised from water containing a trace of acetic acid, and dried in air.

Silver bromate \([7783-89-3]\) M 235.8, m dec on heating, d 5.21. Crystd from hot water (80mL/g).

Silver bromide \([7785-23-1]\) M 187.8, m 432\(^{\circ}\), d 6.47. Purified from Fe, Mn, Ni and Zn by zone melting in a quartz vessel under vacuum.

Silver chlorate \([7783-92-8]\) M 191.3, m 230\(^{\circ}\), b 270\(^{\circ}\)(dec), d 4.43. Recrystd three times from water (10mL/g at 15\(^{\circ}\); 2mL/g at 80\(^{\circ}\)).

Silver chloride \([7783-90-6]\) M 143.3, m 455\(^{\circ}\), b 1550\(^{\circ}\), d 5.56. Recrystd from conc NH\(_3\) solution.

Silver chromate \([7784-01-2]\) M 331.8, d\(^{25}\) 5.625, p\(K_a\)\(^{25}\) 0.74, p\(K_a\)\(^{15}\) 6.49 (for H\(_2\)CrO\(_4\)). Wash the red-brown powder with H\(_2\)O, dry in a vacuum, then powder well and dry again in a vacuum at 90\(^{\circ}\)/5h. Solubility in H\(_2\)O is 0.0014\% at 10\(^{\circ}\). [J Org Chem 42 4268 1977.]
Silver cyanide  [506-64-9]  M 133.9, m dec at 320°, d 3.95. POISONOUS white or grayish white powder. Stir thoroughly with H2O, filter, wash well with EtOH and dry in the dark. It is very insoluble in H2O (0.000023 g in 100 mL H2O) but is soluble in HCN or aqueous KCN to form the soluble Ag(CN)2 complex. [Chem Ber 72 299 1939; J Am Chem Soc 52 184 1930.]


Silver difluoride  [7783-95-1]  M 145.9, m 690°, d 4.7. Highly TOXIC because it liberates HF and F2. Very hygroscopic and reacts violently with H2O. It is a powerful oxidising agent and liberates O3 from dilute acids, and I2 from I- soln. Store in quartz or iron ampoules. White when pure, otherwise it is brown-tinged. Thermally stable up to 700°. [Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol I 241 1963.]

Silver fluoride  [7775-41-9]  M 126.9, m 435°, b ca 1150°, d 5.852. Hygroscopic solid with a solubility of 135 g/100 mL of H2O at 15°, and forms an insoluble basic fluoride in moist air. Purified by washing with AcOH and then kept in a vacuum desiccator at room temperature to remove *benzene and stored in opaque glass bottles. Flaky hygroscopic crystals which darken on exposure to light. It attacks bone and teeth. [J Chem Soc 4538 1952; Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol I 240 1963.]

Silver iodate  [7783-97-3]  M 282.8, m >200°, d 5.53. Washed with warm dilute HNO3, then H2O and dried at 100°, or recrystd from NH3 soln by adding HNO3, filtering, washing with H2O and drying at 100°.

Silver lactate  [128-00-7]  M 196.9, m ~100°. Recrystd from H2O by adding EtOH. The solid was collected washed with EtOH then Et2O and dried at 80° to give the dihydrate. White powder soluble in 15 parts of H2O but only slightly soluble in EtOH. [Justus Liebigs Ann Chem 63 89 1847; Helv Chim Acta 2 251 1919.]

Silver nitrate  [7761-88-8]  M 169.9, m 212°, b 444°(dec), d 4.35. Purified by recrystn from hot water (solubility of AgNO3 in water is 992 g/100 mL at 100° and 122 g/100 mL at 0°). It has also been purified by crystn from hot conductivity water by slow addition of freshly distilled EtOH. CAUTION: avoid using EtOH for washing the ppte; and avoid concentrating the filtrate to obtain further crops of AgNO3 owing to the risk of EXPLOSION (as has been reported to us) caused by the presence of silver fulminate. When using EtOH in the purification the apparatus should be enclosed in a strong protective shield. [Tully, News Ed (Am Chem Soc) 19 3092 1941; Garin and Henderson J Chem Educ 47 741 1970; Bretherick, Handbook of Reactive Chemical Hazards 4th edn, Butterworths, London, 1985, pp 13-14.] Before being used as a standard in volumetric analysis, analytical reagent grade AgNO3 should be finely powdered, dried at 120° for 2 h, then cooled in a desiccator. Recovery of silver residues as AgNO3 [use protective shield during the whole of this procedure] can be achieved by washing with hot water and adding 16M HNO3 to dissolve the solid. Filter through glass wool and concentrate the filtrate on a steam bath until precipitation commences. Cool the solution in an ice-bath and filter the precipitated AgNO3. Dry at 120° for 2 h, then cool in a desiccator in a vacuum. Store over P2O5 in a vacuum in the dark. AVOID contact with hands due to formation of black stains.

Silver nitrite  [7783-99-5]  M 153.9, m 141°(dec), d 4.45. Crystd from hot conductivity water (70 mL/g) in the dark. Dried in the dark under vacuum.

Silver(I) oxide  [20667-12-3]  M 231.7, m ~200°(dec), d 7.13. Leached with hot water in a Soxhlet apparatus for several hours to remove any entrained electrolytes.

Silver (II) oxide  [1301-96-8]  M 123.9, m ~100°(dec), d 25 7.22. Soluble in 40,000 parts of H2O, and should be protected from light. Stir with an alkaline solution of potassium peroxytsulfate (K2S2O8) at 85-
90°. The black AgO is collected, washed free from sulfate with H₂O made slightly alkaline and dried in air in the dark. [Inorg Synth 4 12 1953.]

Silver perchlorate (H₂O) [14242-05-8 (H₂O); 7783-93-9 (anhydr)] M 207.3, pK₂₋₃ -2.4 to -3.1 (for HClO₄). Refluxed with * benzene (6mL/g) in a flask fitted with a Dean and Stark trap until all the water was removed azeotropically (ca 4h). The soln was cooled and diluted with dry pentane (4mL/g of AgClO₄). The ppted AgClO₄ was filtered off and dried in a desiccator over P₂O₅ at 1mm for 24h [Radell, Connolly and Raymond J Am Chem Soc 83 3958 1961]. It has also been recrystallised from perchloric acid. [Caution due to EXPLOSIVE nature in the presence of organic matter.]

Silver permanganate [7783-98-4] M 226.8, d 4.49. Violet crystals which can be crystallised from hot H₂O (sol is 9g/L at 20°). Store in the dark. Oxidising agent, decomposed by light. Silver sulfate [10294-26-5] M 311.8, m 652°, b 1085°(dec), d 5.45. Crystd from hot conc H₂SO₄ contg a trace of HNO₃, cooled and diluted with H₂O. The ppted was filtd off, washed and dried at 120°. Silver thiocyanate [1701-93-5] M 165.9, m 265°(dec), d 3.746, pK₂₋₃ -1.85 (for HSCN). Digest the solid salt with aqueous NH₄NCS, wash thoroughly with H₂O and dry at 1 loo in the dark. Soluble in dilute aqueous NH₃. Dissolve in strong aqueous NH₄CS solution, filter and dilute with large volume of H₂O when the Ag salt separates. The solid is washed with H₂O by decantation until free from NCS⁻ ions, collected, washed with H₂O, EtOH and dried in an air oven at 120°. Alternatively dissolve in dilute aqueous NH₃ and single crystals are formed by free evaporation of the solution in air. [J Chem Soc 836, 2405 1932; IR and Raman: Acta Chem Scand 13 1607 1957; Acta Cryst 10 29 1957.]

Silver tosylate [16836-95-6] M 279.1. The anhydrous salt is obtained by recrystn from H₂O. [Chem Ber 12 1851 1879.]

Silver trifluoroacetate [2966-50-9] M 220.9, m 251-255°. Extract the salt (Soxhlet) with Et₂O. The extract is filtered and evaporated to dryness, then the powdered residue is completely dried in a vacuum desiccator over silica gel. Solubility in Et₂O is 33.5g in 750mL. It can be recrystd from *C₆H₆ (sol: 1.9g in 30mL of *C₆H₆; and 33.5g will dissolve in 750mL of anhydrous Et₂O). [J Org Chem 23 1545 1958; J Chem Soc 584 1951.] It is also soluble in trifluoroacetic acid (15.2% at 30°), toluene, o-xylene and dioxane [J Am Chem Soc 76 4285 1954.]


Sodium (metal) [7440-23-5] M 23.0, m 975°, d 0.97. The metal was placed on a coarse grade of sintered-glass filter, melted under vacuum and forced through the filter using argon. The Pyrex apparatus was then re-evacuated and sealed off below the filter, so that the sodium could be distilled at 460° through a side arm and condenser into a receiver bulb which was then sealed off [Gunn and Green J Am Chem Soc 80 4782 1958]. EXPLODES and IGNITES in water.

Sodium acetate [127-09-3] M 82.0, m 324°, d 1.53. Crystd from acetic acid and pumped under vacuum for 10h at 120°. Alternatively, crysd from aqueous EtOH, as the trihydrate. This material can be converted to the anhydrous salt by heating slowly in a porcelain, nickel or iron dish, so that the salt liquefies. Steam is evolved and the mass again solidifies. Heating is now increased so that the salt melts again. (NB: if it is heated too strongly, the salt chars.) After several minutes, the salt is allowed to solidify and cooled to a convenient temperature before being powdered and bottled (water content should now less than 0.02%).

Sodium acetylide [1066-26-8] M 48.0. It disproportionsates at ca 180° to sodium carbide. It sometimes contains diluents, e.g. xylene, butyl ether or dioxane which can be removed by filtration followed by a vacuum at 65-60°/5mm. Alternatively the acetylide is purged with H₂C=CH at 100-125° to remove diluent. NaC₂H adsorbs 2.2x, 2.0x and 1.6x its wt of xylene, butyl ether and dioxane respectively. Powdered NaC₂H is yellow or yellow-gray in colour and is relatively stable. It can be heated to ca 300° in the absence of air. Although no
explosion or evolution of gas occurs, it turns brown due to disproportionation. At 170-190° in air it ignites slowly and burns smoothly. At 215-235° in air it flash-ignites and burns quickly. It can be dropped into a slight excess of H₂O without flashing or burning but vigorous evolution of H₂C=CH₂ (HIGHLY FLAMMABLE IN AIR) occurs. The sample had been stored in the absence of air for one year without deterioration. Due to the high flammability of H₂C=CH₂ the salt should be stored dry, and treated with care. After long storage, NaC=CH₂ can be redissolved in liquid NH₃ and used for the same purposes as the fresh material. However it may be slightly turbid due to the presence of moisture. [J Org Chem 22 649 1957; J Am Chem Soc 77 5013 1955; Inorg Synth 2 76, 81 1946; Org Synth 30 15 1950.] See p. 89, Chapter 4 for prepartion.

Sodium alginate [9005-38-3]. Freed from heavy metal impurities by treatment with ion-exchange resins (Na⁺-form), or with a dilute solution of the sodium salt of EDTA. Also dissolved in 0.1M NaCl, centrifuged and fractionally ppted by gradual addition of EtOH or 4M NaCl. The resulting gels were centrifuged off, washed with aq EtOH or acetone, and dried under vacuum. [Büchner, Cooper and Wassermann J Chem Soc 3974 1961.]

Sodium n-alkylsulfates. Crystd from EtOH/Me₂CO [Hashimoto and Thomas J Am Chem Soc 107 4655 1985].

Sodium amide [7782-92-5] M 39.0, m 210°. It reacts violently with H₂O and is soluble in liquid NH₃ (1% at 20°). It should be stored in wax-sealed container is small batches. It is very hygroscopic and absorbs CO₂ and H₂O. If the solid is discoloured by being yellow or brown in colour then it should be destroyed as it can be highly EXPLOSIVE. It should be replaced if discoloured. It is best destroyed by covering with much toluene and slowly adding dilute EtOH with stirring until all the ammonia is liberated (FUME CUPBOARD). [Inorg Synth 1 74 1939; Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol I465 1963; Org Synth Coll Vol III, 778 1955.]


Sodium 4-aminosalicylate (2H₂O) [6018-19-5] M 175.1. Crystd from water at room temperature (2mL/g) by adding acetone and cooling.

Sodium ammonium hydrogen phosphate [13011-54-6] M 209.1, m 79°(dec), d 1.55. Crystd from hot water (1mL/g).


Sodium antimonyl tartrate [34521-09-0] M 308.8. Crystd from water.

Sodium arsenate (7H₂O) [10048-95-0] M 312.0, m 50 (loses 5H₂O), m 130°, d 1.88 pK₁² 2.22, pK₂² 6.98 (for H₃AsO₄). Crystd from water (2mL/g).

Sodium azide [26628-22-8] M 65.0, m 300°(dec, explosive), pK² 4.72 (for HN₃). Crystd from hot water or from water by the addition of absolute EtOH or acetone. Also purified by repeated crystn from an aqueous solution saturated at 90° by cooling it to 10°, and adding an equal volume of EtOH. The crystals were washed with acetone and the azide dried at room temperature under vacuum for several hours in an

Sodium barbitone (sodium 5,5-diethylbarbiturate) [144-02-5] M 150.1, \(pK_a^{25} 3.99, pK_d^{25} 12.5\) (barbituric acid). Crystd from water (3mL/g) by adding an equal volume of EtOH and cooling to 5°. Dried under vacuum over P_2O_5.

Sodium benzenesulfinate [873-55-2] M 164.2, m >300°. See benzenesulfinic acid sodium salt on p. 400.

Sodium benzenesulfonate [515-42-4] M 150.1, \(pK_a^{25} 0.70\) (2.55) (for PhSO_3H_2). Crystd from EtOH or aqueous 70-100% MeOH, and dried under vacuum at 80-100°.

Sodium benzoate [532-32-1] M 144.1. Crystd from EtOH (12mL/g).

Sodium bis(trimethylsilyl)amide (hexamethyl disilazane sodium salt) [1070-89-9] M 183.4, m 165-167°(sintering at 140°). It can be sublimed at 170°/2 Torr (bath temp 220-250°) onto a cold finger, and can be recrystd from *C_6H_6 (sol: 10g in 100mL at 60°). It is slightly soluble in Et_2O and is decomposed by H_2O.

Sodium bisulfite [7631-90-5] M 104.1, d 1.48. Crystd from hot H_2O (1mL/g). Dried at 100° under vac for 4h.

Sodium borate (borax) [1330-43-4] M 201.2, m 741°, d 2.37. Most of the water of hydration was removed from the decahydrate by evaporation at 25° for three days, followed by heating to 100° and evacuation with a high-speed diffusion pump. The dried sample was then heated gradually to fusion (above 966°), allowed to cool gradually to 200°, then transferred to a desiccator containing P_2O_5 [Grenier and Westrum J Am Chem Soc 78 6226 1956].

Sodium borate (decahydrate, hydrated borax) [1303-96-4] M 381.2, m 75°(loses 5H_2O at 60°), d 1.73. Crystd from water (3.3mL/g) keeping below 55° to avoid formation of the pentahydrate. Filtered at the pump, washed with water and equilibrated for several days in a desiccator containing an aqueous solution saturated with respect to sucrose and NaCl. Borax can be prepared more quickly (but its water content is somewhat variable) by washing the recrystd material at the pump with water, followed by 95% EtOH, then Et_2O, and air dried at room temperature for 12-18h on a clock glass.

Sodium borohydride [16940-66-2] M 37.8, m ~400°(dec), d 1.07. After adding NaBH_4 (10g) to freshly distilled diglyme (120mL) in a dry three-necked flask fitted with a stirrer, nitrogen inlet and outlet, the mixture was stirred for 30min at 50° until almost all of the solid had dissolved. Stirring was stopped, and, after the solid had settled, the supernatant liquid was forced under N_2 pressure through a sintered-glass filter into a dry flask. [The residue was centrifuged to obtain more of the solution which was added to the bulk.] The solution was cooled slowly to 0° and then decanted from the white needles that separated. The crystals were dried by pumping for 4h to give anhydrous NaBH_4. Alternatively, after the filtration at 50° the solution was heated at 80° for 2h to give a white ppe of substantially anhydrous NaBH_4 which was collected on a sintered-glass filter under N_2, then pumped at 60° for 2h [Brown, Mead and Subba Rao J Am Chem Soc 77 6209 1955]. NaBH_4 has also been crystd from isopropylamine by dissolving it in the solvent at reflux, cooling, filtering and allowing the solution to stand in a filter flask connected to a Dry-ice/acetone trap. After most of the solvent was passed over into the cold trap, crystals were removed with forceps, washed with dry diethyl ether and dried under vacuum. [Kim and Itoh J Phys Chem 91 126 1987] Somewhat less pure crystals were obtained more rapidly by using Soxhlet extraction with only a small amount of solvent and extracting for about 8h. The
crystals that formed in the flask were filtered off, then washed and dried as before. [Stockmayer, Rice and Stephenson J Am Chem Soc 77 1980 1955.] Other solvents used for crystallisation include water and liquid ammonia.

**Sodium bromate** [7789-38-0] M 150.9, m 381°, d 3.3. Crystd from hot water (1.1mL/g) to decrease contamination by NaBr, bromine and hypobromite. [Noszticzius et al. J Am Chem Soc 107 2314 1985.]

**Sodium bromide** [7647-15-6] M 102.9, m 747°, b 1390°, d 3.2. Crystd from water (0.86mL/g) between 50° and 0°, and dried at 140° under vacuum (this purification may not eliminate chloride ion).

**Sodium 4-bromobenzenesulfonate** [5015-75-8] M 258.7. Crystd from MeOH, EtOH or distd water.

**Sodium tert-butoxide** [865-48-5] M 96.1. It sublimes at 180°/1 Torr. Its solubility in tert-BuOH is 0.208M at 30.2° and 0.382M at 60°, and is quite soluble in tetrahydrofuran (32g/100g). It should not be used if it has a brown colour. [J Am Chem Soc 78 4364, 3614 1956, Inorg Synth 1 87 1939; IR: J Org Chem 21 156 1956.]

**Sodium butyrate** [156-54-7] M 110.1. Prepared by neutralisation of the acid and recrystn from EtOH.

**Sodium cacodylate (3H2O)** [1124-65-2] M 214.0, m 60°. Crystd from aqueous EtOH.

**Sodium carbonate** [497-19-8] M 106.0, m 858°, d 2.5. Crystd from water as the decahydrate which was redissolved in water to give a near-saturated soln. By bubbling CO2, NaHCO3 was ppted. It was filtered, washed and ignited for 2h at 800° [MacLaren and Swinehart J Am Chem Soc 73 1822 1951]. Before being used as a volumetric standard, analytical grade material should be dried by heating at 260-270° for 0.5h and allowed to cool in a desiccator. For preparation of primary standard sodium carbonate, see Pure Appl Chem 25 459 1969. After 3 recrystns tech grade had Cr, Mg, K, P, Al, W, Sc and Ti at 0.5, 9.4, 6.6, 3.6, 2.4, 0.6, 0.2 and 0.2 ppm resp; another technical source had Cr, Mg, Mo, P, Sn and Ti at 2.6, 0.4, 4.2, 13.4, 32, 0.6, 0.8 ppm resp.

**Sodium carboxymethylcellulose** [9004-32-4]. Dialysed for 48h against distilled water.

**Sodium cetyl sulfate** [1120-01-0] M 344.5. See sodium hexadecylsulfate on p. 471.

**Sodium chlorate** [7775-09-9] M 106.4, m 248°, b >300°(dec), d 2.5. Crystd from hot water (0.5mL/g).

**Sodium chloride** [7647-14-5] M 58.4, m 800°, b 1413°, d 2.17. Crystd from saturated aqueous solution (2.7mL/g) by passing in HCl gas, or by adding EtOH or acetone. Can be freed from bromide and iodide impurities by adding chlorine water to an aqueous solution and boiling for some time to expel free bromine and iodine. Traces of iron can be removed by prolonged boiling of solid NaCl in 6M HCl, the crystals then being washed with EtOH and dried at 100°. Sodium chloride has been purified by sublimation in a stream of pre-purified N2 and collected by electrostatic discharge [Ross and Winkler J Am Chem Soc 76 2637 1954]. For use as a primary analytical standard, analytical reagent grade NaCl should be finely ground, dried in an electric furnace at 500-600° in a platinum crucible, and allowed to cool in a desiccator. For most purposes, however, drying at 110-120° is satisfactory.

**Sodium chlorite** [7758-19-2] M 90.4, m ~180°(dec). Crystd from hot water and stored in a cool place. Has also been crystd from MeOH by counter-current extraction with liquid ammonia [Curti and Locchi Anal Chem 29 534 1957]. Major impurity is chloride ion; can be recrystallised from 0.001M NaOH.

**Sodium 4-chlorobenzenesulfonate** [5138-90-9] M 214.6, pK<sub>est</sub> < 0 (for SO<sub>3</sub>H). Crystd twice from MeOH and dried under vacuum.
Sodium 3-chloro-5-methylbenzenesulfonate [5138-92-1] M 228.7, pK<sub>EtOH</sub> < 0 (for SO<sub>3</sub>H). Crystd twice from MeOH and dried under vacuum.

Sodium chromate (4H<sub>2</sub>O) [10034-82-9] M 234.0, m ~20°(for 10H<sub>2</sub>O), d 2.7, pK<sub>1</sub> 0.74, pK<sub>2</sub> 6.49 (for H<sub>2</sub>CrO<sub>4</sub>). Crystd from hot water (0.8mL/g).


Sodium cyanate [917-61-3] M 65.0, m 550°, d<sub>20</sub> 1.893, pK 3.47 (for HCNO). Colourless needles from EtOH. Solubility in EtOH is 0.22g/100g at 0°C. Soluble in H<sub>2</sub>O but can be recrystallised from small volumes of it.

Sodium cyanoborohydride [25895-60-7] M 62.8, m 240-242°(dec), d<sub>18</sub> 1.20. Very hygroscopic solid, soluble in H<sub>2</sub>O (212% at 29°C, 121% at 88°C), tetrahydrofuran (37% at 28°C, 42.2% at 62°C), very soluble in EtOH but insoluble in Et<sub>2</sub>O, C<sub>6</sub>H<sub>6</sub> and hexane. It is stable to acid up to pH 3 but is hydrolysed in 12N HCl. The rate of hydrolysis at pH 3 is 10<sup>-8</sup> that of NaBH<sub>4</sub>. The fresh commercially available material is usually sufficiently pure. If very pure material is required one of the following procedures must be used [Synthesis 135 1975]: (a) The NaBH<sub>3</sub>CN is dissolved in tetrahydrofuran (20% w/v), filtered and the filtrate is treated with a fourfold volume of CH<sub>2</sub>Cl<sub>2</sub>. The solid is collected and dried in a vacuum [Inorg Chem 9 2146 1970]. Dissolve the NaBH<sub>3</sub>CN in dry MeNO<sub>2</sub>, filter, and pour the filtrate into a 10-fold volume of CCl<sub>4</sub> with vigorous stirring. The white ppt is collected, washed several times with CCl<sub>4</sub> and dried in a vacuum [Inorg Chem 9 624 1970]. (b) When the above procedures fail to give a clean product then dissolve the NaBH<sub>3</sub>CN (log) in tetrahydrofuran (80mL) and add N MeOH/HCl until the pH is 9. Pour the solution with stirring into dioxane (250mL). The solution is filtered, and heated to reflux. A further volume of dioxane (150mL) is added slowly with swirling. The solution is cooled slowly to room temp then chilled in ice and the crystalline dioxane complex is collected, dried in a vacuum for 4h at 25°C, then 4h at 80°C to yield the amorphous dioxane-free powder is 6.7g with purity >98% [J Am Chem Soc 93 2897 1971]. The purity can be checked by iodometric titration [Anal Chem 91 4329 1969].

Sodium p-cymenesulfonate [77060-21-0] M 236.3. Dissolved in water, filtered and evaporated to dryness. Crystd twice from absolute EtOH and dried at 110°C.

Sodium decanoate (sodium caproate) [1002-62-6] M 194.2. Neutralised by adding a slight excess of the free acid, recovering the excess acid by Et<sub>2</sub>O extraction. The salt is crystd from solution by adding pure acetone, repeating the steps several times, then dried in an oven at ca 110°C [Chaudhury and Awuwallia Trans Faraday Soc 77 3119 1981].

Sodium 1-decanesulfonate [13419-61-9] M 244.33. Recrystd from absolute EtOH and dried over silica gel.

Sodium n-decylsulfate [142-87-0] M 239.3. Rigorously purified by continuous Et<sub>2</sub>O extraction of a 1% aqueous solution for two weeks.

Sodium deoxycholate (H<sub>2</sub>O) [302-95-4] M 432.6, [α]<sub>D</sub><sup>20</sup> +48° (c 1, EtOH). Crystd from EtOH and dried in an oven at 100°C. The solution is freed from soluble components by repeated extraction with acid-washed charcoal.

Sodium dibenzylthiocarbamate [55310-46-8] M 295.4, m 230°(dec), pK<sub>20</sub> 3.13 (for monobenzylthiocarbamic acid). The free acid when recrystd twice from dry Et<sub>2</sub>O has m 80-82°C. The Na salt is reppted from aqueous EtOH or EtOH by addition of Et<sub>2</sub>O or Me<sub>2</sub>CO [Anal Chem 50 896 1978]. The NH<sub>4</sub> salt has m 130-133°C; Cu salt (yellow crystals) has m 284-286°C and the Ti salt has m 64-70°C.

Sodium 2,5-dichlorobenzenesulfonate [5138-93-2] M 249.0, pK<sub>EtOH</sub> < 0 (for SO<sub>3</sub>H). Crystd from MeOH, and dried under vacuum.
Sodium dichromate \([7789-12-0]\) M 298.0, m 84.6° (2H2O), 356° (anhydr); b 400°(dec), d1.25 2.348. Crystd from small volumes of H2O by evaporation to crystallisation. Solubility in H2O is 238% at 0° and 508% at boiling. Red dihydrate is slowly dehydrated by heating at 100° for long periods. It is deliquescent, a powerful oxidising agent-do not place in contact with skin- wash immediately as it is caustic. (Possible carcinogen).

Sodium diethyldithiocarbamate (3H2O) \([20624-25-3]\) M 225.3, m 94-96°(anhydr), pK20 3.65 (diethyldithiocarbamic acid). Recrystd from water.

Sodium di(ethylhexyl)sulfosuccinate (Aerosol-OT) \([577-11-7]\) M 444.6. Dissolved in MeOH and inorganic salts which ppted were filtered off. Water was added and the solution was extracted several times with hexane. The residue was evaporated to one fifth its original volume, *benzene was added and azeotropic distillation was continued until no water remained. Solvent was then evaporated. The white solid was crushed and dried in vacuum over P2O5 for 48h [El Seoud and Fendler J Chem Soc, Faraday Trans I 71 452 1975].

Sodium diethyloxaloacetate \([63277-17-8]\) M 210.2. Extracted several times with boiling Et2O (until the solvent remained colourless) and then the residue was dried in air.

Sodium diformylamide \([I 8197-26-7]\) M 95.0. Grind under dry tetrahydrofuran (fumehood), filter and wash with this solvent then dry in vacuum. [IR and prepn: Synthesis 122 1990; Chem Ber 100 355 1967, 102 4089 1969.]

Sodium dihydrogen orthophosphate (2H2O) \([13472-35-0 \text{(2H2O)}; \ 10049-21-5 \text{(H2O)}; \ 7558-80-7 \text{(anhydr)}]\) M 156.0, m 60°(dec), d 1.91. Crystd from warm water (0.5mL/g) by chilling.

Sodium 2,2’-dihydroxy-1-naphthaleneazobenzene-5′-sulfonate \([2092-55-9]\) M 354.3. See Solochrome Violet R on p. 352 in Chapter 4.

Sodium 2,4-dihydroxyphenylazobenzene-4′-sulfonate \([547-57-9]\) M 304.2. Crystd from absolute EtOH.

Sodium p-(p-dimethylanilinobenzeneazo)-benzenesulfonate \([23398-40-5]\) M 327.3. Crystd from water.

Sodium p-dimethylaminoazobenzene-o’-carboxylate \([845-10-3]\) M 219.2. Ppted from aqueous soln as the free acid which was recrystallised from 95% EtOH, then reconverted to the sodium salt.

Sodium p-dimethylaminoazobenzene-p’-carboxylate \([845-46-5]\) M 219.2. Ppted from aqueous soln as the free acid which was recrystallised from 95% EtOH, then reconverted to the sodium salt.

Sodium 2,4-dimethylbenzenesulfonate \([827-21-4]\) M 208.2. Crystd from MeOH and dried under vacuum.

Sodium 2,5-dimethylbenzenesulfonate \([827-19-0]\) M 208.2. Dissolved in distilled water, filtered, then evaporated to dryness. Crystd twice form absolute EtOH or MeOH and dried at 110° under vacuum.

Sodium dimethyldithiocarbamate hydrate \([128-04-1]\) M 143.2, m 106-108°, 120-122°, pK25 3.36 (diethyldithiocarbamic acid). Crystallise from a small volume of H2O, or dissolve in minimum volume of H2O and add cold Me2CO and dry in air. The solution in Me2CO is ~50g/400mL. The dihydrate loses H2O on heating at 115° to give the hemi hydrate which decomposes on further heating [IR: Can J Chem. 34 1096 1956].

Sodium N,N-dimethylsulfanilate \([2244-40-8]\) M 223.2, m >300°. Crystd from water.
Sodium dithionite (2H₂O) [7631-94-9] M 242.1, m 110⁰ (loses 2H₂O), 267⁰ (dec), d 2.19, pK_{est}[-3.4, pK₂^{25}0.49 (for dithionic acid). Cryst from hot water (1.1mL/g) by cooling.

Sodium dodecanoate (sodium laurate) [629-25-4] M 222.3, pK₂ 5.3 (-COOH). Neutralised by adding a slight excess of dodecanoic acid, removing it by ether extraction. The salt is recrystd from aq soln by adding pure Me₂CO and repeating the process (see sodium decanoate on p. 468). Also recrystd from MeOH.

Sodium 1-dodecanesulfonate [2386-53-0] M 272.4. Twice recrystd from EtOH.

Sodium dodecylbenzenesulfonate [25155-30-0] M 348.5. Recrystd from propan-2-01.

Sodium dodecylsulfate (SDS, sodium laurylsulfate) [151-21-3] M 288.4, m 204-207⁰. Purified by Soxhlet extraction with pet ether for 24h, followed by dissolution in acetone:MeOH:H₂O 90:5:5 (v/v) and recryst [Politi et al. J Phys Chem 89 2345 1985]. Also purified by two recrystns from absolute EtOH, aqueous 95% EtOH, MeOH, isopropanol or a 1:1 mixture of EtOH:isopropanol to remove dodecanol, and dried under vacuum [Ramesh and Labes J Am Chem Soc 109 3228 1987]. Also purified by foaming [see Cockbain and McMullen Trans Faraday Soc 47 322 1951] or by liquid-liquid extraction [see Harrold J Colloid Sci 15 280 1960]. Dried over silica gel. For DNA work it should be dissolved in excess MeOH passed through an activated charcoal column and evaporated until it crystallises out. Also purified by dissolving in hot 95% EtOH (14mL/g), filtering and cooling, then drying in a vacuum desiccator. Alternatively, it was crystd from H₂O, vacuum dried, washed with anhydrous Et₂O, vacuum dried. These operations were repeated five times [Maritato J Phys Chem 89 1341 1985; Leenon and McClelland J Am Chem Soc 108 3771 1986; Dressik J Am Chem Soc 108 7567 1986].

Sodium ethoxide [141-52-6] M 68.1. Hygroscopic powder which should be stored under N₂ in a cool place. Likely impurity is EtOH which can be removed by warming at 60-80° under high vacuum. Hydrolysed by H₂O to yield NaOH and EtOH. Other impurities, if kept in air for long periods are NaOH and Na₂CO₃. In this case the powder cannot be used if these impurities affect the reactivity and a fresh sample should be acquired [IR: J Org Chem 21 156 1956].


Sodium ferricyanide (H₂O) [14217-21-1; 13601-19-9 (anhydr)] M 298.9, pK<sup>25</sup> <1 (for ferricyanide). Cryst from hot water (1.5mL/g) or by precipitation from 95% EtOH.

Sodium ferrocyanide (10H₂O) [13601-19-9] M 484.1, m 50-80⁰ (loses 10H₂O), 435⁰ (dec), d 1.46, pK₂<sup>25</sup> 2.57, pK₄<sup>25</sup> 4.35 (for ferrocyanide). Cryst from hot water (0.7mL/g), until free of ferricyanide as shown by absence of Prussian Blue formation with ferrous sulfate soln.

Sodium fluoride [7681-49-4] M 42.0, m 996⁰, b 1695⁰, d 2.56. Cryst from water by partial evaporation in a vacuum desiccator, or dissolved in water, and ca half of it ppted by addition of EtOH. Ppte was dried in an air oven at 130⁰ for one day, and then stored in a desiccator over KOH.

Sodium fluoroacetate (mono) [62-74-8] M 100.0, m 200-205⁰ (dec). A free flowing white TOXIC powder which is purified by dissolving in ca 4 parts of H₂O and the pH is checked. If it is alkaline, add a few drops of PCH₂CO₂H to make the solution just acidic. Evaporate (fume hood) on a steam bath until crystals start to separate, cool and filter the solid off. More solid can be obtained by adding EtOH to the filtrate. Dry at 100⁰ in vacuum. [J Chem Soc 1778 1948.]

Sodium fluoroacetate (di)}
through a cation-exchange column (Dowex 50, Na⁺-form) to remove any remaining lanthanum [Anbar and Guttman J Phys Chem 64 18961960]. Also recrystd from anhydrous MeOH and dried in a vacuum at 70° for 16h. It is affected by moisture. [Delville et al. J Am Chem Soc 109 7293 1987.]

**Sodium fluoroisilicate** [16893-85-9] M 188.1. Cryst from hot water (40mL/g) by cooling.

**Sodium formaldehyde sulfoxylate dihydrate (sodium hydroxymethylsulfinate, Rongalite)** [149-44-0] M 134.1, m 63-64° (dihydrate). Crystallises from H₂O as the dihydrate, decomposes at higher temperatures. Store in a closed container in a cool place. It is insoluble in EtOH and Et₂O and is a good reducing agent. [X-ray structure: J Chem Soc 3064 1955.] Note that this compound \( \text{HOCH}_2\text{SO}_2\text{Na} \) should not be confused with formaldehyde sodium bisulfite adduct \( \text{HOCH}_2\text{SO}_3\text{Na} \) from which it is prepared by reduction with Zn.

**Sodium formate** (anhydrous) [141-53-7] M 68.0, m 253°, d 1.92. A saturated aqueous solution at 90° (0.8mL water/g) was filtered and allowed to cool slowly. (The final temperature was above 30° to prevent formation of the hydrate.) After two such crystns the crystals were dried in an oven at 130°, then under high vacuum. [Westrum, Chang and Levinj J Phys Chem 66 1553 1960; Roecker and Meyer J Am Chem Soc 108 4066 1986.] The salt has also been recrystd twice from 1mM DTPA (diethylenetriaminepentaacetic acid which was recrystd 4x from MilliQ water and dried in a vac), then twice from water [Bielski and Thomas J Am Chem Soc 109 7761 1987].

**Sodium D-gluconate** [527-07-1] M 472.6. Dissolved in EtOH, filtered and concentrated to crystallisation, and recrystallised from a little EtOH.

**Sodium glycochenodeoxycholate** [6564-43-5] M 472.6. Dissolved in EtOH, filtered and concentrated to crystallisation, and recrystallised from a little EtOH.

**Sodium glycocholate** [863-57-0] M 488.6. Dissolved in EtOH, filtered and concentrated to crystallisation, and recrystallised from a little EtOH.

**Sodium glycolate (2H₂O)** [2836-32-0] M 98.0. Ppted from aqueous solution by EtOH, and air dried.

**Sodium hexadecylsulfate** [120-01-0] M 283.5. Recrystd from absolute EtOH or MeOH and dried in vac [Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol II 1541 1965].

**Sodium hexafluorophosphate** [21324-39-0] M 167.9, \( pK_{1}^{\text{a}} \approx 0.5 \), \( pK_{2}^{\text{a}} \approx 5.12 \) (for fluorophosphoric acid \( \text{H}_{2}\text{PO}_{3}^{\text{F}} \)). Recrystd from acetonitrile and vacuum dried for 2 days at room temperature. It is an irritant and is hygroscopic. [Delville et al. J Am Chem Soc 109 7293 1987.]

**Sodium hexanitrocobaltate III (Na₃[Co(NO)₆])** [13600-98-1] M 403.9. Dissolve (ca 60g) in H₂O (300mL), filter to obtain a clear solution, add 96% EtOH (250mL) with vigorous stirring. Allow the ppte to settle for 2h, filter, wash with EtOH (4 x 25mL), twice with Et₂O and dry in air [Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol II 1541 1965]. Yellow to brown yellow crystals which are very soluble in H₂O, are decomposed by acid and form an insoluble K salt. Used for estimating K.

**Sodium hydrogen diglycollate** [50795-24-9] M 156.1. Cryst from hot water (7.5mL/g) by cooling to 0° with constant stirring, the crystals being filtered off on to a sintered-glass funnel and dried at 110° overnight.

**Sodium hydrogen oxalate (2H₂O)** [1186-49-8] M 130.0, m 100° (loses 2H₂O), b 200° (dec). Crystd from hot water (5mL/g) by cooling.

**Sodium hydrogen succinate** [2922-54-5] M 140.0. Cryst from water and dried at 110°.
Sodium hydrogen d-tartrate [526-94-3] M 190.1, m 100° (loses H₂O), b 234°, [α]₁₅₄⁺ +26° (c 1, H₂O). Crystd from warm water (10mL/g) by cooling to 0°.

Sodium hydroxide (anhydrous) [1310-73-2] M 40.0, m 323°, b 1390°, d 2.13. Common impurities are water and sodium carbonate. Sodium hydroxide can be purified by dissolving 100g in 1L of pure EtOH, filtering the solution under vacuum through a fine sintered-glass disc to remove insoluble carbonates and halides. (This and subsequent operations should be performed in a dry, CO₂-free box.) The soln is concentrated under vacuum, using mild heating, to give a thick slurry of the mono-alcoholate which is transferred to a coarse sintered-glass disc and pumped free of mother liquor. After washing the crystals several times with purified alcohol to remove traces of water, they are vacuum dried, with mild heating, for about 30h to decompose the alcoholate, leaving a fine white crystalline powder [Kelly and Snyder J Am Chem Soc 73 4114 1951].

Sodium hydroxide solutions (caustic), pK₂ 14.77. Carbonate ion can be removed by passage through an anion-exchange column (such as Amberlite IRA-400; OH⁻-form). The column should be freshly prepared from the chloride form by slow prior passage of sodium hydroxide soln until the effluent gives no test for chloride ions. After use, the column can be regenerated by washing with dilute HCl, then water. Similarly, other metal ions are removed when a 1M (or more dilute) NaOH soln is passed through a column of Dowex ion-exchange A-1 resin in its Na⁺-form. Alternatively, carbonate contamination can be reduced by rinsing sticks of NaOH (analytical reagent quality) rapidly with H₂O, then dissolving in distilled H₂O, or by preparing a concentrated aqueous soln of NaOH and drawing off the clear supernatant liquid. (Insoluble Na₂CO₃ is left behind.) Carbonate contamination can be reduced by adding a slight excess of conc BaCl₂ or Ba(OH)₂ to a NaOH soln, shaking well and allowing the BaCO₃ ppt to settle. If the presence of Ba in the soln is unacceptable, an electrolytic purification can be used. For example, sodium amalgam is prepared by the electrolysis of 3L of 30% NaOH with 500mL of pure mercury for cathode, and a platinum anode, passing 15 Faradays at 4Amps, in a thick-walled polyethylene bottle. The bottle is then fitted with inlet and outlet tubes, the spent soln being flushed out by CO₂-free N₂. The amalgam is then washed thoroughly with a large volume of deionised water (with the electrolysis current switched on to minimize loss of Na). Finally, a clean steel rod is placed in contact in the solution with the amalgam (to facilitate hydrogen evolution), reaction being allowed to proceed until a suitable concentration is reached, before being transferred to a storage vessel and diluted as required [Marsh and Stokes Aust J Chem 17 740 1964].


Sodium p-hydroxyphenylazobenzene-p'-sulfonate [2623-36-1] M 288.2. Crystd from 95% EtOH.

Sodium hypophosphite monohydrate [10039-56-2] M 106.0 (see pK of hypophosphorous acid). Dissolve in boiling EtOH, cool and add dry Et₂O till all the salt separates. Collect and dry in vacuum. It is soluble in 1 part of H₂O. It liberates PH₃ on heating and can ignite spontaneously when heated. The anhydrous salt is soluble in ethylene glycol (33% w/w) and propylene glycol (9.7%) at 25°.

Sodium iodate [7681-55-2] M 197.9, m dec on heating, d 4.28. Crystd from water (3mL/g) by cooling.

Sodium iodide [7681-82-5] M 149.9, m 660°, b 1304°, d 3.67. Crystd from water/ethanol soln and dried for 12h under vacuum, at 70°. Alternatively, dissolved in acetone, filtered and cooled to -20°, the resulting yellow crystals being filtered off and heated in a vacuum oven at 70° for 6h to remove acetone. The NaI was then crystd from very dilute NaOH, dried under vacuum, and stored in a vacuum desiccator [Verdin Trans Faraday Soc 57 484 1961].

Sodium ionophore I (ETH 227) (N',N',N''-triheptyl-N,N',N''-trimethyl-4,4',4''-propyldyinetris(3-oxabutynamide) [61183-76-4] M 642.0. It is purified (ca 200mg) by TLC on Kieselgel F₂₅₄ with CHCl₃/Me₂CO (1:1) as solvent, followed by HPLC (50mg) with an octadecytrimethylsilane modified column (Merckssorb SI 100, 10μm) [IR, NMR, MS: Helv Chim Acta 59 2417 1976].
Sodium ionophore V (ETH 4120) [4-octadecanoyloxymethyl-N,N,N',N'-tetracyclohexyl-1,2-phenylenedioxydiacetamide] \(129880-73-5\) M 849.3. Purified by recrystn from EtOAc. [Preparation and properties: Anal Chim Acta 233 295 1990].


Sodium isopropylxanthate \[140-93-2\] M 158.2, pK 2.16 (for -S-). Crystd from ligroin/ethanol.

Sodium laurate \[629-25-4\] M 222.3. See sodium dodecanoate on p. 470.

Sodium RS-mandelate \[114-21-6\] M 174.1. Crystd from 95% EtOH.

Sodium 2-mercaptopoethanesulfonate (MESNA) \[19767-45-4\] M 164.2, pK\(_{12}^{25}\) 9.53 (SH). It can be recrystd from H\(_2\)O and does not melt below 250°. It can be purified further by converting to the free acid by passing a 2M soln through an ion exchange (Amberlite IR-120) column in the acid form, evaporating the eluate in a vacuum to give the acid as a viscous oil (readily dec) which can be checked by acid and SH titration. It is then dissolved in H\(_2\)O, carefully neutralised with aqueous NaOH, evaporated and recrystd from H\(_2\)O [J Am Chem Soc 77 6231 1955].

Sodium metanilate \[1126-34-7\] M 195.2. Crystd from hot water.

Sodium metaperiodate (NaIO\(_4\)) \[7790-28-5\] M 213.9, m ~300°(dec), d 4.17. Crystd from hot water.

Sodium metasilicate \(\text{(5H}_2\text{O)}\) \[6834-92-0\] M 212.1, m 1088°, d 2.4. Crystd from aqueous 5% NaOH solution.

Sodium methanethiolate \(\text{[sodium methylmercaptide]}\) \[5188-07-8\] M 70.1, pK\(_{12}^{25}\) 10.33 (MeS\(^-\)). Dissolve the salt (10g) in EtOH (10mL) and add Et\(_2\)O (100mL). Cool and collect the ppte, wash it with Et\(_2\)O and dry it in vacuum. It is a white powder which is very soluble in EtOH and H\(_2\)O. [Bull Soc Chim Fr 3 2318 1936].

Sodium methoxide \[124-41-4\] M 54.0. It behaves the same as sodium ethoxide. It is hygroscopic and is hydrolysed by moist air to NaOH and EtOH. Material that has been kept under N\(_2\) should be used. If erratic results are obtained, even with recently purchased NaOMe it should be freshly prepared thus: Clean Na (37g) cut in 1-3g pieces is added in small portions to stirred MeOH (800mL) in a 2L three necked flask equipped with a stirrer and a condenser with a drying tube. After all the Na has dissolved the MeOH is removed by distillation under vacuum and the residual NaOMe is dried by heating at 150° under vacuum and kept under dry N\(_2\) [Org Synth 39 51 1959].

Sodium 3-methyl-1-butanesulfonate \[5343-41-9\] M 174.1. Crystd from 90% MeOH.

Sodium molybdate (2H\(_2\)O) \[10102-40-6\] M 241.9, m 100°(loses 2H\(_2\)O), 687°, d 3.28, pK\(_{25}^{25}\) 4.08 (for H\(_3\)MoO\(_4\)). Crystd from hot water (1mL/g) by cooling to 0°.


Sodium 2-naphthalenesulfonate \[532-02-5\] M 230.2. Crystd from hot 10% aqueous NaOH or water, and dried in a steam oven.
Sodium 2-naphthylamine-5,7-disulfonate [79004-97-0] M 235.4. Crystd from water (charcoal) and dried in a steam oven.

Sodium nitrate [7631-99-4] M 85.0, m 307°, b 380°, d 2.26. Crystd from hot water (0.6mL/g) by cooling to 0°, or from concentrated aqueous solution by addition of MeOH. Dried under vacuum at 140°. After 2 recrystns tech grade had K, Mg, B, Fe, Al, and Li at 100, 29, 0.6, 0.4, 0.2 and 0.2 ppm resp.

Sodium nitrite [7632-00-0] M 69.0, m 271°, b 320°, d 2.17. Crystd from hot water (0.7mL/g) by cooling to 0°, or from its own melt. Dried over P₂O₅.

Sodium 1-octanesulfonate [5324-84-5] M 216.2. Recrystd from absolute EtOH.


Sodium oxalate [62-76-0] M 134.0, m 250-270°(dec), d 2.34. Crystd from hot water (16mL/g) by cooling to 0°. Before use as a volumetric standard, analytical grade quality sodium oxalate should be dried for 2h at 120° and allowed to cool in a desiccator.


Sodium perchlorate (anhydrous) [7601-89-0] M 122.4, m 130°(for monohydrate), d 2.02, pK₅ -2.4 to -3.1 (for HClO₄). Because its solubility in water is high (2.1g/mL at 15°) and it has a rather low temperature coefficient of solubility, sodium perchlorate is usually crystd from acetone, MeOH, water-ethanol or dioxane-water (33g dissolved in 36mL of water and 200mL of dioxane). After filtering and crystallising, the solid is dried under vacuum at 140-150° to remove solvent of crystn. Basic impurities can be removed by crystn from hot acetic acid, followed by heating at 150°. If NaClO₄ is ppted from distilled water by adding HClO₄ to the chilled solution, the ppte contains some free acid. EXPLOSIVE

Sodium phenol-4-sulfonate (2H₂O) (4-hydroxybenzenesulfonic acid Na salt) [825-90-1] M 232.2. Crystd from hot water (1mL/g) by cooling to 0°, or from MeOH, and dried in vacuum.

Sodium phenoxide [139-02-6] M 116.1, m 61-64°. Washed with Et₂O, then heated under vacuum to 200° to remove any free phenol.

Sodium phenylacetate [114-70-5] M 158.1. Its aqueous solution was evaporated to crystallisation on a steam bath, the crystals being washed with absolute EtOH and dried under vacuum at 80°.

Sodium o-phenylphenolate (4H₂O) [132-27-4] M 264.3. Crystd from acetone and dried under vacuum at room temperature.

Sodium phosphoamidate [3076-34-4] M 119.0. Dissolved in water below 10°, and acetic acid added dropwise to pH 4.0 so that the monosodium salt was ppted. The ppte was washed with water and Et₂O, then air dried. Addition of one equivalent of NaOH to the solution gave the sodium salt, the solution being adjusted to pH 6.0 before use [Rose and Heald Biochem J 81 339 1961].

Sodium phytate (H₂O) [myo-inositolhexakis(H₂P0₄) Na salt] [14306-25-3] M 857.9. Crystd from water.

Sodium piperazine-N,N'-bis(2-ethanesulfonate) H₂O (PIPEC-Na salt) [76836-02-7] M 364.3. Crystd from water and EtOH.

Sodium polyacrylate (NaPAA) [9003-04-7]. Commercial polyacrylamide was neutralised with an aqueous solution of NaOH and the polymer ppted with acetone. The ppte was redissolved in a small amount of water and freeze-dried. The polymer was repeatedly washed with EtOH and water to remove traces of low
molecular weight material, and finally dried in vacuum at $60^\circ$ [Vink J Chem Soc, Faraday Trans 1 75 1207 1979]. Also dialysed overnight against distilled water, then freeze-dried.

Sodium poly($\alpha$-L-glutamate). It was washed with acetone, dried, dissolved in water and ppted with isopropanol at $5^\circ$. Impurities and low molecular weight fractions were removed by dialysis of the aqueous solution for 50h, followed by ultrafiltration through a filter impermeable to polymers of molecular weights greater the $10^4$. The polymer was recovered by freeze-drying. [Mori et al. J Chem Soc, Faraday Trans 1 2583 1978.]

Sodium propionate [137-40-6] M 96.1, m 287-289°. Recrystd from H$_2$O (solubility 10%), and dried by heating at 100° for 4h. Solubility of anhydrous salt in MeOH is 13% at 15° and 13.77% at 68°. It is insoluble in $^6$C$_6$H$_6$ and Me$_2$CO. [J Chem Soc 1341 1934.]

Sodium pyrophosphate (10H$_2$O) [13472-36-1] M 446.1, d 1.82, pK$_1$ 1.52, pK$_2$ 2.36, pK$_3$ 6.60, pK$_4$ 9.25 (for pyrophosphoric acid, H$_4$P$_2$O$_7$). Crystd from hot H$_2$O and air dried at room temp.

Sodium selenate [13410-01-0] M 188.9, pK$_1$ 2.56, pK$_2$ 1.66 (for selenic acid, H$_2$SeO$_4$). Crystd from water.


Sodium silicate solution [1344-09-8] pK$_1$ 9.51, pK$_2$ 11.77 (for silicic acid, H$_4$SiO$_4$) Purified by contact filtration with activated charcoal.


Sodium sulfate (10H$_2$O) (7727-73-3 (10H$_2$O); 7757-82-6 (anhyd)) M 322.2, m 32°(dec), 884° (anhyd), d 2.68 (anhyd). Crystd from water at 30° (1.1mL/g) by cooling to 0°. Sodium sulfate becomes anhydrous at 32°.

Sodium sulfide (9H$_2$O) [1313-84-4 (9H$_2$O); 1313-82-2 (anhyd)] M 240.2, m -50(loses H$_2$O), 950(anhyd), d 1.43 (10H$_2$O), 1.86 (anhyd). Some purification of the hydrated salt can be achieved by selecting large crystals and removing the surface layer (contaminated with oxidation products) by washing with distilled water. Other metal ions can be removed from Na$_2$S solutions by passage through a column of Dowex ion-exchange A-1 resin, Na$^+$-form. The hydrated salt can be rendered anhydrous by heating in a stream of H$_2$ or N$_2$ until water is no longer evolved. (The resulting cake should not be heated to fusion because it is readily oxidised.) Recrystd from distilled water [Anderson and Azowlay J Chem Soc, Dalton Trans 469 1986].

Sodium sulfite [7757-83-7] M 126.0, d 2.63. Crystd from warm water (0.5mL/g) by cooling to 0°. Purified by repeated crystns from deoxygenated water inside a glove-box, finally drying under vacuum. [Rhee and Dasgupta J Phys Chem 89 1799 1985.]

Sodium R-tartrate (2H$_2$O) [6106-24-7] M 230.1, m 120°(loses H$_2$O), d 1.82. Crystd from warm dilute aqueous NaOH by cooling.


Sodium tetrafluoroborate \([13755-29-8]\) \(M 109.8, d 2.47, pK_{2}^{25} -4.9\) (for \(\text{HBF}_4\)). See Sodium fluoroborate on p. 470.

Sodium tetrametaphosphate \([13396-41-3]\) \(M 429.9, pK_{1} -2.60, pK_{2} -6.4, pK_{3} -8.22, pK_{4} -11.4\) (tetrametaphosphoric acid, \(\text{H}_4\text{P}_4\text{O}_{12}\)). Crystd twice from water at room temperature by adding \(\text{EtOH}\) (300g of \(\text{Na}_4\text{P}_4\text{O}_{12}\cdot\text{H}_2\text{O}, 2L\) of water, and 1L of \(\text{EtOH}\)), washed first with 20% \(\text{EtOH}\) then with 50% \(\text{EtOH}\) and air dried \([\text{Quimby J Phys Chem 58} 603 1954]\).

Sodium tetraphenylborate \([\text{tetraphenyl boron Na}]\) \([143-66-8]\) \(M 342.2\). Dissolve in dry \(\text{MeOH}\) and add dry \(\text{Et}_2\text{O}\). Collect the solid and dry in a vacuum at 80°/2mm for 4h. Also can be extracted (Soxhlet) using \(\text{CHCl}_3\) and crystallizes from \(\text{CHCl}_3\) as snow white needles. It is freely sol in \(\text{H}_2\text{O}, \text{Me}_2\text{CO}\) but insol in pet ether and \(\text{Et}_2\text{O}\). An aqueous soln has \(\text{pH} -5\) and can be stored for days at 25° or lower, and for 5 days at 45° without deterioration. Its solubility in polar solvents increases with decrease in temp \([\text{Justus Liebigs Ann Chem 574} 195 1950]\).

The salt can also be recrystd from acetone-hexane or \(\text{CHCl}_3\), or from \(\text{Et}_2\text{O}-\text{cyclohexane}\) (3:2) by warming the soln to ppte the compound. Dried in a vacuum at 80°. Dissolved in \(\text{Me}_2\text{CO}\) and added to an excess of toluene. After a slight milkiness developed on standing, the mixture was filtered. The clear filtrate was evaporated at room temperature to a small bulk and again filtered. The filtrate was then warmed to 50-60°, giving clear dissolution of crystals. After standing at this temperature for 10min the mixture was filtered rapidly through a pre-heated Büchner funnel, and the crystals were collected and dried in a vacuum desiccator at room temperature for 3 days \([\text{Abraham et al. J Chem Soc, Faraday Trans 1 80} 489 1984]\). If the product gives a turbid aq solution, the turbidity can be removed by treating with freshly prepared alumina gel.

Sodium thioantimonate \((\text{Na}_3\text{SbS}_4\cdot9\text{H}_2\text{O}, \text{Schlippe's salt})\) \([13776-84-6]\) \(M 481.1, m 87°, b 234°, d 1.81\). Crystd from warm water (2mL/g) by cooling to 0°.

Sodium thiocyanate \([540-72-7]\) \(M 81.1, m 300°, pK_{2} -1.85\) (for \(\text{HSCN}\)). It is recrystd from \(\text{EtOH}\) or \(\text{Me}_2\text{CO}\) and the mother liquor is removed from the crystals by centrifugation. It is very deliquescent and should be kept in an oven at 130° before use. It can be dried in vacuum at 120°/\(\text{P}_2\text{O}_5\) \([\text{Trans Faraday Soc 30} 1104 1934]\). Its solubility in \(\text{H}_2\text{O}\) is 113% at 10°, 178% at 46°, 225.6% at 101.4°; in \(\text{Me}_2\text{CO}\) 35% at 15.8°, 53.5% at 52.3°; in \(\text{EtOH}\) 18.4% at 18.8°, 24.4% at 70.9°; and in \(\text{Me}_2\text{CO}\) 6.85% at 18.8° and 21.4% at 56° \([\text{J Chem Soc 2282} 1929]\).

Sodium thiocyanate has also been recrystd from water, acetonitrile or from \(\text{MeOH}\) using \(\text{Et}_2\text{O}\) for washing, then dried at 130°, or dried under vacuum at 60° for 2 days. \([\text{Strasser et al. J Am Chem Soc 107} 789 1985; \text{Szezygiel et al. J Am Chem Soc 91} 1252 1987}\). (The latter purification removes material reacting with iodine.) Sodium thiocyanate solns can be freed from traces of iron by repeated batch extractions with \(\text{Et}_2\text{O}\).

Sodium thioglycolate \([367-51-1]\) \(M 114.1\). Crystd from charcoal. Hygroscopic.

Sodium thiosulfate \((5\text{H}_2\text{O})\) \([10102-17-7\) (hydr); \(7772-98-7\) (anhydr)] \(M 248.2\) (anhydr), \(m 48\) (rapid heat), \(d 1.69, pK_{1}^{25} 0.6, pK_{2}^{25} 1.74\) (for \(\text{H}_2\text{S}_2\text{O}_3\)). Crystd from EtOH-\(\text{H}_2\text{O}\) solns or from water (0.3mL/g) below 60° by cooling to 0°, and dried at 35° over \(\text{P}_2\text{O}_5\) under vacuum.

Sodium p-toluenesulfinate \([824-79-3]\) \(M 178.2, pK_{2}^{25} 2.80\) (1.99)(for \(-\text{SO}_3^-\)). Crystd from water (to constant UV spectrum), and dried under vacuum or extracted with hot benzene, then dissolved in EtOH-\(\text{H}_2\text{O}\) and heated with decolorising charcoal. The solution was filtered and cooled to give crystals of the dihydrate.

Sodium p-toluenesulfonate \([657-84-1]\) \(M 194.2, pK_{2}^{25} -1.34\) (for \(-\text{SO}_3^-\)). Dissolved in distilled water, filtered to remove insoluble impurities and evaporated to dryness. Then cryst from MeOH or EtOH, and dried at 110°. Its solubility in \(\text{EtOH}\) is not high (maximum 2.5%) so that Soxhlet extraction with \(\text{EtOH}\) may be preferable. Sodium p-toluenesulfonate has also been crystd from \(\text{Et}_2\text{O}\) and dried under vacuum at 50°.

Sodium trifluoroacetate \([2923-18-4]\) \(M 136.0, m 206-210°\)(dec), \(pK_{2}^{25} 0.52\) (for \(\text{CF}_3\text{CO}_2^-\)). A possible contaminant is NaCl. The solid is treated with CF\(_3\)CO\(_2\)H and evaporated twice. Its solubility in CF\(_3\)CO\(_2\)H is 13.1% at 29.8°. The residue is cryst from dil EtOH and the solid dried in vacuum at 100°.
Purification of Inorganic and Metal-Organic Chemicals

It can be ppted from EtOH by adding dioxane, then crystd several times from hot absolute EtOH. Dried at 120-130\( ^\circ \)C/1mm.

**Sodium 2,2',4-trihydroxyazobenzene-5'-sulfonate** [3564-26-9] M 295.3. Purified by precipitating the free acid from aqueous solution using concentrated HCl, then washing and extracting with EtOH in a Soxhlet extractor. Evaporation of the EtOH left the purified acid.

**Sodium trimetaphosphate** (6H\(_2\)O) [7785-84-4] M 320.2, m 53\(^\circ\), d 1.79, \(pK_a^{25} 1.64\), \(pK_a^{25} 2.07\) (for trimetaphosphoric acid, H\(_3P_3O_9\)). Ppted from an aq soln at 40\(^\circ\) by adding EtOH. Air dried.

**Sodium 2,4,6-trimethylbenzenesulfonate** [6148-75-0] M 222.1. Crystd twice from MeOH and dried under vacuum.

**Sodium trimethylsilanolate** (sodium trimethylsilanol) [18027-10-6] M 112.2, m 230\(^\circ\)(dec). It is very soluble in Et\(_2\)O and C\(_6\)H\(_6\) but moderately soluble in pet ether. It is purified by sublimation at 130-150\(^\circ\) in a high vacuum. [IR: \(J_{\text{Am Chem Soc}} 75 5615 1953\); \(J_{\text{Org Chem}} 17 1555 1952\).]

**Sodium tripolyphosphate** [7758-29-4] M 367.9, \(pK_a^{25} 1\), \(pK_a^{25} 2.0\), \(pK_a^{25} 5.78\), \(pK_a^{25} 8.56\) (for triplyphosphoric acid, H\(_3P_3O_9\)). Purified by repeated pptn from aqueous solution by slow addition of MeOH and air dried. Also a solution of anhydrous sodium tripolyphosphate (840g) in water (3.8L) was filtered, MeOH (1.4L) was added with vigorous stirring to ppte Na\(_3\)P\(_3\)O\(_{10}\)\(\cdot\)H\(_2\)O. The ppte was collected on a filter, air dried by suction, then left to dry in air overnight. It was crystd twice more in this way, using a 13\% aqueous solution (w/w) and leaching the crystals with 200mL portions of water [Watters, Loughran and Lambert \(J_{\text{Am Chem Soc}} 78 4855 1956\)]. Similarly, EtOH can be added to ppte the salt from a filtered 12-15\% aqueous solution, the final solution containing ca 25\% EtOH (v/v). Air drying should be at a relative humidity of 40-60\%. Heat and vac drying should be avoided. [Quimby \(J_{\text{Phys Chem}} 58 603 1954\).]

**Sodium tungstate** (2H\(_2\)O) [10213-10-2] M 329.9, m 698\(^\circ\), d 4.18, \(pK_a^{25} 2.20\), \(pK_a^{25} 3.70\) (for tungstic acid, H\(_2\)WO\(_4\)). Crystd from hot water (0.8mLg) by cooling to 0\(^\circ\).

**Sodium m-xlenesulfonate** [30587-85-0] M 208.2. Dissolved in distilled water, filtered, then evaporated to dryness. Crystd twice from absolute EtOH and dried at 110\(^\circ\).

**Sodium p-xlenesulfonate** [827-19-0] M 208.2. See sodium 2,5-dimethylbenzenesulfonate on p. 469.

The tin IV chloride, stannic tetrachloride [7646-78-8] M 260.5, m -33\(^\circ\), -30\(^\circ\), b 114\(^\circ\)/760mm, d 2.23, \(pK_a^{25} 14.15\) (for aquo Sn\(^{4+}\) hydrolysis). Fumes in moist air due to hydrate formation. Fractionate in a ground glass still and store in the absence of air. Possible impurities are SO\(_2\) and HCl [Baudler Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol 1 p. 729 1963]. It forms a solid pentahydrate [10026-06-9] which smells of HCl and is formed when the anhydrous salt is dissolved in a small vol of H\(_2\)O. Also refluxed with clean mercury or P\(_2\)O\(_5\) for several hours, then distd under (reduced) N\(_2\) pressure into a receiver containing P\(_2\)O\(_5\). Finally redistd. Alternatively, distd from Sn metal under vacuum in an all-glass system and sealed off in large ampoules. Fumes in moist air. SnCl\(_4\) is available commercially as 1M solns in CH\(_2\)Cl\(_2\) or hexane. HARMFUL VAPOURS.

**Stannic chloride** (tin IV chloride, stannic tetrachloride) [7646-78-8] M 260.5, m -33\(^\circ\), -30\(^\circ\), b 114\(^\circ\)/760mm, d 2.23, \(pK_a^{25} 14.15\) (for aquo Sn\(^{4+}\) hydrolysis). Fumes in moist air due to hydrate formation. Fractionate in a ground glass still and store in the absence of air. Possible impurities are SO\(_2\) and HCl [Baudler Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol 1 p. 729 1963]. It forms a solid pentahydrate [10026-06-9] which smells of HCl and is formed when the anhydrous salt is dissolved in a small vol of H\(_2\)O. Also refluxed with clean mercury or P\(_2\)O\(_5\) for several hours, then distd under (reduced) N\(_2\) pressure into a receiver containing P\(_2\)O\(_5\). Finally redistd. Alternatively, distd from Sn metal under vacuum in an all-glass system and sealed off in large ampoules. Fumes in moist air. SnCl\(_4\) is available commercially as 1M solns in CH\(_2\)Cl\(_2\) or hexane. HARMFUL VAPOURS.

**Stannic iodide** (SnI\(_4\)) [7790-47-8] M 626.3, m 144\(^\circ\), b 340, d 4.46. Crystd from anhydrous CHCl\(_3\), dried under vacuum and stored in a vacuum desiccator. Sublimes at 180\(^\circ\).

**Stannic oxide** (SnO\(_2\)) [18282-10-5] M 150.7, m 1630\(^\circ\), d 6.95. Refluxed repeatedly with fresh HCl until the acid showed no tinge of yellow. The oxide was then dried at 110\(^\circ\).

**Stannous bis-cyclopentadienyl** [26078-96-6] M 248.9. Purified by vacuum sublimation. Handled and stored under dry N\(_2\). The related thallium and indium compounds are similarly prepared.
**Stannous chloride (anhydrous)** [7772-99-8] M 189.6, m 247°, b 606°, d 3.95, pK$^{15}$ 1.7, pK$^{25}$ 3.7 (for aquo Sn$^{2+}$ hydrolysis). Analytical reagent grade stannous chloride dihydrate is dehydrated by adding slowly to vigorously stirred, redistilled acetic anhydride (120g salt per 100g of anhydride). (In a fume cupboard.) After ca an hour, the anhydrous SnCl$_2$ is filtered on to a sintered-glass or Büchner funnel, washed free from acetic acid with dry Et$_2$O (2 x 30mL), and dried under vacuum. It is stored in a sealed container. [Stephen J Chem Soc 2786 1930].

**Strontium acetate** [543-94-2] M 205.7, d 2.1, pK$^{25}$ 13.0 (for aquo Sr$^{2+}$ hydrolysis). Cryst from AcOH, then dried under vacuum for 24h at 100°.

**Strontium bromide** [10476-81-0] M 247.4, m 643°, d 4.22. Cryst from water (0.5mL/g).

**Strontium chloride (6H$_2$O)** [1025-70-4] M 266.6, m 61°(rapid heating), 114-150°(loses 5H$_2$O), 868°(anhydr). Cryst from warm water (0.5mL/g) by cooling to 0°.

**Strontium chromate** [7789-06-2] M 203.6, d 3.9, pK$^{1}$ 0.74, pK$^{2}$ 6.49 (for H$_2$CrO$_4$). Cryst from water (40mL/g) by cooling.

**Strontium hydroxide (8H$_2$O)** [29870-99-3] M 319.8, m 120°(loses 3H$_2$O). Cryst from aq EtOH.

**Strontium lactate (3H$_2$O)** [10042-76-9] M 211.6, m 570°, b 645°, d 2.99. Cryst from hot water (0.5mL/g) by cooling to 0°.

**Strontium nitrate** [814-95-9] M 193.6, m 150°. Cryst from hot water (20mL/g) by cooling.

**Strontium oxalate (H$_2$O)** [526-26-1] M 224.7. Cryst from hot water (4mL/g) or EtOH.


**Sulfamic acid** [5329-14-5] M 97.1, m 205°(dec), pK$^{25}$ 0.99 (NH$_2$SO$_3$H). Cryst from water at 70° (300mL per 25g), after filtering, by cooling a little and discarding the first batch of crystals (about 25g) before standing in an ice-salt mixture for 20min. The crystals were filtered by suction, washed with a small quantity of ice water, then twice with cold EtOH and finally with Et$_2$O. Air dried for 1h, then stored in a desiccator over Mg(ClO$_4$)$_2$ [Butler, Smith and Audrieth Ind Eng Chem (Anal Ed) 10 690 1938]. For preparation of primary standard material see Pure Appl Chem 25 459 1969.

**Sulfamide** [7803-58-9] M 96.1, m 91.5°. Cryst from absolute EtOH.

**Sulfur** [7704-34-9] M 32.1, m between 112.8° and 120°, depending on form. Murphy, Clabaugh and Gilchrist [J Res Nat Bur Stand 64A 355 1960] have obtained sulfur of about 99.999% purity by the following procedure: Roll sulfur was melted and filtered through a coarse-porosity glass filter funnel into a 2L round-bottomed Pyrex flask with two necks. Conc H$_2$SO$_4$ (300mL) was added to the sulfur (2.5Kg), and the mixture was heated to 150°, stirring continuously for 2h. Over the next 6h, conc HNO$_3$ was added in about 2mL portions at 10-15min intervals to the heated mixture. It was then allowed to cool to room temperature and the acid was poured off. The sulfur was rinsed several times with distilled water, then remelted, cooled, and rinsed several times with distd water again, this process being repeated four or five times to remove most of the acid entrapped in the sulfur. An air-cooled reflux tube (ca 40cm long) was attached to one of the necks of the flask, and a gas delivery tube (the lower end about 1in above the bottom of the flask) was inserted into the other. While the sulfur was boiled under reflux, a stream of helium or N$_2$ was passed through to remove any...
water, HNO₃ or H₂SO₄, as vapour. After 4h, the sulfur was cooled so that the reflux tube could be replaced by a bent air-cooled condenser. The sulfur was then distilled, rejecting the first and the final 100mL portions, and transferred in 200mL portions to 400mL glass cylinder ampoules (which were placed on their sides during solidification). After adding about 80mL of water, displacing the air with N₂, and sealing the ampoule was cooled, and the water was titrated with 0.02M NaOH, the process being repeated until the acid content was negligible. Finally, entrapped water was removed by alternate evacuation to 10mm Hg and refilling with N₂ while the sulfur was kept molten. Other purifications include crystm from CS₂ (which is less satisfactory because the sulfur retains appreciable amounts of organic material), benzene or benzene/acetone, followed by melting and degassing. Has also been boiled with 1% MgO, then decanted, and dried under vacuum at 40° for 2 days over P₂O₅. [For purification of S₆, "recryst. S₈" and "Bacon-Fanelli sulfur" see Bartlett, Cox and Davis J Am Chem Soc 83 103, 109 1961.]

Sulfur dichloride [10545-99-0] M 103.0, m -78°, b 59°/760mm(dec), d 1.621. Twice distilled in the presence of a small amount of PCl₃ through a 12in Vigreux column, the fraction boiling between 55-61° being redistilled (in the presence of PCl₃), and the fraction distilling between 58-61° retained. (The PCl₃ is added to inhibit the decomposition of SC₁₂ into S₂C₁₂ and Cl₂). The SC₁₂ must be used as quickly as possible after distillation, within 1h at room temperature. The sample contains 4% S₂C₁₂. On long standing this reaches 16-18%.

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Sulfur dioxide [7446-09-5] M 64.1, b -10°. Dried by bubbling through concentrated H₂SO₄ and by passage over P₂O₅, then passed through a glass-wool plug. Frozen with liquid air and pumped to a high vacuum to remove dissolved gases. HARMFUL VAPOURS.

Sulfuric acid [7664-93-9] M 98.1, d 1.83, pKₐ 15 = -8.3, pKₐ ₂ 1.99. Sulfuric acid, and also 30% fuming H₂SO₄, can be distilled in an all-Pyrex system, optionally from potassium persulfate. Also purified by fractional crystm of the monohydrate from the liquid. Dehydrates and attacks skin—wash immediately with H₂O.

Sulfuric acid pyridine complex [26412-87-3] M 159.2, m 155-165°, 175°. Wash the solid with a little CCl₄, then H₂O to remove traces of pyridine sulfate, and dry over P₂O₅ [Chem Ber 59 1166 1926; Synthesis 59 1979].

Sulfuryl chloride [7791-25-2] M 135.0, m -54.1°, b 69.3°/760mm, d₂ 1.67, n₁ 1.44. Pungent, irritating colourless liquid. It becomes yellow with time due to decomposition to SO₂ and HCl. Distil and collect fraction boiling below 75°/atm which is mainly SO₂Cl₂. To remove HSO₃Cl and H₂SO₄ impurities, the distillate is poured into a separating funnel filled with crushed ice and briefly shaken. The lower cloudy layer is removed, dried for some time in a desiccator over P₂O₅ and finally fractionated at atmospheric pressure. The middle fraction boils at 69-70° and is pure SO₂Cl₂. It decomposes gradually in H₂O to H₂SO₄ and HCl. Reacts violently with EtOH and MeOH and is soluble in *C₆H₆, toluene Et₂O and acetic acid. [Handbook of Preparative Inorganic Chemistry (Ed Brauer) Vol 1 383 1963, Inorg Synth 1 114 1939]. HARMFUL VAPOURS.

Sulfuryl chloride [7791-25-2] M 135.0, m -54.1°, b 69.3°/760mm, d₂ 1.67, n₁ 1.44. Pungent, irritating colourless liquid. It becomes yellow with time due to decomposition to SO₂ and HCl. Distil and collect fraction boiling below 75°/atm which is mainly SO₂Cl₂. To remove HSO₃Cl and H₂SO₄ impurities, the distillate is poured into a separating funnel filled with crushed ice and briefly shaken. The lower cloudy layer is removed, dried for some time in a desiccator over P₂O₅ and finally fractionated at atmospheric pressure. The middle fraction boils at 69-70° and is pure SO₂Cl₂. It decomposes gradually in H₂O to H₂SO₄ and HCl. Reacts violently with EtOH and MeOH and is soluble in *C₆H₆, toluene Et₂O and acetic acid. [Handbook of Preparative Inorganic Chemistry (Ed Brauer) Vol 1 383 1963; Inorg Synth 1 114 1939]. HARMFUL VAPOURS.
needles when pure (yellow when contaminated with even less than 1% of NbCl₅). Sensitive to H₂O, even in conc HCl it decomposes to tantalic acid. Sol in EtOH. [J Am Chem Soc 80 2952 1958; Handbook of Preparative Inorganic Chemistry (Ed Brauer) Vol II 1302 1965.]


Telluric acid [7803-68-1] M 229.6, pk₁^15 7.70, pk₂^15 11.04 (H₂TaO₆). Crystd once from nitric acid, then repeatedly from hot water (0.4mL/g).

Tellurium dioxide [7446-07-3] M 159.6, m 450°. Purified by zone refining and repeated sublimation to an impurity of less than 1 part in 10⁸ (except for surface contamination by TeO₂). [Machol and Westrum J Am Chem Soc 80 2950 1958.]

Tellurium is volatile at 500°/0.2mm. Also purified by electrode deposition [Mathers and Turner Trans Amer Electrochem Soc 54 293 1928.]

Tetrabutylammonium borohydride [33725-74-5] M 257.3, m 128-129°. Purified by recrystn from EtOAc followed by careful drying under vacuum at 50-60°. Samples purified in this way showed no signs of loss of active H after storage at room temperature for more than 1 year. Nevertheless samples should be stored at ca 60° in tightly stoppered bottles if kept for long periods. It is soluble in CH₂Cl₂. [J Org Chem 41 690 1976; Tetrahedron Lett 3173 1972.]

Tetrabutylammonium chlorochromate [54712-57-1] M 429.3, m 161-163°, pk₂^15 -4.9 (for HBF₄). Recryst from H₂O, aq EtOH or from EtOAc by cooling in Dry ice. Also recryst from ethyl acetate/pentane or dry acetonitrile. Dried at 80° under vacuum. [Detty and Jones J Am Chem Soc 109 5666 1987; Hartley and Faulkner J Am Chem Soc 107 3436 1985.] Acetate m 118° (from BuCl); bromide m 118° (from EtOAc) and nitrate m 120° (from C₂H₅O). [J Am Chem Soc 69 2472 1947, 77 2024 1955.]

Tetrabutyl orthotitanate monomer (titanium tetrabutoxide) [5593-70-4] M 340.4, b 142°/0.1mm, 134-136°/0.5mm, 160°/0.8mm, 174°/6mm, 189°/13mm, d₁₅ 1.49. Dissolve in C₂H₅O, filter if solid is present, evaporate and vacuum fractionate through a Widmer 24inch column. The ester hydrolyses when exposed to air to give hydrated ortho-titanic acid. Titanium content can be determined thus: weigh a sample (ca 0.25g) into a weighed crucible and cover with 10mL of H₂O and a few drops of conc HNO₃. Heat (hot plate) carefully till most of the H₂O has evaporated. Cool and add more H₂O (10mL) and conc HNO₃ (2mL) and evaporate carefully (no spillage) to dryness and ignite residue at 600-650°/1h. Weigh the residual TiO₂. [J Chem Soc 2773 1952; J Org Chem 14 655 1949.]
Tetrabutyl tin (tin tetrabutyl) \([1461-25-2]\) M 347.2, b 94.5-96°/0.28mm, 145°/11mm, 245-247°/atm, \(d_4^{10} 1.05, n_D^{24} 1.473\). Dissolve in Et\(_2\)O, dry over MgSO\(_4\), filter, evaporate and distil under reduced pressure. Although it does not crystallise easily, once the melt has crystallised then it will recrystallise more easily. It is soluble in Et\(_2\)O, Me\(_2\)CO, EtOAc and EtOH but insoluble in MeOH and H\(_2\)O and shows no apparent reaction with H\(_2\)O. \(\text{J Org Chem 19 74 1954, J Chem Soc 1992 1954.}\)

Tetraethoxysilane (tetraethyl orthosilicate) \([78-10-4]\) M 208.3, m -77°, b 165-166°/atm, \(d_2^0 0.933, n_2^0 1.382\). Fractionate through an 80cm Podbielniak type column (see p. 141) with heated jacket and partial take-off head. Slowly decomposed by H\(_2\)O, soluble in EtOH. It is flammable - irritates the eyes and mucous membranes. \(\text{J Am Chem Soc 78 5573 1956, cf J Chem Soc 5020 1952.}\)

Tetraethylammonium hexafluorophosphate \([429-07-2]\) M 275.2, m >300°, 331°(dec), \(pK_1^{25} = 0.5, pK_2^{25} 5.12\) (for fluorophosphoric acid H\(_2\)PO\(_3\)F). Dissolve salt (0.8g) in hot H\(_2\)O (3.3mL) and cool to crystallise. Yield of prisms is 0.5g. Solubility in H\(_2\)O is 8.1gL at 19° \([\text{Chem Ber 63 1067 1930}].\)

Tetraethylammonium tetrafluoroborate \([429-06-1]\) M 217.1, m 235°, 356-367°, \(pK_2^{25} -4.9\) (for HBF\(_4\)). Dissolve in hot MeOH, filter and add Et\(_2\)O. It is soluble in ethylene chloride \(\text{J Am Chem Soc 69 1016 1947, 77 2025 1955.}\) See entry on p. 359 in Chapter 4.

Tetraethyl lead \([78-00-2]\) M 323.5, b 200°, 227.7°(dec), \(d_4^0 0.77, n_4^0 1.427\). Its more volatile contaminants can be removed by exposure to a low pressure (by continuous pumping) for 1h at 0°. Purified by stirring with an equal volume of H\(_2\)SO\(_4\) (d 1.40), keeping the temperature below 30°, repeating this process until the acid layer is colourless. It is then washed with dilute Na\(_2\)CO\(_3\) and distilled water, dried with CaCl\(_2\) and fractionally distil at low pressure under H\(_2\) or N\(_2\) \([\text{Calingaert Chem Rev 2 43 1924.}].\) VERY POISONOUS.

Tetraethylsilane \([631-36-7]\) M 144.3, b 153.8°/760mm, \(d_4^0 0.77, n_4^0 1.427\). Fractionate through a 3ft vacuum jacketted column packed with 1/4" stainless steel saddles. The material is finally percolated through a 2ft column packed with alumina and maintained in an inert atmosphere. \(\text{J Am Chem Soc 69 1309 1947.}\)

1.1.3.3-Tetraisopropyldisiloxane \([18043-71-5]\) M 246.5, b 129-130°/6mm, \(d_4^0 0.89, n_4^0 1.47\). Fractionate under reduced pressure in a N\(_2\) atm. \(\text{J Am Chem Soc 69 1500 1947.}\)

Tetraisopropyl orthotitanate (titanium tetraisopropyl) \([546-68-9]\) M 284.3, m 18.5°; b 80°/2mm, 78°/12mm, 228-229°/755mm. Dissolve in dry \(\text{C}_6\text{H}_6\), filter if a solid separates, evap and fractionate. It is hydrolysed by H\(_2\)O to give solid Ti\(_2\)O(iso-OPr)\(_2\) m ca 48°. \(\text{J Chem Soc 2323 1952, 469 1957.}\)

Tetrakis(diethylamin0) titanium (titanium tetrakis(diethylamide)) \([4419-47-0]\) M 336.4, b 85-90°/0.1mm, 112°/0.1mm, \(d_4^{10} 0.93, n_4^{30} 1.54\). Dissolve in \(\text{C}_6\text{H}_6\), filter if a solid separates, evaporate under reduced pressure and distill. Orange liquid which reacts violently with alcohols. \(\text{J Chem Soc 3857 1960.}\)

Tetrakis(hydroxymethylene)phosphonium chloride \([124-64-1]\) M 190.6, m 151°. Crystd from AcOH and dried at 100° in a vacuum. An 80% w/v aqueous solution has \(d_4^{20} 1.33 [\text{J Am Chem Soc 77 3923 1955}].\)

Tetrakis(tripheny1phosphine) palladium \([14221-01-3]\) M 1155.58, m 100-105°(dec). Yellow crystals from EtOH. It is stable in air only for a short time, and prolonged exposure turns its colour to orange. Store in an inert atmosphere below room temp in the dark. \(\text{J Chem Soc 1186 1957.}\)

Tetrakis(triphenylphosphine) platinum \([14221-02-4]\) M 1244.3, m 118°. Recrystd by adding hexane to a cold saturated solution in \(\text{C}_6\text{H}_6\). It is soluble in \(\text{C}_6\text{H}_6\) and CHCl\(_3\) but insoluble in EtOH and hexane. A less pure product is obtained if crystd by adding hexane to a CHCl\(_3\) soln. Stable in air for several hours and completely stable under N\(_2\). \(\text{J Am Chem Soc 2323 1958.}\)
Tetramethoxysilane (tetramethyl orthosilicate) [681-84-5] M 152.2, m 4.5\(^{\circ}\), b 122°/760mm. Purification as for tetraethoxysilane. It has a vapour pressure of 2.5mm at 0\(^{\circ}\). [IR: J Am Chem Soc 81 5109 1959.]

Tetramethy lammonium borohydride [1688-45-7] M 89.0. Recrystn from H\(_2\)O three times yields ca 94% pure compound. Dry in high vacuum at 100\(^{\circ}\) for 3h. The solubility in H\(_2\)O is 48% (20\(^{\circ}\)), 61% (40\(^{\circ}\)); and in EtOH 0.5% (25\(^{\circ}\)) and MeCN 0.4% (25\(^{\circ}\)). It decomposes slowly in a vacuum at 150\(^{\circ}\), but rapidly at 250\(^{\circ}\). The rate of hydrolysis of Me\(_4\)N.BH\(_4\) (5.8M) in H\(_2\)O at 40\(^{\circ}\) is constant over a period of 100h at 0.04% of original wt/h. The rate decreases to 0.02%/h in the presence of Me\(_4\)NOH (5% of the wt of Me\(_4\)N.BH\(_4\)). [J Am Chem Soc 74 2346 1952.]

Tetramethylammonium hexafluorophosphate [558-32-7] M 219.1, m >300\(^{\circ}\), pK\(_{25}\) 5.12 (for fluorophosphoric acid H\(_2\)PO\(_3\)F). The salt (0.63g) is recrystd from boiling H\(_2\)O (76mL), yielding pure (0.45) Me\(_4\)N.PF\(_6\) after drying at 100\(^{\circ}\). It is a good supporting electrolyte. [Chem Ber 63 1067 1930.]

Tetramethylammonium perchlorate [2537-36-2] M 123.6, m >300\(^{\circ}\), pK\(_{25}\) -2.4 to -3.1 (for HClO\(_4\)). Crystallise twice from H\(_2\)O and dry at 100\(^{\circ}\) in an oven. Insol in most organic solvents. [J Chem Soc 1210 1933.]

Tetramethylammonium triacetoxyborohydride [109704-53-2] M 263.1, m 93-98\(^{\circ}\), 96.5-98\(^{\circ}\). If impure, wash with freshly distd Et\(_2\)O and dry overnight in a vac to give a free flowing powder. Check \(^1\)H NMR, and if still suspect prepare freshly from Me\(_4\)NBH\(_4\) and AcOH in \(*\)C\(_6\)H\(_6\) and store away from moisture. [Banan et al. J Am Chem Soc 74 2346 1952; Evans and Chipman Tetrahedron Lett 27 5939 1986. It is an IRRITANT and MOISTURE SENSITIVE.


2,4,6,8-Tetramethylcyclotetrasiloxane [2370-88-9] M 240.5, m -69\(^{\circ}\), b 134.5-134.9\(^{\circ}\)/755mm, d\(_4\) 0.98, n\(_D\) 1.3672. It is purified by repeated redistillation, and fractions with the required \(^1\)H NMR data are collected. [J Gen Chem USSR (Engl Transl) 29 262 1959; J Am Chem Soc 68 962 1946.]

1,1,3,3-Tetramethyldisiloxane [3277-26-7] M 134.3, b 70.5-71\(^{\circ}\)/731mm, 71-72\(^{\circ}\)/atm, d\(_4\) 0.75, n\(_D\) 1.367. Possible impurity is 1,1,5,5-tetramethyl-3-trimethylsiloxytrisiloxane b 154-155\(^{\circ}\)/733mm. Fractionate, collect fractions boiling below 80\(^{\circ}\) and refractionate. Purity can be analysed by alkaline hydrolysis and measuring the volume of H\(_2\) liberated followed by gravimetric estimation of silica in the hydrolysate. It is unchanged when stored in glass containers in the absence of moisture for 2-3 weeks. Small amounts of H\(_2\) are liberated on long storage. Care should be taken when opening a container due to pressure developed. [J Am Chem Soc 79 974 1957; J Chem Soc 1958; IR: Z Anorg Chem 299 78 1959.]

N,N,N'N'-Tetramethylphosphonic diamide (methylphosphonic bis-dimethylamide) [2511-17-3] M 150.2, b 60.5\(^{\circ}\)/0.6mm, 138\(^{\circ}\)/32mm, 230-230\(^{\circ}\)/atm, d\(_4\) 1.0157, n\(_D\) 1.4539. Dissolve in heptane or ethylbenzene shake with 30% aqueous NaOH, stir for 1h, separate the organic layer and fractionate. [J Org Chem 21 413 1956]. IR has v 1480, 1460, 1300, 1184, 1065 and 988-970 cm\(^{-1}\) [Can J Chem 33 1552 1955.]

Tetramethylsilane (TMS) [75-76-3] M 88.2, b 26.3\(^{\circ}\), n 1.359, d 0.639. Distilled from conc H\(_2\)SO\(_4\) (after shaking with it) or LiAlH\(_4\), through a 5ft vacuum-jacketted column packed with glass helices into an ice-cooled condenser, then percolated through silica gel to remove traces of halide.

2,4,6,8-Tetramethyl tetravinyl cyclotetrasiloxane [2554-06-5] M 344.7, m -43.5\(^{\circ}\), b 111-112\(^{\circ}\)/10mm, 145-146\(^{\circ}\)/13mm, 224-224.5\(^{\circ}\)/758mm, d\(_4\) 0.98, n\(_D\) 1.434. A 7mL sample was
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distilled in a small Vigreux column at atmospheric pressure without polymerisation or decomposition. It is soluble in cyclohexane. [J Am Chem Soc 77 1685 1955.]

Tetraphenylarsonium chloride hydrate [507-28-8] M 418.8, m 261-263°. A neutralised aqueous soln was evaporated to dryness. The residue was extracted into absolute EtOH, evaporated to a small volume and ppted by addition of absolute Et₂O. It was again dissolved in a small volume of absolute EtOH or ethyl acetate and reppted with Et₂O. Alternatively purified by adding conc HCl to ppte the chloride dihydrate. Redissolved in water, neutralised with Na₂CO₃ and evaporated to dryness. The residue was extracted with CHCl₃ and finally crystallised from CH₂Cl₂ or EtOH by adding Et₂O. If the aqueous layer is somewhat turbid treat with Celite and filter through filter paper. POISONOUS.


Tetraphenylarsonium perchlorate [3084-10-4] M 482.8, pK⁺ 2.4 to -3.1 (for HClO₄). Crystd from MeOH. POISONOUS.


Tetraphenylphosphonium chloride [2001-45-8] M 374.9, m 273-275°. Crystd from acetone. Dried at 70° under vacuum. Also recrystd from a mixture of 1:1 or 1:2 dichloromethane/pet ether, the solvents having been dried over anhydrous K₂CO₃. The purified salt was dried at room temperature under vacuum for 3 days, and at 170° for a further 3 days. Extremely hygroscopic.


Tetraphenyltin [170-90-4] M 427.1, m 224-225°, 226°. Yellow crystals from CHCl₃, pet ether (b 77-120°), xylene or benzene/cyclohexane, and dried at 75°/20mm. [J Am Chem Soc 74 531 1952.]

Tetrapropylammonium perchlorate [15780-02-6] M 285.8, m 238-240°, pK⁺ 2.4 to -3.1 (for HClO₄). Purified by recrystns from H₂O or MeCN/H₂O (1:4 v/v), and dried in an oven at 60° for several days, or in vacuum over P₂O₅ at 100°. [Phys Chem 165A 245 1933, 144 281 1929, 140 97 1929.]

Tetra-n-propylammonium perruthenate (TPAP, tetrapropyl tetraoxoruthenate) [114615-82-6] M 351.4, m 1600(dec). It is a strong oxidant and may explode on heating. It can be washed with aq n-propanol, then H₂O and dried over KOH in a vac. It is stable at room temp but best stored in a refrigerator. It is sol in CH₂Cl₂ and MeCN. [Dengel et al. Transition Met Chem 10 98 1985; Griffith et al. J Chem Soc, Chem Commun 1625 1987.]


Thallium (I) acetate [563-68-8] M 263.4, m 126-128°, 127°, pK⁺ 13.2 (for TI⁺). Likely impurity is H₂O because the white solid is deliquescent. Dry in a vacuum over P₂O₅ or for several days in a desiccator, and store in a well closed container. 7.5g dissolve in 100g of liquid SO₂ at 0°, and ca 2mol% in AcOH at 25°. POISONOUS. [Trans Faraday Soc 32 1660 1936; J Am Chem Soc 52 516.]

Thallous bromide [7789-40-4] M 284.3, m 460°. Thallous bromide (20g) was refluxed for 2-3h with water (200mL) containing 3mL of 47% HBr. It was then washed until acid-free, heated to 300° for 2-3h and stored in brown bottles. POISONOUS.

Thallous carbonate [6533-73-9] M 468.7, m 268-270°. Crystd from hot water (4mL/g) by cooling. POISONOUS.

Thallous chlorate [13453-30-0] M 287.8, d 5.05. Crystd from hot water (2mL/g) by cooling. POISONOUS.
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Thallous chloride [7791-12-0] M 239.8, m 429.9°, d 7.0. Cryst from 1% HCl and washed until acid-free, or cryst from hot water (50mL/g), then dried at 140° and stored in brown bottles. Also purified by subliming in vacuum, followed by treatment with dry HCl gas and filtering while molten. (Soluble in 260 parts of cold water and 70 parts of boiling water). POISONOUS.

Thallous hydroxide [12026-06-1] M 221.4, m 139°(dec), pK2 13.2 (for Ti+). Cryst from hot water (0.6mL/g) by cooling. POISONOUS.

Thallous iodide [7790-30-9] M 331.3, m 441.8°, b 824°, d 7.1. Cryst from hot water (0.6mL/g) by cooling. POISONOUS.

Thallous nitrate [10102-45-1] M 266.4, m 206°, b 450°(dec), d 5.55. Cryst from warm water (1mL/g) by cooling to 0°. POISONOUS.

Thallous perchlorate [13453-40-2] M 303.8, pK2 25 -2.4 to -3.1 (for HClO4). Cryst from hot water (0.6mL/g) by cooling. Dried under vacuum for 12h at 100° (protect from possible EXPLOSION).

Thallous sulfate [7446-18-6] M 504.8, m 633°, d 6.77. Cryst from hot water (7mL/g) by cooling, then dried under vacuum over P2O5. POISONOUS.

Thexyl dimethyl chlorosilane (dimethyl-[2,3-dimethyl-2-butyl] chlorosilane) [67373-56-2] M 178.8, b 55-56°/10mm, 158-159°/720mm, d 4.0 0.970, n25 1.428. Purified by fractional distillation and stored in small aliquots in sealed ampoules. It is very sensitive to moisture and is estimated by dissolving an aliquot in excess of 0.1M NaOH and titrating with 0.1M HCl using methyl red as indicator. [Helv Chim Acta 67 2128 1984.]

N-(Thexyl dimethylsilyl)dimethylamine (N-[2,3-dimethyl-2-butyl]dimethylsilyl dimethylamine) [81484-86-8] M 187.4, b 156-160°/720mm. Dissolve in hexane, filter, evaporate and distil. Colourless oil extremely sensitive to humidity. It is best to store small quantities in sealed ampoules after distillation. For estimation of purity crush an ampoule in excess 0.1N HCl and titrate the excess acid with 0.1M NaOH using methyl red as indicator. [Helv Chim Acta 67 2128 1984.]

Thionyl chloride [7719-09-7] M 119.0, b 77°, d 1.636. Crude SOCl2 can be freed from sulfuryl chloride, sulfur monochloride and sulfur dichloride by refluxing with sulfur and then fractionally distilling twice. [The SOCl2 is converted to SO2 and sulfur chlorides. The S2Cl2 (b 135.6°) is left in the residue, whereas SCI2 (b 59°) passes over in the forerun]. The usual purification is to distill from quinoline (50g SOCl2 to 50g quinoline) to remove acid impurities, followed by distillation from boiled linseed oil (50g SOCl2 to 20g of oil). Precautions must be taken to exclude moisture.

Thionyl chloride for use in organic syntheses can be prepared by distillation of technical SOCl2 in the presence of diterpene (12g/250mL SOCl2), avoiding overheating. Further purification is achieved by redistillation from linseed oil (1-2%) [Rigby Chem Ind (London) 1508 1969]. Gas chromatographically pure material is obtained by distillation from 10% (w/w) triphenyl phosphite [Friedman and Wetter J Chem Soc (A) 36 1967; Larsen et al. J Am Chem Soc 108 6950 1986]. Harmful vapours.

Thorium chloride [10026-08-1] M 373.8, pK2 10.45, pK2 5 10.80, pK2 5 11.64 (for aquo Th4+). Freed from anionic impurities by passing a 2M soln of ThCl4 in 3M HCl through a Dowex-1 anion-resin column. The eluate was partially evaporated to give crystals which were filtered off, washed with Et2O and stored in a desiccator over H2SO4 to dry. Alternatively, a saturated solution of ThCl4 in 6M HCl was filtered through quartz wool and extracted twice with ethyl, or isopropyl, ether (to remove impurities), then evaporated to a small volume on a hot plate. (Excess silica pptd, and was filtered off. The filtrate was cooled to 0° and saturated with dry HCl gas.) It was shaken with an equal volume of Et2O, agitating with HCl gas, until the mixture becomes homogeneous. On standing, ThCl4.8H2O ppted and was filtered off, washed with Et2O and dried [Kremer J Am Chem Soc 64 1009 1942].

Thorium sulfate (4H2O) [10381-37-0] M 496.2, m 42°(loses H2O), d 2.8. Cryst from water.
Tin (powder) [7440-31-5] M 118.7. The powder was added to about twice its weight of 10% aqueous NaOH and shaken vigorously for 10 min. (This removed oxide film and stearic acid or similar material sometimes added for pulverisation.) It was then filtered, washed with water until the washings were no longer alkaline to litmus, rinsed with MeOH and air dried. [Sisido, Takeda and Kinugama J Am Chem Soc 83 538 1961.]

Tin tetramethyl [594-27-4] M 178.8, m 16.5°, b 78.3°/740 mm. It is purified by fractionation using a Todd column of 35-40 plates at atmospheric pressure (p. 177). The purity of the fractions can be followed by IR [J Am Chem Soc 77 6486 1955]. It readily dissolves stopcock silicone greases which give bands in the 8-10 μm region. [J Am Chem Soc 76 1169 1954.]


Titanium tetrachloride [7705-07-9] M 154.3, m >500°, pK₆ 2.55 (for hydrolysis of Ti³⁺ to TiOH²⁺). Brown purple powder that is very reactive with H₂O and pyrophoric when dry. It should be manipulated in a dry box. It is soluble in CH₂Cl₂ and tetrahydrofuran and is used as a M solution in these solvents in the ratio of 2:1, and stored under N₂. It is a powerful reducing agent. [Inorg Synth 6 52 1960; Synthesis 833 1989.]

Titanocene dichloride [1271-19-8] M 248.9, m 260-280° (dec), 289.2°, 298-291°, d 1.60. Bright red crystals from toluene or xylene-CHCl₃ (1:1) and sublime at 190°/100 mm. It is moderately soluble in EtOH and insoluble in Et₂O, C₆H₅, CS₂, CCl₄, pet ether and H₂O. [IR: J Am Chem Soc 76 4281 1954; NMR and X-ray: Can J Chem 51 2609 1973, 53 1622 1975.]

Titanium trichloride [7705-07-9] M 154.3, m >500°, pK₆ 2.55 (for hydrolysis of Ti³⁺ to TiOH²⁺). Brown purple powder that is very reactive with H₂O and pyrophoric when dry. It should be manipulated in a dry box. It is soluble in CH₂Cl₂ and tetrahydrofuran and is used as a M solution in these solvents in the ratio of 2:1, and stored under N₂. It is a powerful reducing agent. [Inorg Synth 6 52 1960; Synthesis 833 1989.]

Tri-n-butyl borate [688-74-4] M 230.2, b 232.4°, n 1.4092, d 0.857. The chief impurities are n-butyl alcohol and boric acid (from hydrolysis). It must be handled in a dry-box, and can readily be purified by fractional distillation, under reduced pressure.

Tri-n-butyl phosphate (butyl phosphate) [126-73-8] M 266.3, m -80°, b 47°/0.45mm, 98°/0.1mm, 121-124°/3mm, 136-137°/5.5mm, 166-167°/17mm, 177-178°/27mm, 289°/760atm (some dec), d_4 0.980, n_D^4 1.4425. The main contaminants in commercial samples are organic pyrophosphates, mono- and di- butyl phosphates and butanol. It is purified by washing successively with 0.2M HNO_3 (three times), 0.2M NaOH (three times) and water (three times), then fractionally distilled under vacuum. [Yoshida J Znorg Nucl Chem 24 1257 1962.]

It has also been purified via its uranyl nitrate addition compound, obtained by saturating the crude phosphate with uranyl nitrate. This compound was crystd three times with n-hexane by cooling to -40°, and then decomposed by washing with Na_2CO_3 and water. Hexane was removed by steam distn and the water was then evaporated under reduced pressure and the residue was distilled under reduced pressure. [Siddall and Dukes J Am Chem Soc 81 790 1959.]

Alternatively wash with water, then with 1% NaOH or 5% Na_2CO_3 for several hours, then finally with water. Dry under reduced pressure and fractionate carefully under vacuum. Stable colourless oil, sparingly soluble in H_2O (1mL dissolves in 165mL of H_2O), but freely miscible in organic solvents. [Am Chem Soc 74 4953 1952, 5441 1958; 5441 1958; 31P NMR: J Am Chem Soc 78 5715 1956; J Chem Soc 1488 1957.]

Tri-n-butyl phosphine [998-40-3] M 202.3, b 109-110°/10mm, 115-116°/12mm, 149.5°/50mm, 240.4-242.2°/atm, d_4^2 0.822, n_D^2 1.4463, pK_a ~-7.6. Fractionally distilled under reduced pressure in an inert atm (N_2) through an 8° gauze packed column (b 110-111/10mm) and redistilled in a vacuum and sealed in thin glass ampoules. It is easily oxidised by air to tri-n-butylphosphine oxide, b 293-296°/745mm. It has a characteristic odour, it is soluble in EtOH, Et_2O, and C_6H_6 but insoluble in H_2O and is less easily oxidised by air than the lower molecular weight phosphines. It forms complexes, e.g. with CS_2 (1:1) m 65.5° (from EtOH). [J Chem Soc 33 1929, 1401 1956.]

Tri-n-butyl phosphite [998-40-3] M 250.3, b 114-115°/5mm, 122°/12mm, 130°/17mm, 137°/26mm, d_4^2 0.926, n_D^2 1.4924. Fractionate with an efficient column. Stable in air but is slowly hydrolysed by H_2O. [Chem Soc 1464 1940, 1488 1957; J Am Chem Soc 80 2358, 2999 1958.]


Tributyl tin hydride [688-73-3] M 291.1, b 76°/0.7mm, 81°/0.9mm, d_2^0 1.098, n_D^2 1.473. Dissolve in Et_2O, add quinol (500mg for 300mL), dry over Na_2SO_4, filter, evaporate and distil under dry N_2. It is a clear liquid if dry and decompose very slowly. In the presence of H_2O traces of tributyl tin hydroxide are formed in a few days. Store in sealed glass ampoules in small aliquots. It is estimated by reaction with aq NaOH when H_2 is liberated. CARE: stored samples may be under pressure due to liberated H_2. [J Appl Chem 7 366 1957.]


Trichloromethyl trimethylsilane (trimethylsilyl chloromethane) [5936-98-1] M 191.6, m 130-132°, b 146-156°/749mm. It distils at atmospheric pressure without decomposition and readily sublimes at 70°/10mm. It has one peak in the 1H NMR spectrum (CH_2Cl_2) δ: 0.38. [Synthesis 626 1980.]


Triethoxysilane [998-30-1] M 164.3, m -170°, b 131.2-131.8°/atm, 131.5°/760mm, d_4^2 0.98753, n_D^2 1.4377. Fractionated using a column packed with glass helices of ca 15 theoretical plates in

**Triethylborane** [97-94-9] M 146.0, b 118.6\(^\circ\), n 1.378, d 0.678. Distilled at 56-57\(^\circ\)/220mm.

**Triethyl borate** [150-46-9] M 146.0, b 118\(^\circ\), n 1.378, d 0.864. Dried with sodium, then distilled.

**Triethyl phosphate** [78-40-0] M 182.2, b 40-42\(^\circ\)/0.25-0.3mm, 98-98.5\(^\circ\)/8-10mm, 90\(^\circ\)/10mm, 204\(^\circ\)/680mm, 215-216\(^\circ\)/760mm, \(d_2^0\) 1.608, \(n_\text{D}^2\) 1.4053. Dried by refluxing with solid BaO and fractionally distilled under reduced pressure. It is kept with Na and distilled. Stored in the receiver protected from light and moisture. Alternatively it is dried over Na\(_2\)SO\(_4\) and distilled under reduced pressure. The middle fraction is stirred for several weeks over anhydrous Na\(_2\)SO\(_4\) and again fractionated under reduced pressure until the specific conductance reached a constant low value of K\textsubscript{25} 1.19 x 10\(^8\), K\textsubscript{40} 1.68 x 10\(^8\), and K\textsubscript{55} 2.89 x 10\(^8\) ohm\(^{-1}\) cm\(^{-1}\). It has also been fractionated carefully under reduced pressure through a glass helices packed column. It is soluble in EtOH, Et\(_2\)O and H\(_2\)O (dec). \[J Am Chem Soc 72 1377, 2032 1950; J Org Chem 13 280 1948.\]

**Triethyl phosphine** [554-70-1] M 118.2, b 100\(^\circ\)/7mm, 127-128\(^\circ\)/744mm, \(d_2^{15}\) 0.812, \(n_\text{D}^{18}\) 1.457, pK\textsubscript{25} 8.69 (also available as a 1.0M soln in THF). All operations should be carried out in an efficient fume cupboard because it is flammable, toxic and has a foul odour. Purified by fractional distillation at atm pressure in a stream of dry NZ, as it is oxidised by air to the oxide. In 300\% excess of CS\(_2\) it forms Et\(_3\)PCS\(_2\) (m 118-120\(^\circ\) cryst from MeOH) which decomposes in CC\(_14\) to give Et\(_3\)PS as a white solid m 94\(^\circ\) when recryst from EtOH. \[Sorettas and Isbell J Org Chem 27 273 1962; J Am Chem Soc 82 5791 1960; see also trimethylphosphine.\] Store in a sealed vial under N\(_2\).

Alternatively, dissolve in Et\(_2\)O and shake with a solution of AgI and KI to form the insoluble complex. Filter off the complex, dry over P\(_2\)O\(_5\) and the Et\(_3\)P is regenerated by heating the complex in a tube attached to a vacuum system. \[Chem Ber 57 1035 1924.\]

**Triethyl phosphonoacetate** (trithyly carboxymethyl phosphonate) [867-13-0] M 224.2, b 83-84\(^\circ\)/0.5mm, 103\(^\circ\)/12mm, 143-144\(^\circ\)/11mm, 260-262\(^\circ\)/atm, \(d_2^{10}\) 1.1215, \(n_\text{D}^{10}\) 1.4310. Purified by fractional distillation, preferably in vacuo.

**Triethyl phosphonoformate** (trithyly carboxymethyl phosphonate) [1474-78-8] M 210.2, b 70-72\(^\circ\)/0.1mm, 122.5-123\(^\circ\)/8mm, 130-131\(^\circ\)/10mm, 138.2\(^\circ\)/12.5mm, \(d_2^{20}\) 1.22, \(n_\text{D}^{20}\) 1.423. Dissolve in Et\(_2\)O, shake with H\(_2\)O to remove any trace of NaCl impurity, dry (Na\(_2\)SO\(_4\)), evaporate and distil using an efficient fractionating column. \[Chem Ber 57 1035 1924.\]

**Triethyl 2-phosphonopropionate** [3699-66-9] M 238.2, b 76-77\(^\circ\)/0.2mm, 137-138.5\(^\circ\)/17mm, \(d_2^{20}\) 1.096, \(n_\text{D}^{20}\) 1.432. Purified by fractional distillation with high reflux ratio, preferably using a spinning band column. \[J Am Chem Soc 4198 1950.\]

Triethylsilyl-1,4-pentadiene  [(1,4-pentadien-3-yloxy-trimethylsilane)]  [62418-65-9]  M 198.4, b 72-74°/12mm, d₄ 0.842, nᵣ 1.439. Dissolve in pentane, wash with H₂O, dry (Na₂SO₄), evaporate, and distil under vacuum. Rf values on Kieselgel 60 are 0.15 (pentane) and 0.60 (CH₂Cl₂). [IR, NMR, MS: Helv Chim Acta 64 2002 1981.]


Tri-n-hexylborane  [1188-92-7]  M 265.3. Treated with hex-1-ene and 10% anhydrous Et₂O for 6h at gentle reflux under N₂, then vacuum distilled through an 18in glass helices-packed column under N₂ taking the fraction b 130°/2.1mm to 137°/1.5mm. The distillate still contained some di-n-hexylborane [Mirviss J Am Chem Soc 83 3051 1961].

Triiron dodecacarbonyl  [17685-52-8]  M 503.7, m 140°(dec). It usually contains 10% by weight of MeOH as stabiliser. This can be removed by keeping in a vacuum at 0.5mm for at least 5h. It can be sublimed slowly at high vacuum and is soluble in organic solvents. [J Org Chem 37 930 1972, J Chem Soc 4632 1960; Inorg Synth 7 193 1963.]

Triisoamyl phosphate  [919-62-0]  M 308.4, b 143°/3mm. Purified by repeated crystallisation, from hexane, of its addition compound with uranyl nitrate. (see tributyl phosphate.) [Siddall J Am Chem Soc 81 4176 1959].

Triisobutyl phosphate  [126-71-6]  M 266.3, b 119-129°/8-12mm, 192°/760mm, d 0.962, n 1.421. Purified by repeated crystallisation, from hexane, of its addition compound with uranyl nitrate. (see tributyl phosphate.) [Siddall J Am Chem Soc 81 4176 1959.]


Trimethallyl phosphate  [14019-81-9]  M 260.3, b 134.5-140°/5mm, nₑ 1.4454. Purified as for triisooamyl phosphate.

Trimethoxysilane  [2487-90-3]  M 122.2, m -114.8°, 81.9°/760mm, 84°/atm, d₄ 0.957, nᵣ 1.359. Likely impurities are Si(OMe)₄ and H₂Si(OMe)₂. Efficient fractionation is essential for removing these impurities [IR: J Am Chem Soc 81 5109 1959].

Trimethyl borate (methylborate, trimethoxyboron)  [121-43-7]  M 103.9, b 67-68°/742mm, d₄ 0.928, nᵣ 1.3610. Carefully fractionated through a gauze-packed column. Redistill and collect in weighed glass vials and seal. Keep away from moisture. It undergoes alkyl exchange with alcohols and forms azeotropes, e.g. with MeOH the azeotrope consists of 70% (MeO)₃B and 30% MeOH with b 52-54°/atm, d 0.87. [J Chem Soc 2288 1952; Chem Ind (London) 53 1952; J Am Chem Soc 75 213 1953.] Also dried with Na, then distilled.

Trimethyl boroxine  [823-96-1]  M 125.5, b 80°/742mm, 79.3°/755mm, d₄ 0.902. Possible impurity is methylboronic acid. If present then add a few drops of conc H₂SO₄ and distil immediately, then

Trimethyl chlorosilane (chlorotrimethylsilane) [75-77-4] M 108.6, b 56-57°/atm, 58°/760mm, d 0.86, n 1.388. Likely impurities are other chlorinated methylsilanes, and tetrachlorosilane (b 57.6°), some of which can form azeotropes. To avoid the latter very efficient fractional distillation is required. It has been fractionated through a 12 plate glass helices packed column with only the heart-cut material used. It has also been fractionated through a 90cm, 19mm diameter Stedman column (see p. 441). Also purified by redistilling from CaH2 before use. [J Am Chem Soc 70, 4254, 4258 1948; J Org Chem 23 50 1958.] FLAMMABLE and CORROSIVE.

Trimethyl perchlorate (chlorotrimethylsilane) [75-77-4] M 108.6, b 56-57°/atm, 58°/760mm, d 0.86, n 1.388. Likely impurities are other chlorinated methylsilanes, and tetrachlorosilane (b 57.6°), some of which can form azeotropes. To avoid the latter very efficient fractional distillation is required. It has been fractionated through a 12 plate glass helices packed column with only the heart-cut material used. It has also been fractionated through a 90cm, 19mm diameter Stedman column (see p. 441). Also purified by redistilling from CaH2 before use. [J Am Chem Soc 70, 4254, 4258 1948; J Org Chem 23 50 1958.] FLAMMABLE and CORROSIVE.

Trimethyl oxonium tetrafluoroborate [420-37-1] M 147.9, m 141-143° (sinters, open capillary), 179.6-180.0° (dec), 210-220° (dec). The salt must be a white crystalline solid m - 179.6-180.0° (dec, sealed tube). Under a N2 atmosphere (e.g. Dry Box), wash twice with CH2Cl2 then twice with Na-dried Et2O, and dry by passing dry N2 over the salt until free from Et2O [Curphey J Org Synth Coll Vol VI 1019 1988]. The oxonium salt purified in this way can be handled in air for short periods. The sample kept in a desiccator (Drierite) for 1 month at -20° had the same m, and samples stored in this way for >1 year are satisfactory for alkylations. 1H NMR in liq SO2 in a sealed tube had a single peak at δ 4.54 (impurities have δ at 3.39). [Meerwein Org Synth Coll Vol V 1096 1973.] If the sample looks good, dry in a vac desiccator for 2h (25°/1mm) and stored under N2 at -20°. Melting point depends on heating rate.

Trimethylphenylsilane (phenyltrimethylsilane) [12389-34-3] M 180.0° (dec, sealed tube). Under a N2 atmosphere (e.g. Dry Box), wash twice with CH2Cl2 then twice with Na-dried Et2O, and dry by passing dry N2 over the salt until free from Et2O [Curphey J Org Synth Coll Vol VI 1019 1988]. The oxonium salt purified in this way can be handled in air for short periods. The sample kept in a desiccator (Drierite) for 1 month at -20° had the same m, and samples stored in this way for >1 year are satisfactory for alkylations. 1H NMR in liq SO2 in a sealed tube had a single peak at δ 4.54 (impurities have δ at 3.39). [Meerwein Org Synth Coll Vol V 1096 1973.] If the sample looks good, dry in a vac desiccator for 2h (25°/1mm) and stored under N2 at -20°. Melting point depends on heating rate.


Trimethyl phosphine [594-02-2] M 76.1, m -86°, b 38-39°/atm, pk 25 8.65, (also available as a 1.0M soln in THF or toluene). All operations should be carried out in an efficient fume cupboard because it is flammable, toxic and has a foul odor. Distill at atm pressure in a stream of dry N2 (apparatus should be held together with springs to avoid loss of gas from increased pressure in the system) and the distillate run into a soh of AgI in aq KI for 2h. Filter off the complex, wash with satd aq KI soln, then the KI solution, H2O, and dried [Henderson and Streeuli J Am Chem Soc 82 5791 1960]. If the sample looks good, dry in a vac desiccator for 2h (at 25°) and stored under N2 at -20°. Melting point depends on heating rate.

Alternatively, freshly distilled Me3P (6g) is shaken with a solution of AgI (13.2g, 1.lmol) in saturated aqueous KI solution (50mL) for 2h. A white solid, not wetted with H2O, separates rapidly. It is collected, washed with the KI solution, H2O, and dried [J Chem Soc 1829 1937]. The silver complex is stable if kept dry in the dark in which state it can be kept indefinitely. Me3P can be generated from the complex when required. Store under N2 in a sealed container. It has been distill in a vacuum line at -78° in vacuo and condensed at -96° [IR and NMR: Crosbie and Sheldrick J lnorg Nucl Chem 59 59 1967]. Alternatively, freshly distilled Me3P (6g) is shaken with a solution of AgI (13.2g, 1.lmol) in saturated aqueous KI solution (50mL) for 2h. A white solid, not wetted with H2O, separates rapidly. It is collected, washed with the KI solution, H2O, and dried [J Chem Soc 1829 1937]. The silver complex is stable if kept dry in the dark in which state it can be kept indefinitely. Me3P can be generated from the complex when required. Store under N2 in a sealed container.
Triphenylphosphine hydrochloride is unstable and volatilises at 75°C/0.4 mm (120°C/14 mm). [J Am Chem Soc 67 503 1945; IR: Trans Faraday Soc 40 41 1944; Kosolapoff Organophosphorus Compounds, Wiley p. 31 1950.]

Trimethyl phosphite \([121-45-9]\) M 124.1, b 22°C/23 mm, 86.86-5°C/351 mm, 111-112°C/760 mm, 111°C/atm, \(d^4_2\) 1.0495, \(n_D^2\) 1.408. Treated with Na (to remove water and any dialkyl phosphonate), then decanted and distilled with protection against moisture. It has also been treated with sodium wire for 24 h, then distilled in an inert atmosphere onto activated molecular sieves [Connor et al. J Chem Soc, Dalton Trans 511 1986]. It has also been fractionally distilled using a spinning band column at high reflux ratio. It is a colourless liquid which is slowly hydrolysed by \(H_2O\). [J Am Chem Soc 80 2999 1958; IR: J Chem Soc 255 1950, P NMR: J Am Chem Soc 79 2715 1957; Kosolapoff Organophosphorus Compounds, Wiley p. 203 1950.]

Trimethylsilyl acetamide \([134-35-12-6]\) M 131.3, m 38-43°C, 52-54°C, b 84°C/13 mm, 185-186°C/atm. Repeated distillation in an inert atmosphere, all operations to be performed under anhydrous atmosphere. In the presence of moisture trimethylsilanol (b 31-34°C/26 mm) is formed and is likely an impurity (check by NMR). [Chem Ber 96 1473 1963.]

Trimethylsilyl acetonitrile (TMSAN) \([18293-53-3]\) M 113.2, b 49-51°C/10 mm, 65-70°C/20 mm, \(d^2_2\) 0.8729, \(n_D^2\) 1.4420. Check if NMR and IR spectra are correct, if not dissolve in \(C_6H_6\) (10 vols), wash with buffer (AcOH-AcONa pH ca 7) several times, dry (CaCl\(_2\)), evaporate and distill. IR: \(v\) (CCl\(_4\)) 2215 (CN) cm\(^{-1}\); NMR \(\delta\) (CCl\(_4\)): 0.23 (s, 9H, SiMes), and 1.53 (s, 2H, CH\(_2CN\)). [J Chem Soc Perkin Trans 1 26 1979.]

Trimethylsilyl azide M 115.2, b 92-95°C/atm, 95-99°C/atm, \(d^0\) 0.878, \(n_0\) 1.441. Distil through a Vigreux column in a \(N_2\) atmosphere maintaining the oil bath temperature thermostated at 135-140°C. Check the purity by \(^1H\) NMR [CHCl\(_3\), \(\delta\): single peak at 13 cps from Me\(_2\)]. Likely impurities are siloxane hydrolysis products. The azide is thermally stable even at 200°C when it decomposes slowly without explosive violence. All the same it is advisable to carry out the distillation behind a thick safety screen in a fume hood because unforeseen EXPLOSIVE azides may be formed on long standing. [Birkofe and Wagner Org Synth Coll Vol VI 1030 1988.]

Trimethylsilyl cyanide \([7677-24-9]\) M 99.2, m 8-11°C, 10.5-11.5°C, 11-12°C, 12-12.5°C; b 54-55°C/87 mm, 67-71°C/168 mm, 114-117°C/760 mm, 118-119°C/760 mm, \(d^2_2\) 0.79 \(n_D^2\) 1.43916. Material should have only one sharp signal in the \(^1H\) NMR in \(CCL_4\) with CHCl\(_3\) as internal standard \(\delta\): single peak at 13 cps from Me\(_4\)Si. Likely impurities are siloxane hydrolysis products. The azide is thermally stable even at 200°C when it decomposes slowly without explosive violence. All the same it is advisable to carry out the distillation behind a thick safety screen in a fume hood because unforeseen EXPLOSIVE azides may be formed on long standing. [Birkofe and Wagner Org Synth Coll Vol VI 1030 1988.]

Trimethylsilyl ethanol \([2916-68-9]\) M 118.3, m -20°C, 57-58°C/14 mm, 70-71°C/30 mm, 159°C/760 mm, \(d^2_2\) 1.057, \(n_D^2\) 1.4231. Purified by repeated fractionation and taking the fractions with clean NMR spectra. [J Am Chem Soc 2371 1952.]

Trimethylsilyl cyanide \([7677-24-9]\) M 99.2, m 8-11°C, 10.5-11.5°C, 11-12°C, 12-12.5°C; b 54-55°C/87 mm, 67-71°C/168 mm, 114-117°C/760 mm, 118-119°C/760 mm, \(d^2_2\) 0.79 \(n_D^2\) 1.43916. Material should have only one sharp signal in the \(^1H\) NMR in \(CCL_4\) with CHCl\(_3\) as internal standard \(\delta\): single peak at 13 cps from Me\(_4\)Si. Likely impurities are siloxane hydrolysis products. The azide is thermally stable even at 200°C when it decomposes slowly without explosive violence. All the same it is advisable to carry out the distillation behind a thick safety screen in a fume hood because unforeseen EXPLOSIVE azides may be formed on long standing. [Birkofe and Wagner Org Synth Coll Vol VI 1030 1988.]

2-Trimethylsilyl-1,3-dithiane \([134-11-2-2]\) M 192.2, b 54.5°C/0.17 mm, 100°C/8 mm, \(d^2_2\) 1.04, \(n_D^2\) 1.533. Fractionally distill through an efficient column and collect the fractions that have the correct NMR and IR spectra. \(^1H\) NMR \(\delta\) (CCL\(_4\)): 6 3.6 (SiMe\(_3\)), 9.87 (SCHS) and dithiane H at 7 and 8 (ratio 1:9:4:2) from Me\(_4\)Si; UV \(\lambda_{max}\) 244 nm (\(\epsilon\) 1711); sh 227 nm (\(\epsilon\) 800). [J Am Chem Soc 89 434 1967.]

Trimethylsilyl ethanol \([2916-68-9]\) M 118.3, m 53-55°C/11 mm, 75°C/41 mm, 95°C/100 mm, \(d^2_2\) 0.8254, \(n_D^2\) 1.4220. If the NMR spectrum is not clean then dissolve in \(Et_2O\), wash with aqueous \(NH_4\)Cl solution, dry (Na\(_2\)SO\(_4\)), evaporate and distill. The 3,4-dinitrobenzoyl deriv has \(m\) 66°C (from EtOH). [NMR: J Am Chem Soc 79 974 1957; Z Naturforsch 14b 137 1959.]

2-(Trimethylsilyl)ethoxymethyltrimethylphosphonium chloride [82495-75-8] M 429.0, m 140-142°. Wash the solid with AcOH and recryst from CH₂Cl₂-EtOAc. Dry in a vacuum desiccator. Hygroscopic. ¹H NMR (CDCl₃) δ: -0.2 (s, Me₂Si), 0.8 (t, 8Hz, CH₂Si), 3.83 (t, 8Hz, OCH₂), 5.77 (d, JPH 4Hz, P⁻CH₂O) and 7.70 (m, aromatic H). [Justus Liebigs Ann Chem 1031 1983.]


1-Trimethylsilyloxy-1,3-butadiene [6651-43-0] M 156.3, b 131°/760mm (mixt of isomers), 49.5°/25mm (E-isomer), d 0.8237, n 1.447. Purified by fractional distn and collecting the fractions with the required ¹H NMR. Store under N₂ - it is a flammable and moisture sensitive liquid. [Caseau et al. Bull Soc Chim Fr 16658 1972; Belge Patent 670,769, Chem Abstr 65 5487d 1966.]

1-Trimethylsilyloxy)cyclopentene [61550-02-5] M 156.3, b 45°/11mm, 75-80°/20-21mm, d 0.878, nD 1.441. If too impure as seen by the NMR spectrum then dissolve in 10 vols of pentane, shake with cold NaHCO₃(3 x 500mL), then 1.5M HCl (200mL) and aqueous NaHCO₃ (200mL) again, dry (Na₂SO₄), filter, evaporate and distil through a short Vigreux column. ¹H NMR: (CDCl₃) δ: 0.21 (s, 9H), 1.55 (m, 2H), 1.69 (m, 2H), 2.05 (br d, 4H) and 4.88 (br s, 1H). GLPC in a 6ft x 1/8in with 3% SP2100 on 100-120 mesh Supelcoport column should give one peak. [Org Synth Coll Vol VIII 460 1993.]

1-Trimethylsilyloxy)furan [61550-02-5] M 156.3, b 34-35°/9-10mm, 42-50°/17mm, 40-42°/25mm, d 0.950, n 1.436. Fractionally distilled using a short path column. ¹H NMR in CCl₄ has δ: 4.90 (dd, J 1.3Hz, 3H), 6.00 (t, J 3Hz, 4H) and 6.60 (m, 5H). [Heterocycles 4 1663 1976.]

4-Trimethylsilyloxy-3-penten-2-one (cis) (acet lacetone enol trimethylsilyle ether) [13257-81-3] M 172.3, b 66-68°/4mm, 61-63°/5mm, d 0.917, nD 1.480. Fractionally distilled and stored in glass ampoules which are sealed under N₂. It hydrolyses readily in contact with moisture giving, as likely impurities, hexamethyldisiloxane and 2,4-pentanedione. [J Am Chem Soc 80 3246 1958.]

(Trimethylsilyl)methanol [3219-63-4] M 104.2, b 120-122°/754mm, 122-123°/768mm, d 0.83 nD 1.4176. If the NMR indicates impurities (should have only two signals) then dissolve in Et₂O, shake with aqueous 5N NaOH, M H₂SO₄, saturated aqueous NaCl, dry (MgSO₄) and distil using an efficient column at atmospheric pressure. The 3,5-dinitrobenzoate has m 70-70.5° (from 95% EtOH). [Huang and Wang Acta Chem Sin 23 291 1957, Chem Abs 52 19911 1958; Speier et al. J Am Chem Soc 81 1844 1959 and J Am Chem Soc 70 1117 1949.]

(Trimethylsilyl)methylamine (aminomethyl trimethylsilane) [18166-02-4] M 103.2, b 101.6°/735mm, d 0.77, nD 1.416. A possible contaminant is hexamethyldisiloxane. Should have two ¹H NMR signals in CDCl₃, if not, dissolved in C₆H₆ shake with 15%aq KOH, separate, dry (Na₂SO₄), filter, evaporate and distil using a still of ca 10 theoretical plates. The water azeotrope has b 83°/735mm,
hence it is important to dry the extract well. The hydrochloride has m 198/199° (from MeOH or Me₂CO). [J Am Chem Soc 73 3867 1951; NMR, IR: J Organometal Chem 44 279 1972.]

Trimethylsilylmethyl phenylsulfone (phenyltrimethylsilylmethylsulfone) [17872-92-3] M 228.4, m 28-32°, b 121°/0.1mm, 160°/6mm, n₁₀ 1.5250. Fractionate at high vacuum and recrystallise from pentane at -goo. If too impure (cf IR) dissolve in CH₂Cl₂ (ca 800mL for 100g), wash with 2M aqueous NaOH (2 x 200mL), brine, dry, evaporate and distil. [J Chem Soc, Perkin Trans 1 1949 1985; IR and NMR: J Am Chem Soc 76 3713 1954.]

Trimethylsilylmethyl phenylsulfone (phenyltrimethylsilylmethylsulfone) [7872-92-3] M 174.3, b 45-46°/0.1mm, 67°/5mm, 87.5°/9mm, d 0.8961 n 1.5284. Dissolve in Et₂O, wash with H₂O, dry and fractionate through a Todd column (see p. 174). [J Am Chem Soc 80 5298 1958.]

l-(Trimethylsilyl)-2-phenylacetylene (1-phenyl-2-trimethylsilylacetylene) [78905-09-6] M 174.3, b 45-46°/0.1mm, 67°/5mm, 87.5°/9mm, d 0.8961 n 1.5284. Dissolve in Et₂O, wash with H₂O, dry and fractionate through a Todd column (see p. 174). [J Am Chem Soc 80 5298 1958.]

I-Trimethylsilyl-1,2,4-triazole [18293-54-4] M 141.3, b 74°/12mm, d₁₀ 0.99, n₂₀ 1.4604. Fractionally distilled at atmospheric pressure in an inert atmosphere because it is moisture sensitive. [Chem Ber 93 2804 1960.]

Trimethylsilyl trifluoromethane (trifluoromethyl trimethylsilane) [81290-20-2] M 142.2, b 54-55°, 55-55.5°, d₂₀ 0.962, n₂₀ 1.332. Purified by distilling from trap to trap in a vacuum of 20mm using a bath at 45° and Dry ice-Me₂CO bath for the trap. The liquid in the trap is then washed with ice cold H₂O (3x), the top layer is collected, dried (Na₂SO₄), the liquid was decanted and fractionated through a helices packed column at atmospheric pressure. 'H, 13C, 19F, and 29Si NMR can be used for assessing the purity of fractions. [Tetrahedron Lett 25 2195 1984; J Org Chem 56 984 1991.]


Tri-(4-nitrophenyl)phosphosphate [3871-20-3] M 461.3, m 155-156°, 156°, 156-158°, 157-159°. It has been recryst from AcOH, dioxane, AcOEt and Me₂CO and dried in vacuum over P₂O₅. [J Am Chem Soc 72 5777 1950, 79 3741 1957.]

Tri-n-octylphosphine oxide [78-50-2] M 386.7, m 59.5-60°, pKₑₐₐ <0. Mason, McCarty and Peppard [J Inorg Nuclear Chem 24 967 1962] stirred an 0.1M solution in °benzene with an equal volume of 6M HCl at 40°, then washed the °benzene solution successively with water (twice), 5%aq Na₂CO₃ (three times) and water (six times). The °benzene and water were then evaporated under reduced pressure at room temperature. Zingaro and White [J Inorg Nucl Chem 12 315 1960] treated a pet ether solution with aqueous KMnO₄ (to oxidise any phosphinous acids to phosphinic acids), then with sodium oxalate, H₂SO₄ and HCl (to remove any manganese compounds). The pet ether solution was slurried with activated alumina (to remove phosphinic acids) and recrystd from pet ether or cyclohexane at -20°. It can also be cryst from EtOH.


Purification of Inorganic and Metal-Organic Chemicals

Triphenylbismuth (bismuth triphenyl) [603-33-8] M 440.3, m 75-76°, 77-78°, 78.5°, d_4^{25} 1.6427 (melt). Dissolve in EtOH, ppte with H_2O, extract with Et_2O, dry and evaporate when the residue crystallises. It has been recrystd from EtOH and Et_2O-EtOH and is a stable compound. [J Chem Soc suppl p121 1949; Chem Ber 37 4620 1904; J Am Chem Soc 62 665 1940; UV: J Chem Phys 22 1430 1954.]

Triphenyl borane (borane triphenyl) [960-71-4] M 242.1, m 134-140°, 137°, 139-141°, 142-142.5°, 147.5-148°, 151°, b 203°/15mm. Recryst three times from Et_2O or *C_6H_6 under N_2 and dry at 130°. It can be distilled in a high vacuum at 300-350°, and has been distilled (b 195-215°) in vacuum using a bath temp of 230-330°. [J Chem Phys 22 1430 1954.1


Triphenyl phosphate [115-86-6] M 326.3, m 49.5-50°, b 245°/0.1mm. Crystd from EtOH.

Triphenylphosphine M 262.3, m 77-78°, 79°, 79-81°, 80.5°, 80-81°, b >360°(inert gas), d: 1.194, d*: 1.075 (liq), pK 2.73. Crystd from hexane, MeOH, diethyl ether, CH_2Cl_2/hexane or 95% EtOH. Dried at 65°/<1mm over CaSO_4 or P_2O_5. Chromatographed through alumina using (4:1) *benzene/CHC_1_3 as eluent. [Blau and Espenson et al. J Am Chem Soc 108 1962 1986; Buchanan et al. J Am Chem Soc 108 1537 1986; Randolph and Wrighton J Am Chem Soc 108 3366 1986; Asali et al. J Am Chem Soc 109 5386 1987. It has also been crystd twice from pet ether and 5 times from Et_2O-EtOH to give m 80.5°. Alternatively, dissolve in conc HCl, and upon dilution with H_2O it separates because it is weakly basic; it is then crystallised from EtOH-Et_2O. It recrystallises unchanged from AcOH.

Triphenylphosphine dibromide [1034-39-5] M 422.1, m 235°, 245-255°(dec). Recrystd from MeCN-Et_2O. Although it has been recrystd from EtOH, this is not recommended as it converts alcohols to alkyl bromides. It deteriorates on keeping and it is best to prepare it afresh. [Anderson and Freenor J Am Chem Soc 86 5037 1964; Horner et al. Justus Liebigs Ann Chem 626 26 1959.]

Triphenylphosphine oxide [791-28-6] M 278.3, m 152°, pK_{EtOH} ~ -2.10 (aq H_2SO_4). Crystd from absolute EtOH. Dried in vacuo.

Triphenyl phosphite [101-02-0] M 310.3, b 181-189°/1mm, d 1.183. Its ethereal soln was washed successively with aqueous 5% NaOH, distilled water and saturated aqueous NaCl, then dried with Na_2SO_4 and distilled under vacuum after evaporating the diethyl ether.

Triphenylphosphorilidene acetaldehyde (formylmethylenetriphenylphosphorane) [2136-75-6] M 304.3, m 185-187°, 186-187°(dec). Recryst from Me_2CO, or dissolve in *C_6H_6, wash with NaOH, dry (MgSO_4), evap, and cryst residue from Me_2CO. It can be prepd from its precursor, formylmethyltriphenylphosphonium chloride (cryst from CHCl_3/EtOAc), by tratment with Et_3N and extraction with *C_6H_6. [Trippett and Walker Chem Soc 1266 1961.]

Triphenylsilanol (hydroxytriphenylsilane) [791-31-1] M 276.4, m 150-153°, 151-153°, 154-155°, 156°. It can be purified by dissolving in pet ether, passing through an Al₂O₃ column, eluting thoroughly with CCl₄ to remove impurities and then eluting the silanol with MeOH. Evaporation gives crystals m 153-155°. It can be recrystallised from pet ether, CCl₄ or from benzene or Et₂O-pet ether (1:1). It has also been recrystallised by partial freezing from the melt to constant melting point. [J Am Chem Soc 81 3288 1959; IR: J Org Chem 17 1555 1952 and J Chem Soc 124 1949.]

Triphenyltin chloride (chlorotriphenylstannane) [639-58-7] M 385.5, m 103-106° (dec), 105° (dec), b 240°/13.5 mm. Purify by distillation, followed by recrystn from MeOH by adding pet ether (b 30-60°), m 105-106° [Chem Ber 67 1348 1934], or by crystn from Et₂O [Krause Chem Ber 51 914 1918]. It sublimes in a vacuum. HIGHLY TOXIC.

Triphenyltin hydroxide [76-87-9] M 367.0, m 122-123.5°, 124-126°. West, Baney and Powell [J Am Chem Soc 82 6269 1960] purified a sample which was grossly contaminated with tetraphenyltin and diphenyltin oxide by dissolving it in EtOH, most of the impurities remaining behind as an insoluble residue. Evaporation of the EtOH gave the crude hydroxide which was converted to triphenyltin chloride by grinding in a mortar under 12M HCl, then evaporating the acid soln. The chloride, after crystallisation from EtOH, had m 104-105°. It was dissolved in Et₂O and converted to the hydroxide by stirring with excess aqueous ammonia. The ether layer was separated, dried, and evaporated to give triphenyltin hydroxide which, after crystn from EtOH and drying under vacuum, was in the form of white crystals (m 119-120°), which retained some cloudiness in the melt above 120°. The hydroxide retains water (0.1-0.5 moles of water per mole) tenaciously.

Triphenyl vinyl silane [18668-68-7] M 286.5, m 58-59°, 57-59°, 67-68°, b 190-210°/3 mm. It has been recrystallised from EtOH, 95% EtOH, EtOH-CH₆, pet ether (b 30-60°) and Et₂O, and has been distilled under reduced pressure. [J Am Chem Soc 74 4582 1952; J Org Chem 17 1379 1952.]

Tri-n-propyl borate [688-71-1] M 188.1, b 175-177°, d 0.857, n 1.395. Dried with sodium and then distilled.

Triquinol-8-yl phosphate [52429-99-9] M 479.4, m 193-197°, 202-203°. Purified by recrystn from dimethylformamide. Purity was checked by paper chromatography, RF 0.90 [i-PrOH, saturated (NH₄)₂SO₄, H₂O; 2:79:19 as eluent]; IR (KBr) v 1620-1570 (C=C, C=N) and 1253 (Pa). [Bull Chem Soc Jpn 47 779 1974.]


Tri-n-butyl phosphite [132-28-5] M 554.6, m 115.5-117.5°. Crystd from MeOH containing a little acetone.

Tris(1,2-dioxyphenyl)cyclotriphosphazine (trispiro[1,3,5,2,4,6-triazatriphosphorine]-2,2'-:2,2':6,6'-tris(1,3,2)benzodioxaphosphole) [311-03-5] M 459.0, m 244-245°, 245°, 245-246°. Recrystd from C₆H₆ or chlorobenzene, then triple sublimed (175°/0.1 mm, 200°/0.1 mm, 230°/0.05 mm). UV has λmax (log ε): 276 (3.72), 271 (3.79) 266sh (3.68) and 209 (4.38) in MeCN. IR (v): 1270 (0-Ph), 1220 (P=N), 835 (P-O-Ph) and 745 (Ph) cm⁻¹. [Alcock J Am Chem Soc 86 2591 1964; Meirovitch J Phys Chem 88 1522 1984.]

(±)-Tris-(2-ethylhexyl)phosphate (TEHP, tri-isooctylphosphate, "trioctyl" phosphate, [78-42-2; 25103-23-5] M 434.6, b 186°/1 mm, 219°/5 mm, d²⁵ 0.92042, n 1.44464. TEHP, in an equal volume of diethyl ether, was shaken with aqueous 5% HCl and the organic phase was filtered to remove
traces of pyridine (used as a solvent during manufacture) as its hydrochloride. This layer was shaken through a fine sintered-glass disc (with exclusion of moisture), and distill under vacuum. [French and Muggleton J Chem Soc 5064 1957].

*Benzene can be used as a solvent (to give 0.4M soln) instead of ether. IR: 1702, 1701, 481 and 478cm⁻¹ [Bellamy and Becker J Chem Soc 475 1952]. The uranyl nitrate salt was purified by partial crystallisation from hexane [Siddall J Am Chem Soc 81 4176 1959].

**Trisodium citrate (2H₂O)** [68-04-2] M 294.1, m 150° (loses H₂O). Crystd from warm water by cooling to 0°.

**Trisodium 8-hydroxy-1,3,6-pyrenetrisulfonate** [6358-69-6] M 488.8, m >300 (dec). Purified by chromatography with an alumina column, and eluted with n-propanol-water (3:1, v/v). Recrystd from aqueous acetone (5:95, v/v) using decolorising charcoal.

**Trisodium 1,3,6-naphthalenetrisulfonate** [5182-30-9] M 434.2. The free acid was obtained by passage through an ion-exchange column and converted to the lanthanum salt by treatment with La₂O₃. This salt was crystallised twice from hot water. [The much lower solubility of La₂(SO₄)₃ and its retrograde temperature dependence allows a good separation from sulfate impurity]. The lanthanum salt was then passed through an appropriate ion-exchange column to obtain the free acid, the sodium or potassium salt. (The sodium salt is hygroscopic). [Atkinson, Yokoi and Hallada J Am Chem Soc 83 1570 1961]. Also recrystd from aqueous acetone [Okahata et al. J Am Chem Soc 108 2863 1986].

**Trisodium orthophosphate (12H₂O)** [10010-89-0] M 380.1, pK₂¹ 2.15, pK₂² 5.721, pK₂³ 12.33 (for H₃PO₄). Crystd from warm dilute aqueous NaOH (1mL/g) by cooling to 0°.

**Tris(2,4-pentandionate)aluminium** [13963-57-0] M 324.3. See aluminium acetylacetonate on p. 390.

**Tris-(trimethylsilyl)silane (TTMSS)** [1873-77-4] M 248.7, b 73°/5mm, d 0.808, n 1.49. Purified by fractional distillation and taking the middle cut. Store under N₂ or Ar as it is an IRRITANT and PYROPHORIC. [Chatgilialoglu Acc Chem Res 25 188 1992; NMR: Gilman et al. J Organomet Chem 4 163 1965.]


**Tri-p-tolyl phosphate** [20756-92-7; 1330-78-5 (isomeric tritolyl phosphate mixture)] M 368.4, b 232-234°, d²⁵ 1.16484, n 1.56703. Dried with CaCl₂, then distill under vacuum and percolated through a column of alumina. Passage through a packed column at 150°, with a counter-current stream of nitrogen, under reduced pressure, removed residual traces of volatile impurities.


**Tungsten (rod)** [7440-33-7] M 183.6. m 341°, b 590°, d 19.0°. Cleaned with conc NaOH solution, rubbed with very fine emery paper until its surface was bright, washed with previously boiled and cooled conductivity water and dried with filter paper.


**Tungsten (VI) trichloride** [13283-01-7] M 396.6, m 265° (dec), 275°, b 346°, d²⁵ 3.520, pK₂¹ 2.20, pK₂² 3.70 (for tungstic acid, H₂WO₄). Sublimed in a stream of Cl₂ in a high temperature furnace and collected in a receiver cooled in a Dry Ice-acetone bath in an inert atmosphere because it is sensitive to moisture. It is soluble in CS₂, CCl₄, CHCl₃, POCl₃, C₆H₆, pet ether and Me₂CO. Solns decompose on
standing. Good crystals can be obtained by heating WCl₆ in CCl₄ to 100° in a sealed tube, followed by slow cooling (tablets of four-sided prisms). Store in a desiccator over H₂SO₄ in the dark. [Inorg Synth 3 163 1950, 9 1331967; Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol II 1417 1965.]

**Uranium hexafluoride** [7783-81-5] M 352.0, b 0°/17.4mm, 56.2°/765mm, m 64.8°, pK₂5 1.68 (for hydrolysis of U⁴⁺ to UOH³⁺). Purified by fractional distillation to remove HF. Also purified by low temperature trap-to-trap distillation over pre-dried NaF [Anderson and Winfield J Chem Soc, Dalton Trans 337 1986].

**Uranium trioxide** [1344-58-7] M 286.0, d 7.29. The oxide was dissolved in HClO₄ (to give a uranium content of 5%), and the solution was adjusted to pH 2 by addition of dilute ammonia. Dropwise addition of 30% H₂O₂, with rapid stirring, ppted U(VI) peroxide, the pH being held constant during the pptn, by addition of small amounts of the ammonia soln. (The H₂O₂ was added until further quantities caused no change in pH.) After stirring for 1h, the slurry was filtered through coarse filter paper in a Büchner funnel, washed with 1% H₂O₂ acidified to pH 2 with HClO₄, then heated at 350° for three days in a large platinum dish [Baes J Phys Chem 60 878 1956].

**Uranil nitrate (6H₂O)** [13520-83-7] M 502.1, m 60.2°, b 118°, pK₂5 5.82 (for aquo UO₂²⁺). Crystd from water by cooling to -50°, taking only the middle fraction of the solid which separated. Dried as the hexahydrate over 35-40% H₂SO₄ in a vacuum desiccator.

**Vanadium (metal)** [7440-62-2] M 50.9, m 1910°, d 6.0. Cleaned by rapid exposure consecutively to HNO₃, HCl, HF, de-ionised water and reagent grade acetone, then dried in a vacuum desiccator.

**Vanadium (III) acetylacetonate** [13476-99-8] M 348.3, m 181-184°, 185-190°, pK⁺5 2.92, pK⁻5 3.5 (for aquo V⁵⁺ hydrolysis). Crystd from acetylacetone as brown plates. It can be distilled in small quantities without decomposition. It is soluble in CHCl₃ and C₆H₆ and evaporation of a CHCl₃ solution yields brown crystals which are washed with cold EtOH and dried in vacuum or at 100° in a CO₂ atmosphere. Under moist conditions it readily oxidises [V(ACAc)₃ to V(ACAc)₂O]. [J Chem Soc 10378 1913, Inorg Synth 5 105 1957; Anal Chem 30 526 1958; UV: J Am Chem Soc 80 5686 1958.]


**Vanadyl trichloride (VOC1₃)** [7727-18-6] M 173.3, m 79.5°, b 124.5-125.5°/744mm, 127.16°/760mm, d⁰ 1.854, d³² 1.811. Should be lemon yellow in colour. If red it may contain VCl₄ and Cl₂. Fractionally distil and then redistil over metallic Na but be careful to leave some residue because the residue can become EXPLOSIVE in the presence of the metal USE A SAFETY SHIELD and avoid contact with moisture. It readily hydrolyses to vanadic acid and HCl. Store in a tightly closed container or in sealed ampoules under N₂. [Inorg Synth 1 106 1939, 4 80 1953.]

**Vinyl chlorosilane** [75-94-5] M 161.5, b 17.7°/46.3mm, 82.9°/599.4mm, 92°/742mm, 91-91.5°/atm, d⁰ 1.2717, n⁰ 1.435. Fractionally distil at atmospheric pressure. It is H₂O sensitive and is stored in the dark and is likely to polymerise. [Chem Ber 91 1805 1958, 92 1012 1959; Anal Chem 24 1827 1952]

**Vinylferrocene (ferroceneylethene)** [1271-51-8] M 212.1, m 51-52.5°, b 80-85°/0.2mm. Dissolve in Et₂O, wash with H₂O and brine, dry (Na₂SO₄), evap to a small vol. Purify through an Al₂O₃ (Spence grade H) column by eluting the yellow band with pet ether (b 40-60°). The low melting orange crystals which can be sublimed. The tetracyanoethylene adduct [49716-63-4] crystallises from *C₆H₆-pentane and has m 137-
Purification of Inorganic and Metal-Organic Chemicals

Vinyltributylstannane (vinyltributyltin) \([7486-35-3]\) M 317.1, b 104-106°/3.5mm, d 1.081, n 1.4751. Fractionate under reduced pressure and taking the middle fraction to remove impurities such as \((n-\text{Bu})_n\text{Cl}\). [Seyferth and Stone \textit{J Am Chem Soc} 79 515 1957.1

Water \([7732-18-5]\) M 18.0, m 0°, b 100°, pK\textsubscript{25} 14.00. Conductivity water (specific conductance \(ca\ 10^{-7}\) mho) can be obtained by distilling water in a steam-heated (tin-lined still, then, after adding 0.25% of solid NaOH and 0.05% of KMnO\textsubscript{4}, distilling once more from an electrically heated Barnstead-type still, taking the middle fraction into a Jena glass bottle. During these operations suitable traps must be used to protect against entry of CO\textsubscript{2} and NH\textsubscript{3}. Water only a little less satisfactory for conductivity measurements (but containing traces of organic material) can be obtained by passing ordinary distilled water through a mixed bed ion-exchange column containing, for example, Amberlite resins IR 120 (cation exchange) and IRA 400 (anion exchange), or Amberlite MB-1. This treatment is also a convenient one for removing traces of heavy metals. (The metals Cu, Zn, Pb, Cd and Hg can be tested for by adding pure concentrated ammonia to 10mL of sample and shaking vigorously with 1.2mL 0.001% dithizone in CCl\textsubscript{4}. Less than 0.1µg of metal ion will impart a faint colour to the CCl\textsubscript{4} layer.) For almost all laboratory purposes, simple distillation yields water of adequate purity, and most of the volatile contaminants such as ammonia and CO\textsubscript{2} are removed if the first fraction of distillate is discarded.

Xylenol Orange (sodium salt) \([3618-43-7]\). See entry on p. 387 in Chapter 4.

Zinc (dust) \([7440-66-6]\) M 65.4. Commercial zinc dust (1.2Kg) was stirred with 2% HCl (3L) for 1min, (then the acid was removed by filtration), and washed in a 4L beaker with a 3L portion of 2% HCl, three 1L portions of distilled water, two 2L portions of 95% EtOH, and finally with 2L of absolute Et\textsubscript{2}O. (The wash solutions were removed each time by filtration.) The material was then dried thoroughly and if necessary, any lumps were broken up in a mortar.

Zinc (metal) \([7440-66-6]\) M 65.4, m 420°, d 7.141. Fused under vacuum, cooled, then washed with acid to remove the oxide.

Zinc acetate \((\text{CH}_3\text{O})\) \([5970-45-6]\) M 219.5, m 100°(loses 2H\textsubscript{2}O), 237°, d 1.74, pK\textsubscript{25} 8.96 (for hydrolysis of Zn\textsuperscript{2+} to ZnOH\textsuperscript{+}). Crystd (in poor yield) from hot water or, better, from EtOH.

Zinc acetylacetate \([14024-63-6]\) M 263.6, m 138°. Crystd from hot 95% EtOH.

Zinc bromide \([7699-45-8]\) M 225.2, m 384, b 697. Heated to 300° under vacuum (2 x 10\textsuperscript{-2}mm) for 1h, then sublimed.

Zinc caprylate \([557-09-5]\) M 351.8. Crystd from EtOH.

Zinc chloride \([7646-85-7]\) M 136.3, m 283°, 290°. The anhydrous material can be sublimed under a stream of dry HCl, followed by heating to 400° in a stream of dry N\textsubscript{2}. Also purified by refluxing (50g) in dioxiane (400mL) with 5g zinc dust, filtering hot and cooling to ppte ZnCl\textsubscript{2}. Crystd from dioxiane and stored in a desiccator over P\textsubscript{2}O\textsubscript{5}. It has also been dried by refluxing in thionyl chloride. [Weberg et al. \textit{J Am Chem Soc} 108 6242 1986.] Hygroscopic: minimal exposure to the atmosphere is necessary.
Zinc cyanide [557-21-1] M 117.4, m 800°(dec), d 1.852. It is a POISONOUS white powder which becomes black on standing if Mg(OH)₂ and carbonate are not removed in the preparation. Thus wash well with H₂O, then well with EtOH, Et₂O and dry in air at 50°. Analyse by titrating the cyanide with standard AgNO₃. Other likely impurities are ZnCl₂, MgCl₂ and traces of basic zinc cyanide; the first two salts can be washed out. It is soluble in aq KCN solns. However, if purified in this way Zn(CN)₂ is not reactive in the Gattermann synthesis. For this the salt should contain at least 0.33 mols of KCl or NaCl which will allow the reaction to proceed faster. [J Am Chem Soc 45 2375 1923, 60 1699 1938; Org Synth Vol III 549 1955.]

Zinc diethylidithiocarbamate [14324-55-1] M 561.7, pK₂ 3.04 (for Et₂NCS₂⁻). Crystd several times from hot toluene or from hot CHCl₃ by addition of EtOH.

Zinc dimethylidithiocarbamate [137-30-4] M 305.8, m 248-250°, pK₂ 3.36 (for Me₂NCS₂⁻). Crystd several times from hot toluene or from hot CHCl₃ by addition of EtOH.

Zinc ethylenebis[dithiocarbamate] [I 21 22-67-7] M 249.7. Crystd several times from hot toluene or from hot CHCl₃ by addition of EtOH.

Zinc fluoride [7783-49-5] M 103.4, m 872°, b 1500°, d 5.00. Possible impurity is H₂O which can be removed by heating at 100° or by heating to 800° in a dry atmosphere. Heating in the presence of NH₄F produces larger crystals. It is sparingly sol in H₂O (1SLg/lOOmL) but more sol in HCl, HNO₃ and NH₄OH. It can be stored in glass bottles. [Handbook of Preparative Inorganic Chemistry (Ed. Brauer) Vol I 242 1963.]

Zinc formate (2H₂O) [557-41-5] M 191.4, m 140°(loses H₂O), d 2.21. Crystd from water (3mL/g).

Zinc iodide [IO139-47-6] M 319.2, m 446, b 624°(dec), d 4.74. Heated to 300° under vacuum (2 x 10⁻²mm) for 1h, then sublimed.

Zinc RS-lactate (3H₂O) [554-05-2; 16039-53-5 (L)] M 297.5. Crystd from water (6mL/g).

Zincon (o-[1-(2-hydroxy-5-sulfo)-3-phenyl-5-formazono]-benzoic acid) [135-52-4] M 459.4. Main impurities are inorganic salts which can be removed by treatment with dilute acetic acid. Organic contaminants are removed by refluxing with ether. It can be recrystd from dilute H₂SO₄. [Fichter and Schiess Chem Ber 33 751 1900.]

Zincon disodium salt (o-[1-(2-hydroxy-5-sulfo)-3-phenyl-5-formazono]-benzoic acid di-Na salt) [135-52-4; 56484-13-0] M 484.4, m ~250-260°(dec). Zincon salt is prepared by dissolving 0.13g of the powder in aqueous NaOH (2mL diluted to 100mL with H₂O). This gives a deep red colour which is stable for one week. It is a good reagent for zinc ions but also forms stable complexes with transition metal ions. [UV-VIS: Bush and Yoe Anal Chem 26 1345 1954; Hunter and Roberts J Chem Soc 820 1941; Platte and Marcy Anal Chem 31 1226 1959] The free acid has been recrystd from dilute H₂SO₄. [Fichter and Scheiss Chem Ber 33 751 1900.]

Zinc perchlorate (6H₂O) [13637-61-1] M 372.4, m 105-107°, pK₂ -2.4 to -3.1 (for HClO₄). Crystd from water.

Zinc phenol-o-sulfonate (8H₂O) [127-82-2] M 555.8. Crystd from warm water by cooling to 0°.


Zinc sulfate (7H₂O) [7446-20-0] M 287.5, m 100°(dec), 280°(loses all 7H₂O), >500(anhyd), d 1.97. Crystd from aqueous EtOH.
Zinc 5,10,15,20-tetraphenylporphyrin [14074-80-7] M 678.1, $\lambda_{\text{max}}$ 418(556)nm. Purified by chromatography on neutral (Grade I) alumina, followed by recrystallisation from CH$_2$Cl$_2$/MeOH [Yamashita et al. J Phys Chem 91 3055 1987].

Zinc trifluoromethanesulfonate [54010-75-2] M 363.5, m >300°. It should be dried at 125° for 2h at 3mm. It is soluble in CH$_2$Cl$_2$ but insoluble in pet ether. [Tetrahedron Lett 24 169 1983.]

Zirconium (IV) propoxide [23519-77-9] M 327.6, b 198°/0.03mm, 208°/0.1mm, d$^2_4$ 1.06, n$_D$ 1.454. Although it was stated that it could not be crystallised or sublimed even at 150°/10^{-4}mm [J Chem Soc 280 1951], the propoxide has, when properly prepared, been purified by distn in a high vacuum [J Chem Soc 2025 1953].

Zirconium tetrachloride [10026-11-6] M 233.0, m 300°(sublimes), pK$^a$ = 0.32, pK$^b$ = 0.06, pK$^c$ = 0.35, pK$^d$ = 0.46 (for hydrolysis of aquo Zr+4). Crystd repeatedly from conc HCl.

Zirconocene dichloride (bis[cyclopentadienyl]zirconium dichloride) [1291 -32-3] M 292.3, m 242-245°, 248°. Purified by recrystn from CHCl$_3$ or xylene, and dried in vacuum. $^1$H NMR (CDCl$_3$) $\delta$: 6.52 from Me$_2$Si. Store in the dark under N$_2$ as it is moisture sensitive. [IR, NMR, MS: Aust J Chem 18 173 1965; method of J Am Chem Soc 81 1364 1959; and references in the previous entry.]

Zirconyl chloride (6H$_2$O) [7699-43-6] M 286.2, m 150°(loses 6H$_2$O). Crystd repeatedly from 8M HCl as ZrOCl$_2$.8H$_2$O. On drying ZrOCl$_2$.6H$_2$O m 150°. The product was not free from hafnium.

Zirconyl chloride (8H$_2$O) [113520-92-8] M 322.3, m 150°(loses 6H$_2$O), 210°(loses all H$_2$O), 400°(anhydr dec), d 1.91. Recryst several times from water [Ferragina et al. J Chem Soc, Dalton Trans 265 1986]. Recrystn from 8M HCl gives the octahydrate as white needles on concentrating. It is also formed by hydrolysing ZrCl$_4$ with water. After one recryst from H$_2$O, 99+% grade had Ag, Al, As, Cd, Cu, Hf, Mg, Na, Sc and V at 20, 1.8, 0.6, 0.6, 0.4, 8.4, 0.4, 2.4, 80 and 3 ppm resp.
Biochemicals are chemical substances produced by living organisms. They range widely in size, from simple molecules such as formic acid and glucose to macromolecules such as proteins and nucleic acids. Their \textit{in vitro} synthesis is often impossibly difficult and in such cases they are available (if at all) only as commercial tissue extracts which have been subjected to purification procedures of widely varying stringency. The desired chemical may be, initially, only a minor constituent of the source tissue which may vary considerably in its composition and complexity. Recent advances in molecular biology have made it possible to produce substantial amounts of biological materials, which are present in nature in extremely small amounts, by recombinant DNA technology and expression in bacteria, yeast, insect and mammalian cells. The genes for these substances can be engineered such that the gene products, e.g. polypeptides or proteins, can be readily obtained in very high states of purity. However, many such products which are still obtained from the original natural sources are available commercially and may require further purification.

As a preliminary step the tissue might be separated into phases [e.g. whole egg into white and yolk, blood into plasma (or serum) and red cells], and the desired phase may be homogenised. Subsequent treatment usually comprises filtration, solvent extraction, salt fractionation, ultracentrifugation, chromatographic purification, gel filtration and dialysis. Fractional precipitation with ammonium sulfate gives crude protein species. Purification is finally judged by the formation of a single band of macromolecule (e.g. protein) on electrophoresis and/or analytical ultracentrifugation. Although these generally provide good evidence of high purity, none-the-less it does not follow that one band under one set of experimental conditions is an absolute indication of homogeneity.

During the past 20 or 30 years a wide range of methods for purifying substances of biological origin have become available. For small molecules (including many sugars and amino acids) reference should be made to Chapters 1 and 2. The more important methods used for large molecules, polypeptides and proteins in particular, comprise:

1. \textit{Centrifugation}. In addition to centrifugation for sedimenting proteins after ammonium sulfate precipitation in dilute aqueous buffer, this technique has been used for fractionation of large molecules in a denser medium or a medium of varying density. By layering sugar solutions of increasing densities in a centrifuge tube, proteins can be separated in a sugar-density gradient by centrifugation. Smaller DNA molecules (e.g. plasmid DNA) can be separated from RNA or nuclear DNA by centrifugation in aqueous cesium chloride (ca 0.975g/mL of buffer) for a long time (e.g. 40h at 40,000 x g). The plasmid DNA band appears at about the middle of the centrifuge tube, and is revealed by the fluorescent pink band formed by the binding of DNA to ethidium bromide which is added to the CsCl buffer. \textit{Microfuges} are routinely used for centrifugation in Eppendorf tubes (1.2-2mL) and can run up to speeds of 12,000 x g. \textit{Analytical centrifugation}, which is performed under specific conditions in an analytical ultracentrifuge is very useful for determining purity, aggregation of protein subunits and the molecular weight of macromolecules. [D.Rickwood, T.C.Ford and J.Steensgaard \textit{Centrifugation: Essential Data Series}, J Wiley & Sons, NY, 1994].

2. \textit{Gel filtration} with polyacrylamide (mol wt exclusion limit from 3000 to 300,000) and agarose gel (mol wt exclusion limit 0.5 to 150 x 10^6) is useful for separating macromolecules. In this technique high-molecular weight substances are too large to fit into the gel microapertures and pass rapidly through the matrix (with the void volume), whereas low molecular weight species enter these apertures and are held there for longer periods of time, being retarded by the column material in the equilibria, relative to the larger molecules. This method is also used for desalting solutions of macromolecules. \textit{Dry gels} and \textit{crushed beads} are also
3. Ion exchange matrices are microreticular polymers containing carboxylic acid (e.g. Bio-Rad 70) or phosphoric acid (Pharmacia, Amersham Biosciences, Mono-P) exchange functional groups for weak acidic cation exchangers, sulfonic acid groups (Dowex 50W) for strong acidic cation exchangers, diethylaminoethyl (DEAE) groups for weakly basic anion exchangers and quaternary ammonium (QAE) groups for strong anion exchangers. The old cellulose matrices for ion exchanges have been replaced by Sephadex, Sepharose or Fractogel which have more even particle sizes with faster and more reproducible flow rates. Some can be obtained in fine, medium or coarse grades depending on particle size. These have been used extensively for the fractionation of peptides, proteins and enzymes. The use of pH buffers controls the strength with which the large molecules are bound to the support in the chromatographic process. Careful standardisation of experimental conditions and similarly the very uniform size distribution of Mono beads has led to high resolution in the purification of protein solutions. MonoQ (Pharmacia, Amersham Biosciences) is a useful strong anion exchanger, and MonoS (Pharmacia, Amersham Biosciences) is a useful strong cation exchanger whereas MonoP is a weak cation exchanger. These have been successful with medium pressure column chromatography (FPLC, see below in 8). Chelex 100 binds strongly and removes metal ions from macromolecules. [See also Chapter 1, pp. 22-24.]

4. Hydroxylapatite is used for the later stages of purification of enzymes. It consists essentially of hydrated calcium phosphate which has been precipitated in a specific manner. It combines the characteristics of gel and ionic chromatography. Crystalline hydroxylapatite is a structurally organised, highly polar material which, in aqueous solution (in buffers) strongly adsorbs macromolecules such as proteins and nucleic acids, permitting their separation by virtue of the interaction with charged phosphate groups and calcium ions, as well as by physical adsorption. The procedure therefore is not entirely ion-exchange in nature. Chromatographic separations of singly and doubly stranded DNA are readily achievable whereas there is negligible adsorption of low molecular weight species.

5. Affinity chromatography is a chromatographic technique whereby the adsorbant has a particular and specific affinity for one of the components of the mixture to be purified. For example the adsorbant can be prepared by chemically binding an inhibitor of a specific enzyme (which is present in the crude complex mixture) to a matrix (e.g. Sepharose). When the mixture of impure enzyme is passed through the column containing the adsorbant, only the specific enzyme binds to the column. After adequate washing, the pure enzyme can be released from the column by either increasing the salt concentration (e.g. NaCl) in the eluting buffer or adding the inhibitor to the eluting buffer. The salt or inhibitor can then be removed by dialysis, gel filtration (above) or ultrafiltration (see below). [See W.H.Scouten, Affinity Chromatography: Bioselective Adsorption on Inert Matrices, J.Wiley & Sons, NY, 1981, ISBN 0471026492; H.Schott, Affinity Chromatography: Tempipia Chromatography of Nucleic Acids and Proteins, Marcel Dekker, NY, 1984, ISBN 0824771117; P.Matejtschuk ed. Affinity Separations Oxford University Press 1997 ISBN 0199635501 (paperback); M.A.Vijayakulshmi, Biochromatography, Theory and Practice, Taylor & Francis Publ, 2002, ISBN 0415269032; and Chapter 1, p. 25.]

6. In the isoelectric focusing of large charged molecules on polyacrylamide or agarose gels, slabs of these are prepared in buffer mixtures (e.g. ampholines) which have various pH ranges. When a voltage is applied for some time the buffers arrange themselves on the slabs in respective areas according to their pH ranges (prefocusing). Then the macromolecules are applied near the middle of the slab and allowed to migrate in the electric field until they reach the pH area similar to their isoelectric points and focus at that position. This technique can also be used in a chromatographic mode, chromatofocusing, whereby a gel in a column is run (also under HPLC conditions) in the presence of ampholines (narrow or wide pH ranges as required) and the macromolecules are then run through in a buffer. Capillary electrophoresis systems in which a current is applied to set the gradient are now available in which the columns are fine capillaries and are used for qualitative and quantitative purposes [See R.Kuhn and S.Hoffstetter-Kuhn, Capillary Electrophoresis: Principles and Practice, Springer-Verlag Inc, NY, 1993; P.Camilleri ed. Capillary Electrophoresis - Theory and Practice, CRC Press, Boca Raton, Florida, 1993; D.R.Baker, Capillary Electrophoresis, J Wiley & Sons, NY, 1995; P.G.Righetti, A.Stoyanov and M.Zhukov, The Proteome Revisited, Isoelectric Focusing: J.Chromatography Library Vol 63 2001, Elsevier, ISBN 0444505261.] The bands are eluted according to their isoelectric points. Isoelectric focusing standards are available which can be used in a preliminary run in order to calibrate the effluent from the column, or alternatively the pH of the effluent is recorded using a glass electrode designed for the purpose. Several efficient commercially available apparatus are available for separating proteins on a preparative and semi-preparative scale.

7. High performance liquid chromatography (HPLC) is liquid chromatography in which the eluting liquid is sent through the column containing the packing (materials as in 2-6 above, which can withstand higher than atmospheric pressures) under pressure. On a routine basis this has been found useful for purifying

8. Ultrafiltration using a filter (e.g. Millipore) can remove water and low-molecular weight substances without the application of heat. Filters with a variety of molecular weight exclusion limits not only allow the concentration of a particular macromolecule to be determined, but also the removal (by washing during filtration) of smaller molecular weight contaminants (e.g. salts, inhibitors or cofactors). This procedure has been useful for changing the buffer in which the macromolecule is present (e.g. from Tris-Cl to ammonium carbonate), and for desalting. Ultrafiltration can be carried out in a stirrer cell (Amicon) in which the buffer containing the macromolecule (particularly protein) is pressed through the filter, with stirring, under argon or nitrogen pressure (e.g. 20-60psi). During this filtration process the buffer can be changed. This is rapid (e.g. 2L of solution can be concentrated to a few mLs in 1 to 2h depending on pressure and filter). A similar application uses a filter in a specially designed tube (Centricon tubes, Amicon) and the filtration occurs under centrifugal force in a centrifuge (4-6000rpm at 0°/40min). The macromolecule (usually DNA) then rests on the filter and can be washed on the filter by centrifugation. The macromolecule is recovered by inverting the filter, placing a conical receiver tube on the same side where the macromolecule rests, filling the other side of the filter tube with eluting solution (usually a very small volume e.g. 100 µL), and during further centrifugation this solution passes through the filter and collects the macromolecule from the underside into the conical receiver tube.

9. Partial precipitation of a protein in solution can often be achieved by controlled addition of a strong salt solution, e.g ammonium sulfate. This is commonly the first step in the purification process. Its simplicity is offset by possible denaturation of the desired protein and the (sometimes gross) contamination with other proteins. It should therefore be carried out by careful addition of small aliquots of the powdered salt or concentrated solution (below 40, with gentle stirring) and allowing the salt to be evenly distributed in the solution before adding another small aliquot. Under carefully controlled conditions and using almost pure protein it is sometimes possible to obtain the protein in crystalline form suitable for X-ray analysis (see below).

10. Dialysis. This is a process by which small molecules, e.g. ammonium sulfate, sodium chloride, are removed from a solution containing the protein or DNA using a membrane which is porous to small molecules. The solution (e.g. 10mL) is placed in a dialysis bag or tube tied at both ends, and stirred in a large excess of dialysing solution (e.g. 1.5 to 2 L), usually a weak buffer at ca 40. The dialysing buffer is replaced with fresh buffer several times, e.g. four times in 24h. This procedure is similar to ultrafiltration (above) and allows the replacement of buffer in which the protein, or DNA, is dissolved. It is also possible to concentrate the solutions by placing the dialysis tube or bag in Sephadex G25 which allows the passage of water and salts from the inside of the bag thus concentrating the protein (or DNA) solution. Dialysis tubing is available from various distributors but "Spectra/por" tubing (from Spectrum Medical Industries, Inc, LA) is particularly effective because it retains macromolecules and allows small molecules to dialyse out very rapidly thus reducing dialysing time considerably. This procedure is used when the buffer has to be changed so as to be compatible with the next purification or storage step, e.g. when the protein (or DNA) needs to be stored frozen in a particular buffer for extended periods.


12. Crystallisation. The ultimate in purification of proteins or nucleic acids is crystallisation. This involves very specialised procedures and techniques and is best left to the experts in the field of X-ray crystallography who provide a complete picture of the structure of these large molecules. [A. Ducruix and R. Giege eds, Crystallisation of Nucleic Acids and Proteins: A Practical Approach, 2nd Edition, 2000,
Other details of the above will be found in Chapters 1 and 2 which also contain relevant references.

Several illustrations of the usefulness of the above methods are given in the Methods Enzymol series (Academic Press) in which 1000-fold purifications or more, have been readily achieved. In applying these sensitive methods to macromolecules, reagent purity is essential. It is disconcerting, therefore, to find that some commercial samples of the widely used affinity chromatography ligand Cibacron Blue F3GA contained this dye only as a minor constituent. The major component appeared to be the dichlorotriazinyl precursor of this dye. Commercial samples of Procion Blue and Procion Blue MX-R were also highly heterogeneous [Hanggi and Cadd Anal Biochem 149 91 1985]. Variations in composition of sample dyes can well account for differences in results reported by different workers. The purity of substances of biological origin should therefore be checked by one or more of the methods given above. Water of high purity should be used in all operations. Double glass distilled water or water purified by a MilliQ filtration system (see Chapter 2) is most satisfactory.

**Brief general procedures for the purification of polypeptides and proteins.** Polypeptides of up to ca 1-2000 (10-20 amino acid residues) are best purified by reverse phase HPLC. The desired fractions that are collected are either precipitated from solution with EtOH or lyophilised. The purity can be checked by HPLC and identified by microsequencing (1-30 picomoles) to ascertain that the correct polypeptide was in hand. Polypeptides larger than these are sometimes classified as proteins, and are purified by one or more of the procedures described above. The purification of enzymes and functional proteins which can be identified by specific interactions is generally easier to follow because enzyme activities or specific protein interactions can be checked (by assaying) after each purification step. The commonly used procedures for purifying soluble proteins involve the isolation of an aqueous extract from homogenised tissues or extracts from ruptured cells from microorganisms or specifically cultured cells, for example, by sonication, freeze shocking or passage through a small orifice under pressure. Contaminating nucleic acids are removed by precipitation with a basic protein, e.g. protamine sulfate. The soluble supernatant is then subjected to fractionation with increasing concentrations of ammonium sulfate. The required fractions are then further purified by the procedures described in sections 2-9 above. If an affinity adsorbant has been identified then affinity chromatography can provide an almost pure protein in one step sometimes even from the crude extract. The rule of thumb is that a solution with a protein concentration of 1mg/mL has an absorbance $A_{1cm}$ at 280nm of 1.0 units. Membrane-bound proteins are usually insoluble in water or dilute aqueous buffer and are obtained from the insoluble fractions, e.g. the microsomal fractions from the >100,000 x g ultracentrifugation supernatant. These are solubilised in appropriate detergents, e.g. Mega-10 (nonionic), Triton X-100 (ionic) detergents, and purified by methods 2 to 8 (previous section) in the presence of detergent in the buffer used. They are assayed also in the presence of detergent or membrane lipids.

The purity of proteins is best checked by *polyacrylamide gel electrophoresis* (PAGE). The gels are either made or purchased as pre-cast gels and can be with uniform or gradient gel composition. Proteins are applied onto the gels via wells set into the gels or by means of a comb, and travel along the gel surface by means of the current applied to the gel. When the buffer used contains sodium dodecysulfate (SDS) the proteins are denatured and the denatured proteins (e.g. as protein subunits) separate on the gels mainly according to their molecular sizes. These can be identified by running marker proteins, with a range of molecular weights, simultaneously on a track alongside the proteins under study. The protein bands are visualised by fixing the gel (20% acetic acid) and staining with Coomassie blue followed by silver staining if higher sensitivity is required. An Amersham- Pharmacia "Phast Gel Electrophoresis" apparatus is very useful for rapid analysis of proteins. It uses small pre-cast polyacrylamide gels (two gels can be run simultaneously) with various uniform or gradient polyacrylamide concentrations as well as gels for isoelectric focusing. The gels are usually run for 0.5-1h and can be stained and developed (1-1.5h) in the same apparatus. The equipment can be used to electrobloct the protein bands onto a membrane from which the proteins can be isolated and sequenced or subjected to antibody or other identification procedures. It should be noted that all purification procedures are almost always carried out at ca 4°C in order to avoid denaturation or inactivation of the protein being investigated. Anyone contemplating the purification of a protein is referred to: Professor R.K.Scopes's monograph *Protein Purification*, 3rd edn, Springer-Verlag, New York, 1982; A.McPherson, *Crystallisation of Biological Macromolecules*, Cold Spring Harbour Laboratory Press, 2001 ISBN 0879696176.]
Purification of Biochemicals and Related Products


Brief general procedures for purifying DNA. Oligo-deoxyribonucleotides (up to ca 60-mers) are conveniently purified by HPLC (e.g. using a Bio-Rad MA7Q anion exchange column and a Rainin Instrument Co, Madison, Dynamax-300A C₄ matrix column) and used for a variety of molecular biology experiments. Plasmid and chromosomal DNA can be isolated by centrifugation in caesium chloride buffer (see section 1. centrifugation above), and then re-precipitated with 70% ethanol at -70°C (18h), collected by centrifugation (microfuge) and dried in air before dissolving in TE (10mM TrisHC1, 1mM EDTA pH 8.0). The DNA is identified on an Agarose gel slab (0.5 to 1.0% DNA grade in 45mM Tris-borate + 1mM EDTA or 40mM Tris-acetate + 1mM EDTA pH 8.0 buffers) containing ethidium bromide which binds to the DNA and under UV light causes it be visualised as pink fluorescent bands. Marker DNA (from λ phage DNA cut with the restriction enzymes Hind III and/or EcoRI ) are in a parallel track in order to estimate the size of the unknown DNA. The DNA can be isolated from their band on the gel by transfer onto a nitro-acetate paper (e.g. NA 45) electrophoretically, by binding to silica or an ion exchange resin, extracted from these adsorbents and precipitated with ethanol. The DNA pellet is then dissolved in TE buffer and its concentration determined. A solution of duplex DNA (or RNA) of 50µg/mL gives an absorbance of 1.0units at 260nm/1cm cuvette (single stranded DNA or RNA gives a value of 1.3 absorbance units). DNA obtained in this way is suitable for molecular cloning. For experimental details on the isolation, purification and manipulation of DNA and RNA the reader is referred to J.Sambrook, E.F.Fritsch and T.Maniatis, Molecular Cloning - A Laboratory Manual, 2nd edn, (3 volumes), Cold Spring Harbor Laboratory Press, NY, 1989, ISBN 0879693096 (paperback); P.D.Darbre, Basic Molecular Biology: Essential Techniques, J.Wiley and Sons, 1998, ISBN 0471977055; J.Sambrook and D.W.Russell, Molecular Cloning - A Laboratory Manual, 3rd edn, 3rd edn, (3 volumes), Cold Spring Harbor Laboratory Press, NY, 2001, ISBN 0079695777 (paperback), ISBN 0079695765 (cloth bound), also available on line: M.A.Vijayalakshmi, Biochromatography, Theory and Practice, Taylot & Francis Publ, 2002, ISBN 0415269032; A.Travers and M.Buckle, DNA-Protein Interactions: A Practical Approach, Oxford University Press, 2000, ISBN 0199636915 (paperback); R.Rapley and D.L.Manning eds RNA: Isoaltion and Characterisation Protocols, Humana Press 1998 ISBN 086034941; R.Rapley, The Nucleic Acid Protocols Handbook, Humana Press 2000 ISBN 0896038416 (paperback).

This chapter lists some representative examples of biochemicals and their origins, a brief indication of key techniques used in their purification, and literature references where further details may be found. Simpler low molecular weight compounds, particularly those that may have been prepared by chemical syntheses, e.g. acetic acid, glycine, will be found in Chapter 4. Only a small number of enzymes and proteins are included because of space limitations. The purification of some of the ones that have been included has been described only briefly. The reader is referred to comprehensive texts such as the Methods Enzymol (Academic Press) series which currently runs to more than 344 volumes and on enzymes will be found in Advances in Protein Chemistry (59 volumes, Academic Press) and on enzymes will be found in Advances in Enzymology (72 volumes, then became Advances in Enzymology and Related Area of Molecular Biology, J Wiley & Sons). The Annual Review of Biochemistry (Annual Review Inc. Patlo Alto California) also is an excellent source of key references to the up-to-date information on known and new natural compounds, from small molecules, e.g. enzyme cofactors to proteins and nucleic acids.
**Abbreviations** of titles of periodical are defined as in the Chemical Abstracts Service Source Index (CASSI).

**Ionisation constants** of ionisable compounds are given as \( pK \) values (published from the literature) and refer to the \( pK_a \) values at room temperature (\(-15^\circ\text{C} \text{ to } 25^\circ\text{C} \)). The values at other temperatures are given as superscripts, e.g. \( pK_{25} \) for \( 25^\circ\text{C} \). Estimated values are entered as \( pK_{\text{est}} \) (see Chapter 1, p 6 for further information).

**Benzene,** which has been used as a solvent successfully and extensively in the past for reactions and purification by chromatography and crystallisation is now considered a very dangerous substance so it has to be used with extreme care. We emphasise that an alternative solvent to benzene (e.g. toluene, toluene-petroleum ether, or a petroleum ether to name a few) should be used first. However, if benzene has to be used then all operations have to be performed in a well ventilated fume hood and precautions taken to avoid inhalation and contact with skin and eyes. Whenever benzene is mentioned in the text and asterisk e.g. *\( \text{C}_6\text{H}_6 \) or *\( \text{benzene} \), is inserted to remind the user that special precaution should be adopted.

**Amino acids, carbohydrates** and **steroids** not found below are in Chapter 4 (see also CAS Registry Numbers Index and General Index).


**Acetoacetyl coenzyme A trisodium salt trihydrate** [102029-52-7] \( M 955.6, pK_1 4.0 \) (\( \text{NH}_2 \)), \( pK_2 6.4 \) (\( \text{PO}_4^- \)). The pH of solution (0.05g/mL \( \text{H}_2\text{O} \)) is adjusted to 5 with 2N NaOH. This solution can be stored frozen for several weeks. Further purification can be carried out on a DEAE-cellulose formate column, then through a Dowex 50 (\( \text{H}^+ \)) column to remove Na ions, concentrated by lyophilisation and redissolved in \( \text{H}_2\text{O} \). Available as a soln of 0.05g/mL of \( \text{H}_2\text{O} \). The concn of acetoacetyl coenzyme A is determined by the method of Stern et al. *J Biol Chem* 221 15 1956. It is stable at pH 7-7.5 for several hours at 0°C (half life ca 1-2h). At room temperature it is hydrolysed in ca 1-2h at pH 7-7.5. At pH 1.0/20°C it is more stable than at neutrality. It is stable at pH 2-3/-17°C for at least 6 months. [J Biol Chem 159 1961 1964; 242 3468 1967; Clikenbeard et al. *J Biol Chem* 250 3108 1975; *J Am Chem Soc* 75 2520 1953; 81 1265 1959; see Simon and Shemin *J Am Chem Soc* 75 2520 1953; Salem et al. *Biochem J* 258 563 1989.]

**Acetobromo-\( \alpha \)-D-galactose** [3068-32-4] \( M 411.2, m 87^\circ, [\alpha]_{546}^\circ +255^\circ, [\alpha]_D^\circ +210^\circ \) (c 3, \( \text{CHCl}_3 \)). Purified as for the glucose analogue (see next entry). If the compound melts lower than 87°C or is highly coloured then dissolve in \( \text{CHCl}_3 \) (ca 3 vols) and extract with \( \text{H}_2\text{O} \) (2 vols), 5% aqueous NaHCO\(_3\), and again with \( \text{H}_2\text{O} \) and dry over \( \text{Na}_2\text{SO}_4 \). Filter and evaporate in a vacuum. The partially crystalline solid or syrup is dissolved in dry Et\(_2\text{O}\) (must be very dry) and recryst from Et\(_2\text{O}\)-pentane. Alternatively dissolve in diisopropyl ether (dried over CaCl\(_2\) for 24h, then over P\(_2\text{O}_5\) for 24h) by shaking and warming (for as short a period as possible), filter warm. Cool to ca 45°C then slowly to room temperature and finally at 5°C for more than 2 hours. Collect the solid, wash with cold dry diisopropyl ether and dry in a vacuum over Ca(OH)\(_2\) and NaOH. Store dry in a desiccator in the dark. Solutions can be stabilised with 2% CaCO\(_3\). [Redemann and Niemann *Organ Synth* 65 236 1987, Coll Vol III 11 1955.]

**Acetoin dehydrogenase** [from beef liver; acetoacet NAD oxidoreductase] [9028-49-3] \( M_r 76000, [\text{EC} 1.1.1.5] \). Purified via the acetone cake then Ca-phosphate gel filtration (unabsorbed), lyophilised and then fractionated through a DEAE-22 cellulose column. The \( \text{Km} \) for diacetyl in 40μM and for
NADH it is 100μM in phosphate buffer at pH 6.1. [Burgos and Martin Biochim Biophys Acta 268 261 1972; 289 13 1972.]

-19.9° (c 1, Me2CO), -36° (c 1, Dioxane), -33.5° (CHCl3), pKest ~ 4.7. It is purified by recryst from Me2CO, Et2O-pentane, or AcOH, and dried in a vacuum oven (105°/20mm) and sublimed at high vacuum. [Staunton and Eisenbram Org Synth 42 4 1962; Steiger and Reichstein Helv Chim Acta 20 1404 1937.]


Acetylcholine bromide [66-23-9] M 226.1, m 143°, 146°. Hygroscopic solid but less than the hydrochloroide salt. It cryst from EtOH as prisms. Some hydrolysis occurs in boiling EtOH particularly if it contains some H2O. It can also be recryst from EtOH or MeOH by adding dry Et2O. [Acta Chem Scand 12 1492, 1497, 1502 1958.]

Acetylcholine chloride [60-31-1] M 181.7, m 148-150°, 151°. It is very sol in H2O (> 10%), and is very hygroscopic. If pasty, dry in a vacuum desiccator over H2SO4 until a solid residue is obtained. Dissolve in abs EtOH, filter and add dry Et2O and the hydrochloride separates. Collect by filtration and store under very dry conditions. [J Am Chem Soc 52 310 1930.] The chloroplatinate crystallises from hot H2O in yellow needles and can be recryst from 50% EtOH, m 242-244° [Biochem J 23 1069 1929], other m given is 256-257°. The perchlorate crystallises from EtOH as prisms m 116-117°. [J Am Pharm Assocn 36 272 1947.]

N4-Acetylcytosine [14631-20-0] M 153.1, m >300°, 326-328°, pKest(1) ~1.7, pKest(2) ~10.0. If TLC or paper chromatography show that it contains unacetylated cytosine then reflux in Ac2O for 4h, cool at 3-4° for a few days, collect the crystals, wash with cold H2O, then EtOH and dry at 100°. It is insoluble in EtOH and difficulty soluble in H2O but crystallises in prisms from hot H2O. It is hydrolysed by 80% aq AcOH at 100°/1h. [Am Chem J 29 500 1933; UV: J Chem Soc 2384 1956; J Am Chem Soc 80 5164 1958.] It forms an Hg salt differing in absorbance from that of guanosine. [J Am Chem Soc 79 5060 1957.]

β-D-N-Acetylglucosaminidase [from M sexta insects] [9012-33-3] M 17, ~61,000, [EC 3.2.1.52]. Purified by chromatography on DEAD-Biogel, hydroxylapatite chromatography and gel filtration through Sephacryl S200. Two isoforms: a hexosaminidase E1 with Km 177μM (Vmax 328 sec⁻¹) and E11 a

β-D-N-Acetylhexosaminidase A and B (from human placenta) [9012-33-3] M 17, ~61,000, [EC 3.2.1.52]. Purified by Sephadex G-200 filtration and DEAE-cellulose column chromatography. Hexosaminidase A was further purified by DEAE-cellulose column chromatography, followed by an ECTEOLA-cellulose column, Sephadex-200 filtration, electrofocusing and Sephadex G-200 filtration. Hexosaminidase B was purified by a CM-cellulose column, electrofocusing and Sephadex G-200 filtration. [Srivastava et al. J Biol Chem 249 2034 1974.]

N-Acetyl-D-lactosamine [2-acetamino-O-β-D-lactopyranosyl-2-deoxy-D-glucose] [32181-59-2] M 383.4, m 169-171°, 170-171°, [α]D18 +51.5°→ +28.8° (in 3h, c 1, H2O). Purified by recrystn from MeOH (with 1 mol of MeOH) or from H2O. It is available as a soln of 0.5g /mL of H2O. [Zilliken J Biol Chem 271 181 1955.]

O-Acetyl-β-methylcholine chloride [Methacholine chloride, Amechol, Provocholine, 2-acetoxypropyl-ammonium chloride] [62-51-1] M 195.7, m 170-173°, 172-173°. It forms white hygroscopic needles from Et2O and is soluble in H2O, EtOH and CHCl3. It decomposes readily in alkaline solns and slowly in H2O. It should be handled and stored in a dry atmosphere. The bromide is less
N-Acetyl muramic acid [NAMA, R-2-(acetylamino)-3-O-(1-carboxyethyl)-2-deoxy-D-glucose] $\{10597-89-4\}$ M 292.3, m $-125^\circ$ (dec), $[\alpha]_D^{25} +41.2^\circ$ (c 1.5, H$_2$O, after 24h), $pK_{est}$ $\sim 3.6$. See muramic acid below.

N-Acetyl neuraminic acid (NANA, O-Sialic acid, 5-acetamido-3,5-dideoxy-D-glycero-D-glacto-2-nonulosonic acid, lactaminic acid) $\{131-48-6\}$ M 309.3, m 159$^\circ$ (dec), 181-183$^\circ$ (dec), $[\alpha]_D^{25} -33^\circ$ (c 2, H$_2$O, after 24h), $pK_{est}$ 2.6. A Dowex-1x8 (200-400 mesh) in the formate form was used, and was prepd by washing with 0.1M NaOH, then 2N sodium formate, excess formate was removed by washing with H$_2$O. N-Acetyl neuraminic acid in H$_2$O is applied to this column, washed with H$_2$O, then eluted with 2N formic acid at a flow rate of 1mL/min. Fractions (20mL) were collected and tested (Bial’s orcinol reagent, cfBiochem Prep 7 1 1959). NANA eluted at formic acid molarity of 0.38 and the Bial positive fractions are collected and lyophilised. The residue is recrystd from aqueous AcOH: Suspend 1.35g of residue in AcOH, heat rapidly to boiling, add H$_2$O dropwise until the suspension dissolves (do not add excess H$_2$O, filter hot and then keep at $+5^\circ$ for several hours until crystn is complete. Collect and dry in a vacuum over P$_2$O$_5$. Alternatively dissolve 1.35g of NANA in 14mL of H$_2$O, filter, add 16OmL of MeOH followed by 36hL of Et$_2$O. Then add pet ether (b 40-60$^\circ$) until heavy turbidity. Cool at 20$^\circ$ overnight. Yield of NANA is ca 1.3g. Dry over P$_2$O$_5$ at lmm vacuum and 100$^\circ$ to constant weight. It mutarotates in Me$_2$SO: $[\alpha]$ io $-1$ 150 (after 7min) to $-32^\circ$ (after 24h). It is available as aqueous soln (0.0lg/mL). [IR and synthesis: Cornforth et al. Biochem J 68 57 1958; Zillikin and O'Brien Biochem Prep 7 1 1960; $^{13}$C NMR and $^{1-13}$C synthesis: Nguyen, Perry J Org Chem 43 551 1978; Danishevski, DeNinno J Org Chem 51 2615 1986; Gottschalk, The Chemistry and Biology of Sialic Acids and Related Substances. Cambridge University Press, London, 1960.]

N-Acetyl neuraminic acid aldolase [from Clostridium perfringens, N-acetylneuraminic acid pyruvate lyase] $\{9027-60-5\}$ M$_r$ 32,000 [EC 4.1.3.3]. Purified by extraction with H$_2$O, protamine pptn, (NH$_4$)$_2$SO$_4$ pptn, Me$_2$CO pptn, acid treatment at pH 5.7 and pptn at pH 4.5. The equilibrium constant for pyruvate $+$ n-acetyl-D-mannosamine $\rightleftharpoons$ N-acetylneuraminidate at 37$^\circ$ is 0.64. The Km for N-acetylneuraminic acid is 3.9mM in phosphate at pH 7.2 and 37$^\circ$. [Comb and Roseman Methods Enzymol 5 391 1962. The enzyme from Hogg kidney (cortex) has been purified 1700 fold by extraction with H$_2$O, protamine sulfate pptn, (NH$_4$)$_2$SO$_4$ pptn, heating between 60-80$^\circ$, a second (NH$_4$)$_2$SO$_4$ pptn and starch gel electrophoresis. The Km for N-acetylneuraminic acid is 1.5mM. [Brunetti et al. J Biol Chem 237 2447 1962.]

N-Acetyl penicillamine [D- 15537-71-0, DL-59-53-0] M 191.3, m 183$^\circ$, 186-187$^\circ$ (DL-form), 189-190$^\circ$ (D-form), $[\alpha]_D^{25} +18^\circ$ (c 1, 50% EtOH), $pK_{est}(1)$-3.0 (CO$_2$H), $pK_{est}(2)$- 8.0 (SH). Both forms are recrystd from hot H$_2$O. A pure sample of the D-form was obtained after five recrystns. [Crooks in The Chemistry of Penicillin Clarke, Johnson and Robinson eds, Princeton University Press, 470 1949.]

p-Acetylphenyl sulfate potassium salt, $\{38533-41-4\}$ M 254.3, m dec on heating, $pK_{est}$ $\sim 2.1$. Purified by dissolving in the minimum vol of hot water (60$^\circ$) and adding EtOH, with stirring, then left at 0$^\circ$ for 1h. Crystals were filtred off and recrystd from H$_2$O until free of Cl$^-$ and SO$_4^{2-}$ ions. Dried in a vac over P$_2$O$_5$ at room temperature. It is a specific substrate for arylsulfatases which hydrolyse it to p-acetylphenol [Amax 327nm (c 21700 M$^{-1}$cm$^{-1}$)] [Milsom et al. Biochem J 128 331 1972.]

S-Acetylthiocholine bromide $\{25025-59-6\}$ M 242.2, m 217-223$^\circ$ (dec). It is a hygroscopic solid which can be recrystd from ligroin-EtOH (1:1), dried and kept in a vacuum desiccator. Crystn from C$_6$H$_5$-EtOH gave m 227$^\circ$ or from propan-1-ol the m was 213$^\circ$. [Acta Chem Scand 11 537 1957, 12 1481 1958.]

S-Acetylthiocholine chloride $\{6050-81-3\}$ M 197.7, m 172-173$^\circ$ The chloride can be purified in the same way as the bromide, and it can be prepared from the iodide. A few milligrams dissolved in H$_2$O can be purified by applying onto a Dowex-1 Cl$^-$ resin column (prepared with washing with N HCl followed by CO$_2^-$—free distilled H$_2$O and
3mL fractions are collected and their OD at 229nm measured. The fractions with appreciable absorption are pooled and lyophilised at 0-5°C. Note that at higher temps decomposition of the ester is appreciable; hydrolysis is appreciable at pH >10.5/20°. The residue is dried in vacuo over P₂O₅, checked for traces of iodine (conc H₂SO₄ and heat, violet vapours are released), and recrystd from propan-1-ol. [Clin Chim Acta 2 316 1957.]

S-Acetylthiocholine iodide [1866-15-5] M 289.2, m 203-204°, 204°, 204-205°. Recrystd from propan-1-ol (or iso-PrOH, or EtOH/Et₂O) until almost colourless and dried in a vacuum desiccator over P₂O₅. Solubility in H₂O is 1% w/v. A 0.075M (21.7mg/mL) solution in 0.1M phosphate buffer pH 8.0 is stable for 10-15 days if kept refrigerated. Store away from light. It is available as a 1% soln in H₂O.

Actinomycin D (Dactinomycin) [50-76-0] M ~1255. A commercial mixture of Actinomycin C₁ ~5%, C₂ ~30% and C₃ ~65%. Actinomycin C₁ (native) crystallizes from EtOAc as red crystals, is sol in CHCl₃, *C₆H₆ and Me₂CO and has m 246-247°(dec), [α]D₀ = +328° (0.22, MeOH) and λmax 443nm (ε 25,000) and 240nm (ε 34,000). Actinomycin C₂ (native) crystallizes as red needles from EtOAc and has m 244-246°(dec), [α]D₀ = -325° (0.2, MeOH), λmax 443nm (ε 25,300) and (ε 33,400). Actinomycin C₃ (native) recryst from cyclohexane, or *C₆H₆/MeOH/cyclohexane as red needles m 238-241°(dec), [α]D₀ = +321° (0.2, MeOH), λmax 443nm (ε 25,000) and 240nm (ε 33,300). [Brockman and Lackner, Chem Ber 101 1312 1968.] It is light sensitive.

Actinomycin A Synthase [from beef liver] [9013-18-7] Mᵣ 57,000, [EC 6.2.1.2]. Purified by extraction with sucrose-HCO₃ buffer, protamine sulfate pptn, (NH₄)₂SO₄ (66-65%) pptn at pH 4.35 and a second (NH₄)₂SO₄ (35-60%) pptn at pH 4.35. It has Km 0.15mM (Vᵢ 1.0) for octanoate; 0.41mM (Vᵢ 2.37) for heptanoate and 1.59mM (Vᵢ 0.63). Km for ATP is 0.5mM all at pH 9.0 in ethylene glycol buffer at 38°. [Jencks et al. J Biol Chem 204 453 1953; Methods Enzymol 5 467 1962.]

Adenosine-5'-diphosphate [adenosine-5'-pyrophosphate, ADP] [58-64-0] M 427.2, [α]D₀²⁺ = -25.7° (c 2, H₂O), pKᵢ²⁺ = 2 (PO₄H), pKᵢ²⁻ = 2 (PO₄H), pKᵢ³⁺ = 3.95 (NH₂), pKᵢ₅⁺ = 6.26 (PO₄H). Characterised by conversion to the acridine salt by addition of alcoholic acridine (1.1g in 50mL), filtering off the yellow salt and recrystallising from H₂O. The salt has m 215°(dec), λmax 259nm (ε 15,400) in H₂O. [Baddiley and Todd J Chem Soc 648 1947, 582 1949, cf LePage Biochem Prep 1 1 1949; Martell and Schwarzenbach Helv Chim Acta 39 653 1956.]

Adenosine-3'-monophosphoric acid hydrate [3'-adenylic acid, 3'-AMP] [84-21-9] M 347.3, m 197°(dec, as 2H₂O), 210°(dec), m 210°(dec), [α]₀ = -50° (c 0.5, 0.5M Na₂HPO₄), pKᵢ²⁺ = 3.65, pKᵢ₅⁺ = 6.05. It crystallises from large volumes of H₂O in needles as the monohydrate, but is not very soluble in boiling H₂O. Under acidic conditions it forms an equilibrium mixture of 2' and 3' adenyllyc acids via the 2',3'-cyclic phosphate. When heated with 20% HCl it gives a quantitative yield of furfural after 3hours, unlike 5'-adenylic acid which only gives traces of furfural. The yellow monoacrididine salt has m 175°(dec) and

Adenosine-5'-monophosphoric acid monohydrate [5'-adenylic acid, 5'-AMP] [18422-05-4] M 365.2, m 178°, 196-200°, 200° (sintering at 181°), [α]D +87.5°, [α]1546 -55° (c 2, in 2% NaOH), -26.0° (c 2, 10% HCl), -38° (c 1, 0.5M Na2HPO4), pK12 3.89, pK2 6.14, pK3 13.1. It has been recrystallized from H2O (fine needles) and is freely soluble in boiling H2O. Crystals also from H2O by addition of acetic acid. Purified by chromatography on Dowex 1 (in formate form), eluting with 0.25M formic acid. It was then adsorbed onto charcoal (which had been boiled for 15 min with M HCl, washed free of chloride and dried at 100°), and recovered by stirring three times with isooctyl alcohol-M20 (1:9 vlv). The aqueous layer from the combined extracts was evaporated to dryness under reduced pressure, and the product was crystallized twice from hot H2O. [Morrison and Doherty Biochem J 79 433 1961]. It has λmax 259nm (± 15,400) in H2O at pH 7.0. [Albert et al. J Biol Chem 193 425 1951; Martell and Schwarzenbach Helv Chim Acta 39 653 1956]. The acridinium salt has m 208° [Baddiley and Todd J Chem Soc 648 1947; Pettit Synthetic Nucleotides, van Nostrand-Reinhold, NY, Vol 1 252 1972; NMR: Sarma et al. J Am Chem Soc 96 7337 1974; Norton et al. J Am Chem Soc 98 1007 1976; IR of diNa salt: Miles Biochem Biophys Acta 27 324 1958].


Adenosine 5"-([α-thio]monophosphate di-lithium salt [19341-57-2] M 375.2. Purified as for the diNa salt [Murray and Atkinson Biochemistry 7 4023 1968]. Dissolve 0.3g in dry MeOH (7mL) and M Li1 (6mL) in dry Me2CO containing 1% of mercaptoethanol and the Li salt is ppted by adding Me2CO (75mL). The residue is washed with Me2CO (4 x 30mL) and dried at 55°/25mm. [Baddiley and Jameison J Biochem 1959; Baddiley and Todd J Chem Soc 648 1947; Pettit Synthetic Nucleotides, van Nostrand-Reinhold, NY, Vol 1 252 1972; NMR: Sarma et al. J Am Chem Soc 96 7337 1974; Norton et al. J Am Chem Soc 98 1007 1976; IR of diNa salt: Miles Biochem Biophys Acta 27 324 1958].

Adenosine-5'-triphosphate (ATP) [56-65-5] M 507.2, [α]1546 -35.5° (c 1, 0.5M Na2HPO4), pK1 7.00, pK2 6.48. Ppted as its barium salt when excess barium acetate soln was added to a 5% soln of ATP in water. After filtering off, the ppte was washed with distilled water, dissolved redissolved in 0.2M HNO3 and again filtered with barium acetate. The ppte, after several washings with distilled water, was dissolved in 0.2M HNO3 and slightly more 0.2M H2SO4 than was needed to ppte all the barium as BaSO4, was added. After filtering off the BaSO4, the ATP was ppterred by addition of a large excess of 95% ethanol, filtered off, washed several times with 100% EtOH and finally with dry diethyl ether. [Kashiwagi and Rabinovitch J Phys Chem 59 498 1955.]

S-(5'-Adenosyl)-L-homosysteine [1979-92-0] M 384.4, m 202°(dec), 204°(dec), 205°-207°(dec), [α]D +93° (c 1, 0.2N HCl), [α]D +44° (c 0.1, 0.05N HCl), (pK see SAM hydrochloride below). It has been recrystallized several times from aqueous EtOH or H2O to give small prisms and has λmax 260nm in H2O. The picrate has m 170°(dec) from H2O. [Baddiley and Jameson J Chem Soc 1085 1955; de la Haba and Cantoni J Biol Chem 234 603 1959; Borchardt et al. J Org Chem 41 565 1976; NMR: Follmann et al. Eur J Biochem 47 187 1974.]

(-)-S-Adenosyl-L-methionine chloride (SAM hydrochloride) [24346-00-7] M 439.9, pK1 2.13, pK2 4.12, pK3 9.28. Purified by ion exchange on Amberlite IRC-150, and eluting with 0.1-4M HCl. [Stolowitz and Minch J Am Chem Soc 103 6015 1981.]. It has been isolated as the tri-reinneckate salt by adding 2 volumes of 1% solution of ammonium reinneckate in 2% perchloric acid. The reinneckate salt separates at once but is kept at 2° overnight. The salt is collected on a sintered glass funnel, washed with 0.5% of ammonium reinneckate, dried (all operations at 2°) and stored at 2°. To obtain adenosylmethionine, the reinneckate is dissolved in a small volume of methyl ethyl ketone and centrifuged at room temp to remove a small amount of solid. The clear dark red supernatant is extracted (in a separating funnel) with a slight excess of 0.1 N H2SO4. The aqueous phase is re-extracted with fresh methyl ethyl ketone until it is colourless. [Note that reinneckates have UV absorption at 305nm (± 15,000), and the optical density at 305nm is used to detect the presence of reinneckate ions.] Methyl ethyl ketone is removed from the aqueous layer containing adenosylmethionine sulfate, the pH is adjusted to 5.6-6.0 and extracted with two volumes of Et2O.
The sulfate is obtained by evaporating the aqueous layer in vacuo. The hydrochloride can be obtained in the same way but using HCl instead of H₂SO₄. SAM-HCl has a solubility of 10% in H₂O. The salts are stable in the cold at pH 4-6 but decompose in alkaline media. [Cantoni Biochem Prep 5 58 1957.] The purity of SAM can be determined by paper chromatography [Cantoni J Biol Chem 204 403 1953; Methods Enzymol 3 601 1957], and electrophoretic methods or enzymic analysis [Cantoni and Vignos J Biol Chem 209 647 1954].

L-Adrenaline [L-epinephrine, L-(−)-(3,4-dihydroxyphenyl)-2-methylaminoethanol] [51-43-4] M 183.2, m 210°(dec), 211-212°(dec), 215°(dec), [α]₀ ≤ 52° (c 2, 5% HCl), pK₆ 8.88, pK₉ 9.90, pK₁ 12.0. It has been recrystd from EtOH + AcOH + NH₃ [Jensen J Am Chem Soc 57 1765 1935]. It is sparingly soluble in H₂O, readily in acidic or basic solns but insoluble in aqueous NH₃, alkali carbonate solns, EtOH, CHCl₃, Et₂O or Me₂CO. It is readily oxidised in air and turns brown on exposure to light and air. Store in the dark under N₂. Its pKa values in H₂O are 8.88 and 9.90 [Lewis Br J Pharmacol Chemother 9 488 1954]. The hydrogen oxalate salt has m 191-192°(dec, evac capillary) after recryst from H₂O or EtOH [Pickholz J Chem Soc 928 1945].

Adrenolone hydrochloride [3',4'-dihydroxy-2-methylaminoacetophenone hydrochloride] [62-13-5] M 217.7, m 244-249°(dec), 248°(dec), 256°(dec), pK 5.5. It was purified by recryst from EtOH or aqueous EtOH. [Gero J Org Chem 16 1222 1951; Kindler and Peschke Arch Pharm 269 581, 603 1931.]

ADP-Ribosyl transferase (from human placenta) [9026-30-6]. Purified by making an affinity absorbent for ADP-ribosyltransferase by coupling 3-aminobenzamide to Sepharose 4B. [Burtscher et al. Anal Biochem 152 285 1986.]


Albumin (bovine and human serum) [9048-46-8 (bovine); 70024-90-7 (human)] Mᵣ -67,000 (bovine), 69 000 (human), UV: A 280nm 6.6 (bovine) and 5.3 (human) in H₂O, [α]²₀,₀,₀ -78.2° (H₂O). Purified by soln in conductivity water and passage at 2-4° through two ion-exchange columns, each containing a 2:1 mixture of anionic and cationic resins (Amberlite IR-120, H-form; Amberlite IRA-400, OH-form). This treatment removed ions and lipid impurities. Care was taken to exclude CO₂, and the soln was stored at -15°. [Möller, van Os and Overbeek Trans Faraday Soc 57 312 1961.] More complete lipid removal was achieved by lyophilising the de-ionised soln, covering the dried albumin (human serum) with a mixture of 5% glacial acetic acid (v/v) in iso-octane (previously dried with Na₂SO₄) and allowing to stand at 0° (without agitation) for upwards of 6h before decanting and discarding the extraction mixture, washing with iso-octane, re-extracting, and finally washing twice with iso-octane. The purified albumin was dried under vacuum for several days to crystallise. 35% EtOH (1 L) was then added to dilute the crystalline suspension, and the solution was stored at -10°C. [Goodman Science 125 1296 1957.]

The high EtOH recryst was as follows: To 1 Kg of Fraction V albumin paste at -5° was added 300mL of 0.4 M pH (pH 5.5) acetate buffer in 35% EtOH pre-cooled to -10° and 430 mL of 0.1 M NaOAc in 25% EtOH also at -10°. Best results were obtained by adding all of the buffer and about half of the NaOAc and stirring slowly for 1 hour. The rest of the NaOAc was added when all the lumps had disintegrated. The mixture was set aside at -5° for several days to crystallise. 35% EtOH (1 L) was then added to dilute the crystalline suspension and lower the ionic strength prior to centrifugation at -5° (yield 80%). The crystals were further dissolved in 1.5 volumes of 15% EtOH-0.02M NaCl at -5° and clarified by filtration through washed, calcined diatomaceous earth. This soln may be recryst by re-adjusting to the conditions in the first crystallisation, or it may be recryst at 22% EtOH with the aid of a very small amount of decanol (enough to give a final concn of 0.02%).
Note that crystall from lower EtOH gave better purification (i.e. by removing globulins and carbohydrates) and producing a more stable product.

The low EtOH recryst was as follows: To 1 Kg of Fraction V at -10° to -15° was added 500mL of 15% EtOH at -5°, stirred slowly until a uniform suspension was formed. 15% EtOH was added (500mL) to bring the pH (1:10 diln) to 5.3. This required 125- 150mL. Some temp rise occurs and care must be taken to keep the temp < -5°. If the albumin is incompletely dissolved a small amount of H2O was added (100mL) at a time at 0°, allowing 15min between additions. Undissolved albumin can be easily distinguished from small amounts of undissolved globulins, or as the last albumin dissolves, the appearance of the soln changes from milky white to hazy grey-green in colour. Keep the soln at -5° for 12h and filter by suspending in 15g of washed fine calcined diatomaceous earth, and thus filtering using a Büchner funnel precoated with coarser diatomaceous earth. The filtrate may require two or more similar filtrations to give a clear soln. To crystallise the filtrate add through a capillary pipette, and with careful stirring, 1/100 volume of a soln containing 10% decanol and 60% EtOH (at -10°), and seeded with the needle-type albumin crystals. After 2-3 days crystn is complete. The crystals are centrifuged off. These are suspended in 15g of washed fine calcined diatomaceous earth, and thus filtering using a Büchner funnel precoated with coarser diatomaceous earth. The filtrate contains lO% decanol and 60% EtOH (at -10°), and seeded with the needle-type albumin crystals. After 2-3 days crystn is complete. The crystals are centrifuged off. These are suspended with gentle mechanical stirring in an amount equal to 1.7 times the weight of the crystals. At this stage there is about 7% EtOH and the temp cannot be made lower than -25° to -15°. Clarify and collect as above. [Cohn et al. J Am Chem Soc 69 1753 1947.]

Human serum albumin has been purified similarly with 25% EtOH and 0.2% decanol. The isoelectric points of bovine and human serum albumins are 5.1 and 4.9.

Amethopterin (Methotrexate, 4-amino-4-deoxy-N10-methylpteroyl-L-glutamic acid) [59-05-2] M 454.4, m 185-204°(dec), [α]2°+19° (c 2, 0.1N aq NaOH), pK1 < 0.5 (pyrimidine+), pK2 2.5 (N5-Me+), pK3 3.49 (α-C02H), pK4 4.99 (γ-C02H), pK5 5.50 (pyrimidine+). Commonest impurities are 4-amino-4-deoxy-N10-methylpteroyl-L-glutamic acid, 4-amino-10-methylpteroylglutamic acid, aminopterin and pteroylglutamic acid. Purified by chromatography on Dowex-1 acetate, followed by filtration through a mixture of cellulose and charcoal. It has been recrystd from aqueous HCl or by dissolution in the H20 (also by centrifugation) and dry at 100°/3rnm. It has

α-Amino acids. All the α-amino acids 'natural' configuration [S (L), except for cysteine which is R (L)] at the α- carbon atom are available commercially in a very high state of purity. Many of the 'non-natural' α-amino acids with the [R (D)] configuration as well as racemic mixtures are also available and generally none require further purification before use unless they are of 'Technical Grade'. The R or S enantiomers are optically active except for glycine which has two hydrogen atoms on the carbon atom, but these are replaced by the pro-α-hydrogen atom of glycine with CH2OH (from formaldehyde) to make S-serine. The twenty common natural α-amino acids are: amino acid, three letter abbreviation, one letter abbreviation, pK (-COOH) and pK (-NH3+): Alanine, Ala, A, 2.34, 9.69; Arginine, Arg, R, 2.17, 9.04; Asparagine, Asn, N, 2.01, 8.80; Aspartic acid, Asp, E, 2.19, 9.60; Cysteine, Cys, C, 1.96, 8.18; Glutamine, Gin, Q, 2.17, 9.13; Glutamic acid, Glu, E, 2.19, 9.67; Glycine, Gly, G, 2.34, 9.60; Histidine, His, H, 1.8, 9.17; Isoleucine, Ile, I, 2.35, 9.68; Leucine, Leu, L, 2.36, 9.60; Lysine, Lys, K, 2.18, 8.95; Methionine, Met, M, 2.28, 9.20; Phenylalanine, Phe, F, 1.83, 9.12; Proline, Pro, P, 1.99, 10.96; Serine, Ser, S, 2.21, 9.15; Threonine, Thr, T, 2.11, 9.62; Tryptophan, Trp, W, 2.38, 9.39; Tyrosine, Tyr, Y, 2.2, 9.11; Valine, Val, V, 2.32, 9.61 respectively. Technical grade amino acids can be purified on ion exchange resins (e.g. Dowex 50W and eluting with a gradient of HCl or AcOH) and the purity is checked by TLC in two dimensions and stained with ninhydrin. [J.P.Greenstein and M.Winicz, Chemistry of the Amino Acids (3 Volumes), J.Wiley & Sons, NY, 1961; C.Cooper, N.Packer and K.Williams, Amino Acid Analysis Protocols, Humana Press, 2001, ISBN 0896036561). Recently codons for a further two amino acids have been discovered which are involved in ribosome-mediated protein synthesis giving proteins containing these amino
acids. The amino acids are (L)-selenocysteine [Stadtman Ann Rev Biochem 65 83 1996] and pyrrolysin [(4R, 5R)-4-substituted (with Me, NH2 or OH) pyrroline-5-carboxylic acid] [Krzychi and Chan et al. Science 296 1459 and 1462 2002]. They are, however, rare at present and only found in a few microorganisms.

9-Aminoacridine hydrochloride monohydrate (Acramine yellow, Monacrin) [52417-22-8] M 248.7, \( m >355^\circ \), \( \text{pK}_{1}^{10} 4.7, \text{pK}_{2}^{10} 9.99 \). Recrystd from boiling \( \text{H}_2\text{O} \) (charcoal; 1g in 300 mL) to give pale yellow crystals with a neutral reaction. It is one of the most fluorescent substances known. At 1:100 dilution in \( \text{H}_2\text{O} \) it is pale yellow with only a faint fluorescence but at 1:100,000 dilution it is colourless with an intense blue fluorescence. [Albert and Ritchie Org Synth Coll Vol III 53 1955; Falk and Thomas Pharm J 153 158 1944] See entry in Chapter 4 for the free base.

Aminopterin (4-amino-4-deoxypteroyl-L-glutamic acid) [54-62-6] M 440.4, m 231-235°(dec), \( \alpha \)D\( ^{18} \) +18° (c 2, 0.1N aq NaOH), \( \text{pK}_{1} <0.5 \) (pyrimidine\( ^{2+} \)), \( \text{pK}_{2} 2.5 \) (N5-Me\( ^{+} \)), \( \text{pK}_{3} 3.49 \) (\( \alpha\)-CO\( _{2}\text{H} \)), \( \text{pK}_{4} 4.65 \) (\( \gamma\)-CO\( _{2}\text{H} \)), \( \text{pK}_{5} 5.50 \) (pyrimidine\( ^{+} \)). Purified by recryst from \( \text{H}_2\text{O} \), and has properties similar to those of methotrexate. It has \( \lambda_{\text{ext}} 244, 290 \) and 355nm. \( \text{pK}_{1}^{10} 1.5, \text{pK}_{2}^{10} 8.0. \) Recrystd by dissolving in \( \text{H}_2\text{O} \) (1g in 3 mL), adjusting the pH to 5.5 with \( \text{aq NH}_3 \), diluting with \( \text{MeOH} \) (20 mL), stirring, adjusting the pH to 5.5 and cooling to 0°. Also recrystd from small vols of \( \text{H}_2\text{O} \). [R-isomer: Nishimura et al. Nippon Kagaku Zasshi 82 1688 1961; S-isomer: Johnson and Panetta Chim Abstr 63 14869h 1965; Johnson and Hardcastle Chim Abstr 66 10930m 1967; RS-isomer: Li Bassi et al. Gazz Chim Ital 107 253 1977.] The \( \pm \) N-acetyl derivative has \( m 191^{0} \) (from \( \text{H}_2\text{O} \)) [Schouteenten et al. Bull Soc Chim Fr II-248, II-252 1978].


\( \alpha\)-Amino-thiophene-2-acetic acid 2-(2-thienyl)glycine \( [R(+)] 65058-23-3; S(-). \) 4052-59-9; (-)-43189-45-3; \( \text{pK}_{1}^{10} 4.5-4.8; \text{pK}_{2}^{10} 5.5. \) Recryst from small vols of \( \text{H}_2\text{O} \). [R-isomer: Johnson and Panetta Chim Abstr 63 14869h 1965; Johnson and Hardcastle Chim Abstr 66 10930m 1967; RS-isomer: Li Bassi et al. Gazz Chim Ital 107 253 1977.] The \( \pm \) N-acetyl derivative has \( m 191^{0} \) (from \( \text{H}_2\text{O} \)) [Schouteenten et al. Bull Soc Chim Fr II-248, II-252 1978].

4(6)-Aminouracil (4-amino-2,6-dihydroxypyrimidine) [373-83-6] M 127.1, \( m >350^{0}, \text{pK}_{1}^{10} 0.00 \) (basic), \( \text{pK}_{2}^{10} 8.69 \) (acidic), \( \text{pK}_{3}^{10} 15.32 \) (acidic). Purified by dissolving in 3M aq NH\( _{3} \), filter hot, and add 3M formic acid until pptn is complete. Cool, filter off (or centrifuge), wash well with cold \( \text{H}_2\text{O} \), then \( \text{EtOH} \) and dry in air. Dry further in a vac at ~80°. [Barlin and Pfeiderer J Chem Soc B (1947)]

Amylose [9005-82-7] (C\( _{6}\)H\( _{10}\)O\( _{5} \))\( _{n} \) (for use in iodine complex formation). Amylopectin was removed from impure amylose by dispersing in aqueous 15% pyridine at 80-90° (conen 0.6-0.7%) and leaving the soln stand at 44-45° for 7 days. The pptn was re-dispersed and recrystd during this temperature for 12hours, then cooled.
to 25° and left for a further 10 hours. The combined ppte was dispersed in warm water, pted with EtOH, washed with absolute EtOH, and vacuum dried [Foster and Paschal J Am Chem Soc 75 1181 1953].


**Anion exchange resins.** Should be conditioned before use by successive washing with water, EtOH and water, and taken through two OH—H+—OH+ cycles by successive treatment with N NaOH, water, N HCl, water and N NaOH, then washed with water until neutral to give the OH- form. (See commercial catalogues on ion exchange resins).

**β-Apo-4'-carotenal** [12676-20-9] M 414.7, m 139°, A 1% ε 2640 at 461nm Recrystd from CHCl₃/EtOH mixture or n-hexane. [Bobrowski and Das J Org Chem 91 12 1987]


**Apocodeine** [641-36-1] M 281.3, m 124°, pKₐ 7.0, pKₐ 8.2. Crystd from MeOH and dried at 80°/2mm.

**Apomorphine** [58-00-4] M 267.3, m 195°(dec), pKₐ 7.20 (NH₃), pKₐ 8.91 (phenolic OH). Crystd from CHCl₃ and pet ether, also from Et₂O with 1 mol of Et₂O which it loses at 100°. It is white but turns green in moist air or in alkaline soln. NARCOTIC

**Apomorphine hydrochloride** [41372-20-7] M 312.8, m 285-287°(dec), [α]D 48° (~ 1 H₂O). Cryst from H₂O and EtOH. Crystals turn green on exposure to light. NARCOTIC

**Aureomycin** (7-chlorotetracycline) [57-62-5] M 478.5, m 172-174°(dec), [α]D -275° (MeOH), pKₐ 3.3, pKₐ 7.44, pKₐ 9.27. Dehydrated by azeotropic distillation of its soln with toluene. On cooling anhydrous material crystallises out and is recrystd from CH₃H₂O, then dried under vacuum at 100° over paraffin wax. (If it is crystd from MeOH, it contains MeOH which is not removed on drying.) [Stephens et al. J Am Chem Soc 76 3568 1954; Biochem Biophys Res Commun 14 137 1964].

**Aureomycin hydrochloride** (7-chlorotetracycline hydrochloride) [64-72-2] M 514.0, m 234-236°(dec), [α]D 23.5° (H₂O). Purified by dissolving 1g rapidly in 20mL of hot water, cooling rapidly to 40°, treating with 0.1mL of 2M HCl, and chilling in an ice-bath. The process is repeated twice. Also recrystd from Me₃NCHO + Me₃CO. [Stephens et al. J Am Chem Soc 76 3568 1954 ; UV: McCormick et al. J Am Chem Soc 79 2849 1975.]

Azurin (from *Pseudomonas aeruginosa*) [12284-43-4] \( M_r 30,000 \). Material with \( \lambda_{254}/A_{280} = 0.56 \) was purified by gel chromatography on G-25 Sephadex with 5mM phosphate pH 7 buffer as eluent [Cho et al. *J Phys Chem* 91 3690 1987]. It is a blue Cu protein used in biological electron transport and its reduced form is obtained by adding a slight excess of Na$_2$S$_2$O$_4$. [See *Structure and Bonding* Springer Verlag, Berlin 23 1 1975.]

**Bacitracin (Altracin, Topitracin)** [1405-87-4] \( M 1422.7, [\alpha]_D^{25} +5^\circ \) (H$_2$O). It has been purified by carrier displacement using n-heptanol, n-octanol and n-nonanol as carriers and 50% EtOH in 0.1 N HCl. The pure material gives one spot with \( R_F = 0.56 \) on paper chromatography using AcOH:n-BuOH: H$_2$O (4:1:5). [Porath *Acta Chem Scand* 6 1237 1952] It has also been purified by ion-exchange chromatography. It is a white powder soluble in H$_2$O and EtOH but insoluble in Et$_2$O, CHCl$_3$ and Me$_2$CO. It is stable in acidic soln but unstable in base. (Abraham and Betton *Biochem J* 47 257 1950; Synthesis: Munekata et al. *Bull Chem SOC Jpn* 46 3187, 3835 1973.)

*N*-Benzyladenine [1214-39-7] \( M 225.3, m 231-232^\circ, 232.5^\circ \) (dec). \( pK_{Ea}(1) = 4.2, pK_{Ea}(2) = 10.1 \). Purified by recrystn from aqueous EtOH. It has \( h_{max} \) at 207 and 270nm (H$_2$O), 268 nm (pH 6), 274nm (0.1 N HCl) and 275nm (0.1 N NaOH). [Daly *J Org Chem* 21 1553 1956; Bullock et al. *J Am Chem Soc* 78 3693 1956.]

*N*-Benzyladenosine [4294-16-0] \( M 357.4, m 177-179^\circ, 185-187^\circ, [\alpha]_D^{15} -68.6^\circ \) (c 0.6, EtOH) (see above entry for \( pK \)). Purified by recrystn from EtOH. It has \( A_{max} \) 266nm (aq EtOH-HCl) and 269 nm (aqueous EtOH-NaOH). [Kissman and Weiss *J Org Chem* 21 1053 1956.]


*R*-(*)-*N*-Benzylicchoninium chloride [69257-04-1] \( M 421.0, m 212-213^\circ \) (dec), \( [\alpha]_D^{15} +175.4^\circ, -183^\circ \) (c 5, 0.4, H$_2$O), \( pK_{Ea} = 5 \). Dissolve in minimum volume of H$_2$O and add absolute Me$_2$CO. Filter off and dry in a vacuum. Also recrystd from hot EtOH or EtOH-Et$_2$O. (A good chiral phase transfer catalyst - see above) [Colonna et al. *J Chem Soc Perkin Trans I* 1 547 1981, Imperali and Fisher *J Org Chem* 57 757 1992]. See chinchonidine below.

*N*-BenzyIpenicillin sodium salt [69-57-8] \( M 356.37, m 215^\circ \) (charring and dec), 225° (dec), \( [\alpha]_D^{15} +269^\circ \) (c 0.7, MeOH), \( [\alpha]_D^{15} +305^\circ \) (c 1, H$_2$O), \( pK_{Ea} = 2.76 \) (4.84 in 80% aq EtOH) (for free acid). Purified by dissolving in a small volume of MeOH (in which it is more soluble than EtOH) and treating gradually with ~5 volumes of EtOAc. This gives an almost colourless crystalline solid (rosettes of clear-cut needles) and recrystallising twice more if slightly yellow in colour. The salt has also been conveniently recrystd from the minimum amount of 90% Me$_2$CO and adding an excess of absolute Me$_2$CO. A similar procedure can be used with wet n-BuOH. If yellow in colour then dissolve (~3.8g) in the minimum volume of H$_2$O (3mL), add n-BuOH and filter through a bed of charcoal. The salt forms long white needles on standing in a refrigerator overnight. More crystals can be obtained on concentrating the mother liquors in vacuo at 40°. A further recrystn (without charcoal) yields practically pure salt. A good preparation has ~600 Units/mg. The presence of H$_2$O in the solvents increases the solubility considerably. The solubility in mg/100mL at 0° is 6.0 (Me$_2$CO), 15.0 (Me$_2$CO + 0.5% H$_2$O), 31.0 (Me$_2$CO + 1.0% H$_2$O), 2.4 (methyl ethyl ketone), 81.0 (n-butanol) and 15.0 (dioxane at 14°). Alternatively it is dissolved in H$_2$O (solubility is 10%), filtered if necessary and pptd by addition of EtOH and dried in a vacuum over P$_2$O$_5$. A sample can be kept for 24h at 100° without loss of physiological activity. [IR: *Anal Chem* 19 620 1947; *The Chemistry of Penicillin* [Clarke, Johnson and Robinson eds.] Princeton University Press, Princeton NJ, Chapter V 85 1949.]

Other salts, e.g. the potassium salt can be prepared from the Na salt by dissolving it (147mg) ice-cold in H$_2$O acidified to pH 2, extracting with Et$_2$O (~50mL), wash once with H$_2$O, and extract with 2mL portions of 0.3% KHCO$_3$ until the pH of the extract rose to ~6.5 (~7 extractions). The combined aqueous extracts are
**Purification of Biochemicals and Related Products**

Lyophilised and the white residue is dissolved in n-BuOH (1mL, absolute) with the addition of enough H2O to effect soln. Remove insoluble material by centrifugation and add absolute n-BuOH and EtOAc and dried (yield 51.4mg). The potassium salt has m 214-217°C (dec) (block preincubated at 200°C; heating rate of 3°C/min) and [α]D +285° (c 0.748, H2O). The free acid has m 186-187°C (MeOH-Me2CO), 190-191°C (H2O) ([α]D +522°).

(+)-Bicuculine [R-6(5,6,7,8-tetrahydro-6-methyl-1,3-dioxolo[4,5-g]isoquinolon-5-yl)-furo[3,4-c]-1,3-benzodioxolo-8(6H)-one] 485-49-4


It is soluble in CHCl3, C6H6, EtOAc but sparingly soluble in EtOH, MeOH and Et2O.


L-erythro-Biopterin (2-amino-4-hydroxy-6-[1R,2S]-1,2-dihydroxypropyl)pteridine) 22150-76-1

M 237.2, m >300°C (dec), -65°C (c 2.0, HCl), ~K'~'2.23 (2.45), pK'i5 7.89 (8.05). Purified by chromatography on Horisil washed thoroughly with 2M HCl, and eluted with 2M HCl. The fractions with the W-fluorescent band are evapd in vacuo and the residue recrystd. Biopterin is best recrystd (90% recovery) by dissolving in 1% aq NH3 (ca 100 parts), and adding this soh dropwise to an equal vol of M aq formic acid at 100°C and allowing to cool at 4°C overnight. It is dried at 20°C to 50°C/01mm in the presence of P2O5. [Schircks, Bieri and Viscontini Helv Chim Acta 60 211 1977; Armarego, Waring and Paal Aust J Chem 35 785 1982]. Also crystd from ca 50 parts of water or 100 parts of hot 3M aq HCl by adding hot 3M aq NH3 and cooling. It has UV: h, at 212, 248 and 321nm (log E 4.21, 4.09 and 3.94) in H2O at pH 0.0; 223infl, 235.5, 274.5 and 345nm (log E 4.07inflexion, 4.10, 4.18 and 3.82) in H2O at pH 5.0; 221.5, 254.5 and 364nm (log E 3.92, 4.38 and 3.84) in H2O at pH 10.0 [Sugimoto and Matsuura Bull Chem SOC Jpn 48 3767 1975].

D-(+)-Biotin (vitamin H, hexahydro-2-oxo-1H-thieno[3,4-d]imidazole-4-pentanoic acid) 58-85-5

M 244.3, m 229-231°C, 230.2°C(dec), 230-231°C, 232-234°C(dec), [α]D+108°C, [α]D+91.3°C (c 1, 0.1N NaOH), pKw ~ 4.8. Crystd from hot water in fine long needles with a solubility of 22 mg/100mL at 25°C. Its solubility in 95% EtOH is 80 mg/100 mL at 25°C. Its isoelectric point is at pH 3.5. Store solid and solutions under sterile conditions because it is susceptible to mould growth. [Confalone J Am Chem Soc 97 5936 1975; Wolf et al. J Am Chem Soc 67 2100 1945; Synthesis: Ohuri and Emoto Tetrahedron Let 2765 1975; Harris et al. J Am Chem Soc 66 1756 1944]. The (+)-methyl ester has m 166-167°C (from MeOH-Et2O), [α]D+57°C [du Vigneaud et al. J Biol Chem 140 643, 763 1941]; the (+)-S-oxide has m 200-203°C, [α]D+130°C (c 1.2, 0.1N NaOH) [Melville J Biol Chem 208 495 1954]; the SS- dioxide has m 274-275°C(dec, 268-270°C) and the SS-dioxide methyl ester has m 239-241°C (from MeOH-Et2O) [Hofmann et al. J Biol Chem 141 207, 241 1942].

D-(+)-Biotin hydrazide [66640-86-6] M 258.4, m 238-240°C, 245-247°C, [α]D+66.6°C (c 1, Me2NCHO). Wash the material with H2O, dry, wash with MeOH then Et2O, dry, and recrystallise from hot H2O (clusters of prisms) [Hofmann et al. J Biol Chem 144 513 1942].


D-(+)-Biotin 4-nitrophenyl ester [33755-53-2] M 365.4, m 160-163°C, 163-165°C, [α]D+47°C (c 2, Me2NCHO containing 1% AcOH). It has been recryst by dissolving 2g in 95% EtOH (30mL), heated to 65°C, then cooled in an ice-water bath. The crystals are collected, washed with ice-cold 95% EtOH (5mL) and dried over P2O5. The Rf on silica plates (CHCl3:MeOH-19:1) is 0.19 [Bodanszky and Fagan J Am Chem Soc 99 235 1977].
N- (+)-Biotinyl-6-aminocaproic N-succinimidyl ester [6929-40-4] M 363.4, m 295-297°, 295-300°, [α]D +56.55° (c 0.5, 0.1N NaOH), pKcat -4.0. Dissolve in NaHCO3 soln, cool and ppte by adding N HCl. Collect the solid, dry at 100° and recrystallise from MeOH. Note that it is hydrolysed byaq 3M, 1M and 0.2M HCl at 120°, but can be stored in 5%aq NaHCO3 at -20° without appreciable hydrolysis [Knappe et al. Biochem Zeitschrift 338 599 1963; J Am Chem Soc 73 1412 1951; Bayer and Wilchek Methods Enzymol 26 1 1980]

N-Biotinyl-6-aminocaproic N-succinimidyl ester [72040-63-2] M 454.5, m 149-152°. Dissolve ~400mg in dry propan-2-ol (-25mL) with gentle heating. Reduce the volume to ~10mL by gentle boiling and allow the soln to cool. Decant the supernatant carefully from the white crystals, allow to stand overnight at 4°, filter and dry the solid in a vacuum. Recrystd from isoPrOH. RF 0.26 on Si02 (7:3 as eluent). [O'Shanessy et al. Anal Biochem 163 204 1987.]

N- (+)-Biotinyl-6-aminocaproyl hydrazide (biotin-6-aminohexanoic hydrazide) [109276-34-8] M 371.5, m 189-191°, 210°, [α]D +23° (c 1, Me2NCHO). Suspend in ice-water (100mg/mL), allow to stand overnight at 4°, filter and dry the solid in a vacuum. Recrystd from isoPrOH. Rf 0.26 on SiO2 plate using CHCl3-MeOH (7:3) as eluent. [Costello et al. Clin Chem 25 1572 1979; Kincaid et al. Methods Enzymol 159 619 1988.]

N- (+)-Biotinyl-L-lysine (Biocytin) [576-19-2] M 372.5, m 228.5°, 228-230° (dec), 241-243°, 245-252° (dec, sintering at 227°), [α]D +53° (c 1.05, 0.1 N NaOH). Recryst rapidly from dilute MeOH or Me2CO. Also recryst from H2O by slow evaporation or by dissolving in the minimum volume of H2O and adding Me2CO until solid separates. It is freely soluble in H2O and AcOH but insoluble in Me2CO. [Wolf et al. J Am Chem Soc 76 2002 1952, 72 1048 1050.] It has been purified by chromatography on superfiltrol-Celite, Al2O3 and by countercurrent distribution and then recrystd [IR: Peck et al. J Am Chem Soc 74 1991 1952]. The hydrochloride can be recrystd from aqueous Me2CO + HCl and has m 227° (dec).

2-(4-Biphenylyl)-5-phenyl-1,3,4-oxadiazole [852-38-0] M 298.4, m 166-167°, 167-170°. Recryst from toluene. It is a good scintillating material [Brown et al. Discussion Faraday Soc 27 43 1959].

2,5-Bis(4-biphenylyl)-1,3,4-oxadiazole (BBOD) [2043-06-3] M 374.5, m 229-230°, 235-236°. Recryst from heptane or toluene. It is a good scintillant. [Hayes et al. J Am Chem Soc 77 1850 1955.]

4,4-Bis(4-hydroxyphenyl)valeric acid [126-00-1] M 286.3, m 168-171°, 171-172°, pKbH1~ 4.8 (CO2H), pKe1H2~ 7.55 (OH), pKe2H2~9.0 (OH). When recryst from *C6H6 the crystals have 0.5 mol of *C6H6 (m 120-122°) and when recryst from toluene the crystals have 0.5 mol of toluene. Purified by recrystn from hot H2O. It is sol in Me2CO, AcOH, EtOH, propan-2-ol, methyl ethyl ketone. It is also recrystallised from AcOH, heptane-Et2O or Me2CO + *C6H6. It has λmax 225 and 279nm in EtOH. The methyl ester has m 87-89° (aqueous MeOH to give the trihydrate). [Bader and Kantowicz J Am Chem Soc 76 4465 1954.]

Bis(2-mercaptoethyl)sulfone (BMS) [145626-87-5] M 186.3, m 57-58°, pK1257.9, pK225 9.0. Recryst from hexane as white fluffy crystals. Large amounts are best recryst from de-oxygenated H2O (charcoal). It is a good alternative reducing agent to dithiothreitol. Its IR (film) has ν 2995, 2657, 1306, 1248, 1124 and 729 cm-1. The synthetic intermediate thiocetate has m 82-83° (white crystals from CCl4). The disulfide was purified by flash chromatography on SiO2 and elution with 50% EtOAc-hexane and recryst from hexane, m 137-139°. [Lamoureux and Whitesides J Org Chem 58 633 1993.]

Bombesin (2-L-glutamin-3-L-asparagineleutysine) [31362-50-2] M 619.9. Purified by gel filtration on a small column of Sephadex G-10 and eluted with 0.01 M AcOH. This procedure removes lower molecular weight contaminants which are retarded on the column. The procedure should be repeated twice and the material should now be homogeneous on electrophoresis, and on chromatography gives a single active spot which is negative to ninhydrin but positive to Cl2 and iodosplatinate reagents. Rf on paper chromatography (n-BuOH-pyridine-AcOH-H2O (37: 25:7:5: 30) is 0.55 for Bombesin and 0.65 for Alytin. [Bernardi Experientia B 27 872 1971; A 27 166 1971.] The hydrochloride has m 185°(dec) (from EtOH) [α]D +24° -20.6° [c 0.65, Me2NCHO-(Me2N)3PO (8:2)].

Brefeldin A \([1R\cdot 2c,15c\cdot dihydroxy\cdot 7t\cdot methyl\cdot (1r,13t)\cdot 6\cdot oxabicyclo[11.3.0]hexadeca- 3\c,11\c\cdot dien-5\c\cdot one, Decumbin\] \[20350-15-6\] M 280.4, m 200-202°, 204°, 204-205°, \([\alpha]_D^{25} +95°\) (c 0.81, MeOH). Isolated from \(Penicillium brefeldianum\) and recrystd from aqueous MeOH-EtOAc or MeOH. Solubility in \(H_2O\) is 0.6mg/mL, 10mg/mL in MeOH and 24.9mg/mL in EtOH. The \(O\cdot acetate\) recrystallises from Et_2O-pentane and has \(Brefeldin\ A\) Pharmacol. Biochem. Br. 31 1979; X-ray: Weber et al. Helv Chim Acta 54 2763 1971.]

Bromelain (anti-inflammatory Ananase from pineapple) \[37189-34-7\] M_r ~33 000, [EC 3.4.33.4]. This protease has been purified via the acetone powder, G-75 Sephadex gel filtration and Bio-Rex 70 ion-exchange chromatography and has \(\lambda_{\text{max}}^{\text{NMR}}\) 20.1 at 280nm. The protease from pineapple hydrolyses benzoyl glycine ethyl ester with a \(K_m\) (app) of 210mM and \(k_{cat}\) of 0.36 sec\(^{-1}\). [Murachi Methods Enzymol 19 273 1970; Balls et al. Ind Eng Chem 33 950 1941.]

5-Bromo-2-deoxyuridine \[59-14-3\] M 307.1, m 193-197°(dec), 217-218°, \([\alpha]_D^{25} +41°\) (c 0.1, \(H_2O\)). Recrystd from EtOH or 96% EtOH. It has \(\lambda_{\text{max}}\) 279 nm at pH 7.0, and 279 nm (log \(\varepsilon\) 3.95) at pH 1.9. Its \(R_p\) values are 0.49, 0.46 and 0.53 in \(n\)-BuOH-AcOH:H_2O (4:1:1), \(n\)-BuOH-EtOH-H_2O (40:11:19) and \(i\)-PrOH-25% aq NH_3-H_2O (7:1:1) respectively. [Nature 209 230 1966; Collect Czech Chem Comm 29 2956 1964.]

5-Bromouridine \[5975-75-5\] M 323.1, m 215-217°, 217-218°, \([\alpha]_D^{25} +4.1°\) (c 0.1, \(H_2O\)), \(pK_2^{25} 8.1\). Recrystd from 96% EtOH. UV \(\lambda_{\text{max}}\) 279nm (log \(\varepsilon\) 3.95) in \(H_2O\) pH 1.9. \(R_p\) in \(n\)-BuOH:AcOH:H_2O (4:1:1) is 0.49; in \(n\)-BuOH:EtOH:H_2O (40:11:9) is 0.46 and in isoPrOH:25% aq NH_3:H_2O (7:1:2) is 0.53 using Whatman No 1 paper. [Prystas and Sorm Collect Czech Chem Commun 29 2956 1964.]

Butyryl choline iodide \[[(2-butryloxyethyl)trimethyl ammonium iodide\] \[2494-56-6\] M 301.7, m 85-89°, 87°, 93-94°. Recrystd from isoPrOH or Et_2O. [Tammelin Acta Chem Scand 10 145 1956.] The perchlorate has m 72° (from isoPrOH). [Aldridge Biochem J 53 62 1953.]

Butyryl thiocholine iodide \[[(2-butrylmercaptoethyl)trimethyl ammonium iodide\] \[1866-16-6\] M 317.2, m 173°, 173-176°. Recrystd from propan-1-ol and dried in vacuo; store in the dark under \(N_2\). The \(bromide\) has m 150° (from MeCO) or m 140-143° (from butan-1-ol). [Gillis Chem and Ind (London) 111 1957; Hansen Acta Chem Scand 11 537 1957.]
L-Canavanine sulfate (from jackbean, O-guanidino-L-homoserine) \([2219-31-0]\) M, 274.3, m 160-165\(^{\circ}\text{C})(\text{dec}), 172^{\circ}\text{C})(\text{dec}), [\alpha]_D^{15} +19.8^{\circ} (\text{c} 7, \text{H}_2\text{O}), \text{pK}^+_2 7.40 (\text{CO}_2\text{H}), \text{pK}^-_2 9.25 (\alpha-\text{NHz}), \text{pK}^+_2 11.5 (\text{guanidino}).\) Recrystd by dissolving (-1g) in \(\text{H}_2\text{O}\) (10mL), and adding with stirring 0.5 to 1.0 vols of 95% EtOH whereby crystals separate. These are collected, washed with Me\(_2\text{CO}\) and dried over P\(_2\text{O}_5\) in a vacuum. [Hunt and Thompson Biochem Prep 13 416 1971; Feacon and Bell Biochem J 59 221 1955.]

Carbonic anhydrase (carbinate hydrolase) \([9001-03-0]\) M, 31,000 [EC 4.2.1.1]. Purified by hydroxyapatite and DEAE-cellulose chromatography [Tiselius et al. Arch Biochem Biophys 65 132 1956, Biochim Biophys Acta 39 218 1960], and is then dialysed for crystn. A 0.5 to 1% soln of the enzyme in the 0.05 M Tris-\(\text{HCl}\) pH 8.5 was dialysed against 1.75M soln of (NH\(_4\))\(_2\text{SO}_4\) in the same buffer, and this salt soln was slowly increased in salt concn by periodic removal of small amounts of dialysate and replacement with an equal volume of 3.5M (NH\(_4\))\(_2\text{SO}_4\). The final salt concn in which the DEAE-cellulose fractions which gave beautiful birefringent suspensions of crystals ranged from 2.4 to 2.7M, and appeared first as fine crystals then underwent transition to thin fragile plates. Carbonic anhydrase is a Zn enzyme which exists as several isoenzymes of varying degrees of activity [J Biol Chem 243 6474 1968; crystal structure: Nature, New Biology 235 131 1972; see also P.D. Boyer Ed. The Enzymes Academic Press NY, pp 587-665 1971.]

Carboxypeptidase A (from bovine pancreas, peptidyl-L-aminoacid lyase) \([11075-17-5]\) M, 34,600 [EC 3.4.17.1]. Purified by DEAE-cellulose chromatography, activation with trypsin and dialysed against 0.1M NaCl, yielding crystals. It is recrystd by dissolving in 20 mL of M NaCl and dialysed for 24hours each against the following salts present in 500mL of 0.02M sodium veronal pH 8.0: .05M NaCl, 0.2M NaCl and 0.15M NaCl. The last dialysate usually induces crystn. If it does not crystallise then dialyse the last soln slowly as the change of optical density at 254nm (reaction extinction coefficient is \(-0.592 \text{ cm}^2/\text{pmole} \) at pH 7.5 [Bergmyer Methods in Enzymatic Analysis (Academic Press) 1 436 1974].

Carminic acid (7-\(\alpha\)-D-glucopyranosyl-9,10-dihydro-3,5,6,8-tetrahydroxy-1-methyl-9,10-dioxo-2-anthracene carboxylic acid, Neutral Red: CI 75470) \([1260-17-9]\) M, 492.4, m 120\(^{\circ}\text{C})(\text{dec}), [\alpha]_D^{15} +51.6^{\circ} (\text{H}_2\text{O}), (\text{several phenolic pKs}).\) Forms red prisms from EtOH. It gives a red colour in \(\text{AqO}\) and yellow to violet in acidic solution. 

Carnitine (\(\alpha\)-hydroxy-\(\beta\)-N,N,N-trimethylaminopropionic acid) \([R(+): 541-14-0 ; \ S(L-) 541-15-1; \ RS 461-06-3]\) M 161.2, m R or S isomer 197-198\(^{\circ}\text{C})(\text{dec}), 210-212^{\circ}\text{C})(\text{dec}), \text{RS isomer} 195-197^{\circ}, [\alpha]_D^{15} 36^{\circ} (\text{c} 10, \text{H}_2\text{O}), \text{pK}^+_2 3.6.\) The S(L) isomer is levocarnitine, Vitamin B\(_7\). The R or S isomers crystallize from EtOH + Me\(_2\text{CO}\) (hygroscopic). The R or S hydrochlorides crystallise from hot EtOH and have m 142\(^{\circ}\text{C})(\text{dec}).\) The RS isomer crystallises from hot EtOH (hygroscopic). The RS hydrochloride crystallizes in needles from hot EtOH and has m 196\(^{\circ}\text{C})(\text{dec}).

L-Carnosine (\(\beta\)-alanyl-L-histidine) \([305-84-0]\) M 226.2, m 258-260\(^{\circ}\text{C})(\text{dec}), 260^{\circ}\text{C})(\text{capillary tube}), 262^{\circ}\text{C})(\text{dec}), [\alpha]_D^{15} +20.5^{\circ} (\text{c} 1.5, \text{H}_2\text{O}), \text{pK}^+_2 2.64, \text{pK}^-_2 6.83, \text{pK}^+_2 9.51.\) Likely impurities: histidine, \(\beta\)-alanine. Crystal from water by adding EtOH in excess. Recrystd from aqueous EtOH by slow addition of EtOH to a strong aqueous soln of the dipeptide. Its solubility in \(\text{H}_2\text{O}\) is 33.3% at 25\(^{\circ}\). [Vinick and Jung J Org Chem 48 392 1983; Turner J Am Chem Soc 75 2388 1953; Sifford and du Vigneaud J Biol Chem 108 753 1935.]
\( \alpha \)-Carotene \:[7488-99-5] \) M 536.9, m 184-188°C, \([\alpha]_{D}^{20} + 385^\circ (c 0.08, *C_8H_8) \lambda_{\text{max}} 422, 446, 474 \text{nm, in hexane, } A_{1\text{cm}} 2725 \text{ (at 446nm), } 2490 \text{ (at 474nm).} \) Purified by chromatography on columns of calcium hydroxide, alumina or magnesia. Crystd from CS\(_2/\)MeOH, toluene/MeOH, diethyl ether/pet ether, or acetone/pet ether. Stored in the dark, under inert atmosphere at -20°C.

\( \text{all-trans-} \beta \)-Carotene \:[7235-40-7] M 536.9, m 178-179°C, 179-180°C, 180°C, 181°C, 183°C (evac capillary), \( \varepsilon_{1\text{cm}} 2590 \text{ (450nm), } 2280 \text{ (478nm), in hexane. It forms purple prisms when crystd from *C_8H_6-MeOH and red rhombs from pet ether. Its solubility in hexane is 0.1% at 0°C. It is oxygen sensitive and should be stored under N}_2 \text{ at -20°C in the dark. UV: } \lambda_{\text{max}} 2720 \text{ (at 446nm), } 2490 \text{ (at 474nm).} \) [Synthesis: Surmatis and Ofner J Org Chem 26 1171 1961; Milas et al. J Am Chem Soc 72 4844 1950.] \( \beta \)-Carotene was also purified by chromatography (Al\(_2\)O\(_3\) activity 1-II) - it was dissolved in pet ether-*C_8H_6 (10:1), applied to the column and eluted with pet ether-EtOH, the desired fraction was evaporated and the residue recrystd from *C_8H_6-MeOH as violet-red plates. [UV: Inhoffen et al. Justus Liebigs Ann Chem 570 54,68 1950; Review: Fleming Selected Organic Synthesis (J Wiley, Lond) pp. 70-74 1973.] Alternatively it can be purified by chromatography on a magnesia column, thin layer of Kieselguhr or magnesia. Crystd from CS\(_2/\)MeOH, Et\(_2\)O/pet ether, acetone/pet ether or toluene/MeOH. Stored in the dark, under inert atmosphere, at -20°C. Recrystd from 1:1 EtOH/CHC\(_3\).

\( \gamma \)-Carotene \:[472-93-5, 10593-83-6] M 536.9, \( A_{1\text{cm}}^{\lambda} \lambda_{\text{max}} 2055 \text{ (437nm), } 3100 \text{ (462nm), } 2720 \text{ (494nm) in hexane.} \) Purified by chromatography on alumina or magnesia columns. Cryst from *C_8H_6-MeOH (2:1). Stored in the dark, under inert atmosphere, at 0°C.

\( \xi \)-Carotene \:[38894-81-4] M 536.9, m 38-42°, \( \lambda_{\text{max}} 378, 400, 425\text{nm, } A_{1\text{cm}}^{\lambda} \lambda_{\text{max}} 2270 \text{ (400nm), in pet ether.} \) Purified by chromatography on 50% magnesia-HyfloSupercel, developing with hexane and eluting with 10% EtOH in hexane. It was crystd from toluene/MeOH. [Gorman et al. J Am Chem Soc 107 4404 1985.] Stored in the dark under inert atmosphere at -20°C.

\( \lambda \)-Carrageenan \:[9064-57-7, 9000-07-1 (k + little of \( \lambda \))] This D-galactose-anhydro-D or L-galactoside polysaccharide is pptd from 4g of Carrageenan in 600mL of water containing 12g of KOAc by addn of EtOH. The fraction taken, pptd between 30 and 45% (v/v) EtOH. [Pal and Schubert J Phys Chem 23 570 1919; Johnston and Scaiano J Am Chem Soc 108 2349 1986].

Cation exchange resins. Should be conditioned before use by successive washing with water, EtOH and water, and taken through two H+-OH--H+ cycles by successive treatment with M HCl, water, M NaOH, water, and washed with water until neutral to give the H\(^+\) form. (See commercial catalogues on ion exchange resins).


Cathepsin D (from bovine spleen) \:[9025-26-7] M\(_r\) 56,000, [EC 3.4.23.5]. Purified on a CM column after ammonium sulfate fractionation and dialysis, then starch-gel electrophoresis and by ultracentrifugal analysis. Finally chromatographed on a DEAE column. [Press et al. Biochem J 74 501 1960].

Cephalosporin C potassium salt \:[28240-09-7] M 453.5, \([\alpha]_{D}^{20} + 103^\circ \) (H\(_2\)O), pK\(_1\) <2.6, pK\(_2\) 3.1, pK\(_3\) 9.8. Purified by dissolving in the minimum volume of H\(_2\)O (filter) and adding EtOH until separation of solid is complete. A soln is stable in the pH range 2.5-8. It has UV \( \lambda_{\text{max}} \) is 260nm (log \( \varepsilon \) 3.95) in H\(_2\)O. The Ba salt has \([\alpha]_{D}^{20} +80^\circ \) (c 0.57, H\(_2\)O) [Woodward et al. J Am Chem Soc 88 852 1966; Abraham and Newton Biochem J 79 277 1967; Hodgkin and Maslen Biochem J 79 402 1961; see also Quart Reviews Chem Soc London 21 231 1967].

Ceruloplasmin (from human blood plasma) \:[9031-37-2] M\(_r\) 134,000. This principle Cu transporter (90-90% of circulating Cu) is purified by precipitation with polyethylene glycol 4000, batchwise desorption and elution from QAE-Sephadex, and gradient elution from DEAE-Sepharose CL-6B. Ceruloplasmin
was purified 1640-fold. Homogeneous on anionic polyacrylamide gel electrophoresis (PAGE), SDS-PAGE, isoelectric focusing and low speed equilibrium centrifugation. [Oestnuizen Anal Biochem 146 1 1985; Cohn et al. J Am Chem Soc 68 459 1946.]

**Chemokines.** These are small proteins formed from longer precursors and are chemoattractants for lymphocytes and lymphoid organs. They are characterised by having cysteine groups in specific relative positions. The two largest families are the α and β families that have four cysteine residues arranged (C-C-X) and (C-C-X-C) respectively. The mature chemokines have ~70 amino acids with internal cys S-S bonds and attract myeloid type cells in vitro. The γ-family (Lymphotactin) has only two cys residues. The δ-family (Neutrotactin, Fractalkine) has the C-C-X-X-C sequence (ca 387 amino acids), binds to membrane promoting adhesion of lymphocytes. The soluble domain of human Fractalkine chemoattracts monocytes and T cells. Several chemokines are available commercially (some prepared by recombinant DNA techniques) including 6Ckine/exodus/SLC which belongs to the β-family with 6 cys (110 amino acids mature protein), as the name implies (C-C-C-X-....X-C-C) and homes lymphocytes to secondary lymphoid organs with lymphocyte adhesion antitumor properties. Other chemokines available are C10 (βCC and Biotaxin. Several chemokine receptors and antibodies are available commercially and can generally be used without further purification. [Murphy 'Molecular biology of lymphocyte chemoattractant receptors' in Ann Rev Immunol 12 593 1994.]

**Chirazymes.** These are commercially available enzymes e.g. lipases, esterases, that can be used for the preparation of a variety of optically active carboxylic acids, alcohols and amines. They can cause regio and stereospecific hydrolysis and do not require cofactors. Some can be used also for esterification or trans-esterification in neat organic solvents. The proteases, amidases and oxidases are obtained from bacteria or fungi, whereas esterases are from pig liver and thermophilic bacteria. For preparative work the enzymes are covalently bound to a carrier and do not therefore contaminate the reaction products. Chirazymes are available form Roche Molecular Biochemicals and are used without further purification.

**Chlorambucil** [4-{bis(2-chloroethyl)amino}benzene]butyric acid ] [305-03-3] M 304.2, m 64-66°, pK1 5.8 (6.0 at 66°, 50% aq Me2CO), pK2 8.0. It is recrystd from pet ether (flat needles) and has a solubility at 20° of 66% in EtOH, 40% in CHC13, 50% in Me2CO but is insoluble in H2O [Everett et al. J Chem Soc 2386 1953]. CARCINOGEN.

**Chloramphenicol** [Amphicol, 1R,2R-(-)-2-{2,2-dichloroacetylamino}-1-{4-nitrophenyl}-propan-1,3-diol] [56-75-7] M 323.1, m 149-151°, 150-151°, 151-152°, [α]D20 +20.5° (c 3, EtOH), [α]O20 -25.5° (EtOAc). Purified by recryst from H2O (sol 2.5mg/mL at 25°) or ethylene dichloride or needles or long plates and by sublimation at high vacuum. It has Amax in H2O (0.25%) and propylene glycol (1.50%) at 25° but is freely soluble in MeOH, EtOH, BuOH, EtOAc and Me2CO. [Relstock et al. J Am Chem Soc 71 2458 1949; Confroulis et al. J Am Chem Soc 71 2463 1949; Long and Troutman J Am Chem Soc 71 2469, 2473 1949, Ehrhart et al. Chem Ber 90 2088 1957.]

**Chloramphenicol palmitate** [530-43-8] M 561.5, m 90°, [α]D20 +24.6° (c 5, EtOH). Crystd from benzene.

**2-Chloroadenosine** [146-77-0] M 301.7, m 145-146°(dec), 147-149°(dec), pK1 7.6. Purified by recryst from H2O (~1% in cold) and has Amax at 264 nm (pH 1 and 7) and 265 nm (pH 13) in H2O. [Brown and Weliky J Org Chem 23 125 1958; Schaeffer and Thomas J Am Chem Soc 80 3738 1958; IR: Davoll and Lewy J Am Chem Soc 74 1563 1952.]

**Chlorophylls a and b** see entries on p. 167 in Chapter 4.

6-Chloropurine riboside (6-chloro-9-β-D-ribofuranosyl-9H-purine) [2004-06-0] M 286.7, m 158-162°(dec), 165-166°(sintering At 155°), 168-170°(dec), [α]D20 -45° (c 0.8, H2O). Purified by suspending the dry solid (~12 g) in hot MeOH (130 mL) and then adding enough hot H2O (~560 mL) to cause solution, filter and set aside at 5° overnight. The colourless crystals of the riboside are filtered off, washed with Me2CO, Et2O and dried at 60°/0.1mm. More material can be obtained from the filtrate by evapn to
Purification of Biochemicals and Related Products

Dryness and recrystn of the residue from MeOH-H₂O (2:1) (15mLg). It has λ_max 264nm (ε 9140) in H₂O. [Robins *Biochem Prep* 10 145 1963; Baker et al. *J Org Chem* 22 954 1957.]

**Chromomycin A₃ [7059-24-7]** M 1183.3, m 185° dec, [α] D 264nm (ε 9140) in H₂O.

**Cinchomycin A₃** [7059-24-7] M 1183.3, m 185O dec, [α] D -20° (c 1, EtOH).

**Clostripain** [9028-00-6] [EC 3.4.22.8] M₁₀⁻⁵ , 000. Isolated from *Clostridium histolyticum* callogenase by extraction in pH 6.7 buffer, followed by hydroxylapatite chromatography with a 0.1-0.2 M phosphate gradient, then Sephadex G-75 gel filtration with 0.05M phosphate pH 6.7, dialysis and a second hydroxylapatite chromatography (gradient elution with 0.1M + 0.3M phosphate, pH 6.7). It has proteinase and esterase activity and is assayed by hydrolysing n-benzoyl-L-arginine methyl ester. [Mitchell and Harrington *J Biol Chem* 243 4683 1968, *Methods Enzymol* 635 1970.]

**Cloxacillin sodium salt** (sodium 3-o-chlorophenyl-5-methyl-4-isoxazolyl penicillin monohydrate) [642-78-4] M 457.9, m 170°, [α] D +163° (H₂O pH 6.0-7.5), pKₖₚ ≈ 2.8 (COOH). Purified by dissolving in isoPrOH containing 20% of H₂O, and diluting with isoPrOH to a water content of 5% and chilled, and recrystallised from hexane. [Jen et al. *J Med Chem* 18 90 1975; NMR: Jackman and Jen *J Am Chem Soc* 97 281 1975.]

**Cocarboxylase tetrahydrate** (aneurine pyrophosphoric acid tetrahydrate, thiamine pyrophosphoric acid tetrahydrate) [136-09-4] M 496.4, m 220-222O (sinters at 130-140°), 213-214°, pKₖₚ(1) 2, pKₖₚ(2) -6, pKₖₚ(3) -9. Recryst from aqueous Me₂CO. [Wenz et al. *Justus Liebigs Ann Chem* 618 210 1958; UV: Melnick *J Biol Chem* 131 615 1939; X-ray: Carlisle and Cook *Acta Cryst* (B) 25 1359 1969.] The hydrochloride salt has m 242-244°(dec), 241-243°(dec) or 239-240°(dec) and is
recrystd from aqueous HCl + EtOH, EtOH containing HCl or HCl + Me₂CO. [Weijlard *J Am Chem Soc* 63 1160 1941; Synthesis: Weijlard and Tauber *J Am Chem Soc* 60 2263 1938.]

**Codeine** [76-57-3] M 299.4, m 154-156°, [α]_D^20 -138° (in EtOH), pK_2^2 8.21. Crystd from water or aqueous EtOH. Dried at 80°.


**Coenzyme Q₀ (2,3-Dimethoxy-5-methyl-1,4-benzoquinone, 3,4-dimethoxy-2,5-tolu-quinone, fumigatin methyl ether)** [605-94-7] M 182.2, m 56-58°, 58-60°, 59°. It crystallises in red needles from pet ether (b 40-60°) and can be sublimed in high vacuum with a bath temperature of 46-48° [Ashley, Anslow and Raistrick *Biol Chem* 244 1975 p 4911. It has also been dissolved in MeOHEtOH (1:1 v/v) and kept at 2t,6t,1Ot,14t,18t,22t,26t,3Ot,34t,38-decaenyl]-1,4-benzoquinone) (275nm) 185.

**Coenzyme Q₅ (Ubiquinone-5, 2,3-dimethoxy-5-methyl-6-[3,7,11,15,19,23,27,31,35-nonamethyl-hexatriaconta-2t,6t,1Ot,14t,18t,22t,26t,3Ot,34t,38-decaenyl]-1,4-benzoquinone) [4370-62-1] M 454.7, m 30°, 33-45°, A_1cm (275nm) 185. A red oil purified by TLC chromatography on SiO₂ and eluted with Et₂O-hexane. Purity can be checked by HPLC (silica column using 7% Et₂O-hexane). It has λ_max 270 nm (ε 14,800) in pet ether. [NMR and MS: Naruta *J Org Chem* 40 997 1980; cf Morton *Biochemical Spectroscopy* (Adam Hilger, London, 1975) p 491. It has also been dissolved in MeOH/EtOH (1:1 v/v) and kept at 5° until crystals appear [Lester and Crane *Biochim Biophys Acta* 32 497 1958].

**Coenzyme Q₉ (Ubiquinone-9, 2,3-dimethoxy-5-methyl-6-[3,7,11,15,19,23,27,31,35-nonamethyl-hexatriaconta-2t,6t,1Ot,14t,18t,22t,26t,3Ot,34t,38-decaenyl]-1,4-benzoquinone) [303-97-9] M 795.3, m 40.5-42.5°, 44-45°, 45°. Yellow crystals purified by recrystn from pet ether and by TLC chromatography on SiO₂ and eluted with Et₂O-hexane. Purity can be checked by HPLC (silica column using 7% Et₂O-hexane). It has λ_max 270nm (ε 14,850) in pet ether. [NMR and MS: Naruta *J Org Chem* 45 4097 1980; Le et al. *Biochem Biophys Acta* 32 497 1958; cf Morton *Biochemical Spectroscopy* (Adam Hilger, London, 1975) p 491; IR: Lester et al. *Biochim Biophys Acta* 33 169 1959; UV: Ruegg et al. *Helv Chim Acta* 42 2616 1959; Shunk *J Am Chem Soc* 81 5000 1959.]


**Colcemide (Demecocine)** [477-30-5] M 371.4, m 182-185°, 183-185°, 186°, [α]_D^20 -129° (c 1, CHCl₃). It has been purified by chromatography on silica and eluting with CHCl₃-MeOH (9:1) and recrystn from EtOAc-Et₂O and forms yellow prisms. UV in EtOH has λ_max 243nm (ε 30,200) and 350nm (ε 16,3000). [Synthesis, IR, NMR, MS: Caprarolo and Brossi *Helv Chim Acta* 62 965 1979.]

**Colchicine** [64-86-8] M 399.5, m 155-157°(dec), [α]_D^20 +570° (c 1, H₂O), pK_2^20 1.85. Commercial material contains up to 4% desmethylcolchicine. Purified by chromatography on alumina, eluting with CHCl₃ [Ashley and Harris *J Chem Soc* 677 1944]. Alternatively, an acetone solution on alkali-free alumina has been used, and eluting with acetone [Nicholls and Tarbell *J Am Chem Soc* 75 1104 1953].
Colchicoside \[477-29-2\] M 547.5, m 216-218\(^\circ\). Crystd from EtOH.

Colicin E (from \textit{E. coli}) \(11032-88-5\). Purified by salt extraction of extracellular-bound colicin followed by salt fractionation and ion-exchange chromatography on a DEAE-Sephadex column, and then by CM-Sephadex column chromatography [Schwartz and Helinski \textit{J Biol Chem} 246 6318 1971].

Collagenase (from human polymorphonuclear leukocytes) \[9001-12-1\] M 68,000-125,000 [EC 3.4.24.3]. Purified by using N-ethylmaleimide to activate the enzyme, and wheat germ agglutinin-agarose affinity chromatography [Callaway et al. Biochemistry 25 4757 1986].

Collagenase (from human polymorphonuclear leukocytes) \[9001-12-1\] M 68,000-125,000 [EC 3.4.24.3]. Purified by using N-ethylmaleimide to activate the enzyme, and wheat germ agglutinin-agarose affinity chromatography [Callaway et al. Biochemistry 25 4757 1986].

Compactin \[73573-88-3\] M 390.5, m 151-153\(^\circ\), 152\(^\circ\), \([\alpha]_D^{20} +283\(^\circ\) (c 0.48, acetone). Purified by recrystn from aqueous EtOH. UV: \(h_{\text{max}}\) 230, 237 and 246nm (log \(E\) 4.28, 4.30 and 4.11); IR (KBr): \(v\) 3520, 1750 (lactone CO) and 1710 (CO ester) cm\(^{-1}\) [Clive et al. J \textit{Am Chem Soc} 110 6914 1988; Synthesis review: Rosen and Heathcock \textit{Tetrahedron} 42 4909 1986; IR, NMR, MS: Brown et al. J \textit{Chem Soc Perkin Trans I} 1165 1976.]

Convallatoxin (α cardenolide mannmoside) \[508-75-8\] M 550.6, m 238-239\(^\circ\), \([\alpha]_D^{15} 9.4\(^\circ\) (c 0.7, dioxane). Crystd from EtOAc. Tetra-acetate has m 238-242\(^\circ\) (MeOH/Et\(_2\)O), \([\alpha]_D^{19} -5\(^\circ\) (CHCl\(_3\)).

Copper-zinc-superoxide dismutase (from blood cell haemolysis) \[9054-89-1\] M \(\sim 32,000\) [EC 1.15.1.1]. Purified by DEAE-Sepharose and copper chelate affinity chromatography. The preparation was homogeneous by SDS-PAGE, analytical gel filtration chromatography and by isoelectric focusing [Weselake et al. \textit{Anal Biochem} 155 193 1986; Fridovich \textit{J Biol Chem} 244 6049 1969].

Corticotropin \[92307-52-3\] polypeptide \(M_r \sim 4697\). Extract separated by ion-exchange on CM-cellulose, desalted, evapd and lyophilised. Then run on gel filtration (Sephadex G-50) [Lande et al. \textit{Biochemical Preparations} 13 45 1971; Esch et al. \textit{Biochem Biophys Res Comm} 122 899 1984].

Cortisol see hydrocortisone on p. 541.

Cortisone \[53-06-5\] M 360.5, m 230-231\(^\circ\), \([\alpha]_D^{20} +225\(^\circ\) (c 1, in EtOH). Crystd from 95% EtOH or acetone.

Cortisone-21-acetate \[50-04-4\] M 402.5, m 242-243\(^\circ\), \([\alpha]_D^{20} +227\(^\circ\) (c 1, in CHCl\(_3\)). Crystd from acetone.

Creatine (H\(_2\)O) (N-guanidino-N-methylglycine) \[6020-87-7\] M 131.1, m 303\(^\circ\), \(pK_1^{25} 2.63\), \(pK_2^{25} 14.3\). Likely impurities are creatinine and other guanidino compounds. Crystd from water as monohydrate. Dried under vacuum over P\(_2\)O\(_5\) to give anhydrous material.

Creatine phosphate di Na, 4H\(_2\)O salt (phosphocreatine) \[922-32-7\] M 327.1, \(pK_1^{27} 2.7\), \(pK_2^{27} 4.58\), \(pK_3^{27} 12\). To 3-4g of salt in H\(_2\)O (220mL) is added 4 vols of EtOH with thorough stirring and allowed to stand at 20\(^\circ\) for 12hrs (this temp is critical as crystals did not readily form at 23\(^\circ\) or 25\(^\circ\)). The salt first appears as oily droplets which slowly settle and crystallise. After 12hrs the supernatant is clear. Stirring
and scratching the flask containing the filtrate brings out additional (0.3-1g) crystals if the salt is kept at 20° for 12hrs. Filter at room temp, wash with 3 x 5mL of ice-cold 90% EtOH then 5mL of abs EtOH and dry in a vac desiccator (Drierite or CaCl₂) for 16-30hrs. The hexahydrate (plates) is converted to the tetrahydrate salt (needles) in vac at -10°. [Ennor and Stocken Biochem Prep 5 9 1957; Biochem J 43 190 1958.]

Creatinine (2-imino-1-methyl-4-oxoimidazolidine) {60-27-5} M 113.1, m 260°(dec), pK₁ 4.80, pK₂ 9.2. Likely impurities are creatine and ammonium chloride. Dissolved in dilute HCl, then neutralised by adding ammonia. Recrystd from water by adding excess of acetone. Recrystd from water and dried for 12hours in a vacuum at 110°, or 24hours in a vacuum at 70°. The purity was assessed by TLC on cellulose with a fluorescent indicator. [Taguchi, J Am Chem Soc 107 2015 1985; Culvenor and Smith Aust J Chem 10 474 1957.] The hydrochloride has m 212-214° (from MeOH-Et₂O) and (α)₂ +38.4° (c 5, H₂O) [Adams and Gianturco J Am Chem Soc 78 1922 1956]. The picrate has m 230-231.5°(dec) [Adams et al. J Am Chem Soc 74 5614 1952].

α-Cyclodextrin (H₂O) {10016-20-3} M 972.9, m >280°(dec), (α)₂ 175° (c 10, H₂O). Recrystd from 60%aq EtOH, then twice from water, and dried for 12hours in a vacuum at 80°. Also purified by pptn from water with 1,1,2-trichloroethylene. The pptg was isolated, washed and resuspended in water. This was boiled to steam distil the trichloroethylene. The soln was freeze-dried to recover the cyclodextrin. [Armstrong et al. J Am Chem Soc 108 1418 1986.]

β-Cyclodextrin (H₂O) {7585-39-9} M 1135.6, m >300°(dec), (α)₂ 170° (c 10, H₂O). Recrystd from water and dried for 12hours in a vacuum at 110°, or 24hours in a vacuum at 70°. The purity was assessed by TLC on cellulose with a fluorescent indicator. [Taguchi, J Am Chem Soc 108 2705 1986; Tabushi et al. J Am Chem Soc 108 4514 1986; Orstam and Ross J Phys Chem 91 2739 1987.]

D-(R-natural) and L-(S-non-natural) Cycloserine (2-amino-3-isoxazolidine) {R- 68-41-7 and S- 339-72-0} M 102.1, m 145-150°(dec), 154-155°, 155-156° (dec), 156° (dec), (α)₂ 45° (c 5, 2N NaOH), pK₁ 4.5, pK₂ 7.74, pK₃ 4.50, pK₄ 7.43, pK₅ 4.44, pK₆ 7.20. Purified by recrystn from aqueous EtOH or MeOH or aqueous NH₃ + EtOH or isoPrOH. Also recrystd from aqueous ammoniacal soln at pH 10.5 (100mg/mL) by diluting with 5 volumes of isopropanol and then adjusting to pH 6 with acetic acid. An aqueous soln buffered to pH 10 with Na₂CO₃ can be stored in a refrigerator for 1 week without decomposition. UV: λmax 226nm (A₄₁⁰ 4.02). The tartrate salt has m 165-166° (dec), 166-168° (dec), and (α)₂ 41° (c 0.7, H₂O). [Stammer et al. J Am Chem Soc 79 3236 1959; UV: Kuehle J Am Chem Soc 77 2344 1955.]

Cystamine dihydrochloride [2,2'-diaminodiethylene disulfide dihydrochloride, 2,3'-dithiobis(ethylenedine) dihydrochloride] {56-17-7} M 225.2, m 219-220°(dec), pK₁ 8.62, pK₂ 9.58. Recrystd by dissolving in EtOH containing a few drops of dry EtOH-HCl, filtering and adding dry Et₂O. The solid is dried in a vacuum and stored in dry and dark atmosphere. It has been recrystd from EtOH (solubility: 1g in 60mL of boiling EtOH or MeOH (plates). The free base has b 90-100°/0.001mm, 106-108°/5mm and 135-136°/atm, d₂⁰ 1.1559, nD 1.5720. [Verly and Koch Biochem J 58 663 1954; Gonick et al. J Am Chem Soc 76 4671 1954; Jackson and Block J Biol Chem 113 137 1936.]. The dihydrobromide has m 238-239° (from EtOH-Et₂O) [Viscontini Helv Chim Acta 36 835 1953].

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**Cysteamine** (2-aminoethanethiol, 2-mercaptoethylamine) \[\{60-23-1\} M 77.2, m 97-98.5\celsius, 98-99\celsius, 99-100\celsius, pK\textsubscript{1} 11.93, pK\textsubscript{2} 8.42, pK\textsubscript{2} 10.83. Soluble in H\textsubscript{2}O giving an alkaline reaction and it has a disagreeable odour. Likely impurity is the disulfide, cystamine which is not soluble in alkaline solution. Under a N\textsubscript{2} atmosphere dissolve in EtOH, evaporate to dryness and wash the white residue with dry pet ether, then sublime at 0.1 mm and store under N\textsubscript{2} (out of contact with air) at 0-10\celsius in the dark. Its HgCl\textsubscript{2} (2:3) complex has m 181-182\celsius (from H\textsubscript{2}O), and its picrate has m 125-126\celsius. [Mills and Bogert *J Am Chem Soc* 57 2328 1935, 62 1173 1940; Baddiley and Thain *J Chem Soc* 800 1952; Shirley *Preparation of Organic Intermediates* (J. Wiley) Vol 3 189 1951; Barkowski and Hedberg *J Am Chem Soc* 109 6989 1987.]

**Cysteamine hydrochloride** [156-57-0] M 113.6, m 70.2-70.7\celsius, 70-72\celsius. Purified by recrystn from EtOH. It is freely soluble in H\textsubscript{2}O and should be stored in a dry atmosphere. [Mills and Bogert *J Am Chem Soc* 62 1177 1940]. The picrate has m 125-126\celsius, see previous entry for free base.

(±)-Cysteic acid (3-sulfoalanine, 1-amino-3-sulfopropionic acid) \[\{13100-82-8, 3024-83-7\} M 169.2, m 260\celsius (dec). Likely impurities are cystine and oxides of cysteine. Crystd from water by adding 2 volumes of EtOH. When recryst from aqueous MeOH it has m 264-266\celsius, and the anhydrous acid has m -260\celsius (dec). [Chapeville and Formageot *Biochim Biophys Acta* 26 538 1957; *J Biol Chem* 72 435 1927.]

\(R(\mathcal{L})\)-Cysteic acid (H\textsubscript{2}O) \[\{23537-25-9\} M 187.2, m 275-280\celsius (dec), 289\celsius, [α]\textsubscript{D}^0 +8.66\celsius (c 7.4, H\textsubscript{2}O, pH 1) and +1.54\celsius (H\textsubscript{2}O, pH 13), pK\textsubscript{1} 1.92 (CO\textsubscript{2}H), pK\textsubscript{2} 8.35 (NH\textsubscript{3}), pK\textsubscript{3} 10.46 (SH). Likely impurities are cystine and oxides of cysteine. Crystd from water by adding 2 volumes of EtOH. When recryst from aqueous MeOH it has m 264-266\celsius, and the anhydrous acid has m -260\celsius (dec). [Chapeville and Formageot *Biochim Biophys Acta* 26 538 1957; *J Biol Chem* 72 435 1927.]

D-(S)- and L-(R)- Cysteine (S- and R-2-amino-3-mercaptopropionic acid) \[S(\mathcal{R})+\cdot 921-01-7 and R(\mathcal{L})-\cdot 52-90-4\] M 121.2, m 230\celsius, 240\celsius (dec), [α]\textsubscript{D}^0 (+) and (-) 7.6\celsius (c 2, M HCl) and (+) and (-) 10.1\celsius (c 2, H\textsubscript{2}O, pH 10), pK\textsubscript{1} 1.92 (CO\textsubscript{2}H), pK\textsubscript{2} 8.35 (NH\textsubscript{3}), pK\textsubscript{3} 10.46 (SH). Purified by recrystn from H\textsubscript{2}O (free from metal ions) and dried in a vacuum. It is soluble in H\textsubscript{2}O, EtOH, Me\textsubscript{2}CO, EtOAc, AcOH, C\textsubscript{6}H\textsubscript{6} and CS\textsubscript{2}. Acidic solns can be stored under N\textsubscript{2} for a few days without deterioration. [For synthesis and spectra see Greenstein and Winitz *Chemistry of the Amino Acids* (J. Wiley) Vol 3 p1879 1961.]

L-Cysteine hydrochloride (H\textsubscript{2}O) \[\{52-89-1\} M 175.6, m 175-178\celsius (dec), [α]\textsubscript{D}^0 +6.53\celsius (5M HCl). Likely impurities are cystine and tyrosine. Crystd from MeOH by adding diethyl ether, or from hot 20% HCl. Dried under vacuum over P\textsubscript{2}O\textsubscript{5}. Hygroscopic.

(±)-Cysteine hydrochloride \[\{10318-18-0\} M 157.6. Crystd from hot 20% HCl; dried under vacuum over P\textsubscript{2}O\textsubscript{5}.]

L-Cystine \[\{56-89-3\} M 240.3, [α]\textsubscript{D}^0 229\celsius (c 0.92 in M HCl), pK\textsubscript{1} 1.04 (1.65), pK\textsubscript{2} 2.05 (2.76), pK\textsubscript{3} 8.00 (7.85), pK\textsubscript{4} 10.25 (8.7, 9.85). Cystine disulfoxide was removed by treating an aqueous suspension with H\textsubscript{2}S. The cystine was filtered off, washed with distilled water and dried at 100\celsius under vacuum. Crystd by dissolving in 1.5M HCl, then adjusting to neutral pH with ammonia. Likely impurities are D-cystine, meso-cystine and tyrosine.

Cytidine \[\{65-46-3\} M 243.2, m 210-220\celsius (dec), 230\celsius (dec), 251-252\celsius (dec), [α] \textsubscript{D}^0 237\celsius (c 9, H\textsubscript{2}O), [α]\textsubscript{D}^0 229\celsius (c 9, H\textsubscript{2}O), pK 3.85. Crystd from 90% aqueous EtOH. Also has been converted to the sulfate by dissolving (~200mg) in a soln of EtOH (10mL) containing H\textsubscript{2}SO\textsubscript{4} (50mg), whereby the salt crystallises out. It is collected, washed with EtOH and dried for 5hours at 120\celsius/0.1mm. The sulfate has m 225\celsius. The free base can be obtained by shaking with a weak ion-exchange resin, filtering, evaporating and recrystallising the residue from EtOH as before. [Fox and Goodman *J Am Chem Soc* 73 3256 1956; Fox and

Cytisine see entry in Chapter 4.

**Cytochalasin B** (from dehydrated mould matter) [14930-96-2] M 479.6. Purified by MeOH extraction, reverse phase C18 silica gel batch extraction, selective elution with 1:1 v/v hexane/tetrahydrofuran, crysyt, subjected to TLC and recrystallised [Lipski et al. *Anal Biochem* 161 332 1987].

**Cytochrome c** (from horse, beef or fishes' heart, or pigeon breast muscle) [9007-43-6] M 13,000. Purified by chromatography on CM-cellulose (CM-52 Whatman) [Brautigan et al. *Methods Enzymol* 53D 131 1978]. It has a high PI (isoelectric point) and has been purified further by adsorption onto an acidic cation exchanger, e.g. Amberlite IRC-50 (polycarboxylic) or in ground form Amberlite XE-40 (100-200 mesh) or Decalso-F (aluminium silicate), where the non-cytochrome protein is not adsorbed and is readily removed.

The cytochrome is eluted using a soln containing 0.25g ions/L of a univalent cation at pH 4.7 an acidic cation exchanger, e.g. Amberlite IRC-50 (polycarboxylic) or in ground form Amberlite XE-40 (100-200 mesh) or Decalso-F (aluminium silicate), where the non-cytochrome protein is not adsorbed and is readily removed. The cytochrome is eluted using a soln containing 0.25g ions/L of a univalent cation at pH 4.7 adsorbed onto the NH4+ salt of Amberlite IRC-50 at pH 7, washed with H2O and then with 0.12M NH4OAc to remove non-cytochrome protein. When the cytochrome begins to appear in the eluate then the NH4OAc concn is increased to 0.25 M. The fractions with ca Fe = 0.465—0.467 are collected, dialysed against H2O and adsorbed onto a small IRC-50 column and eluted with 0.5M NH4OH, then dialysed and lyophilised. (A second fraction (II) can be eluted from the first resin with 0.5M NH4OH but is discarded). [Keilin and Hartree *Biochem Prep* 1 1 1952; Margoliash *Biochem Prep* 8 33 1957.]

**Cytochrome c** has been recrystallised as follows: The above eluate (ca 100mL) is dialysed against H2O (10 vols) at 4ºC for 24 h. When the column has washed with 0.1% (NH4)2SO4 pH 8.0 and the dark red resin in the upper part of the column is collected and in 0.1% (NH4)2SO4 pH 8.0 transferred to another column (7 mm diameter) and the cytochrome c is eluted with 5% (NH4)2SO4 pH 8.0. More than 98% of the red colour is collected in a volume of ca 4mL in a weighed centrifuge tube. Add a drop of octanol, 0.43g of (NH4)2SO4/g of soln. When the salt has dissolved ascorbic acid (5mg), add a few drops of 30% NH3 and keep the soln at 10oC for 10min (turns lighter colour due to reduction). Then add finely powdered (NH4)2SO4 in small portions (stir with a glass rod) until the soln becomes turbid. Stopper the tube tightly, and set aside at 15-25ºC for 2 days while the cytochrome c separates as fine needles or rosettes. Further (NH4)2SO4 (20mg) are added per mL of suspension and kept in the cold for a few days to complete the crystallisation. The crystals are collected by centrifugation (5000xg), suspended in saturated (NH4)2SO4 (pH 8.0 at 10ºC) then centrifuged again. For recrystals the crystals are dissolved in the least volume of H2O, one drop of ammonia and 1 mg of ascorbic acid are added and the above process is repeated. The yield of twice recryst cytochrome c from 2Kg of muscle is ca 200 mg but this varies with the source and freshness of the muscle used. The crystals are stored as a solid after dialysis against 0.08M NaCl or 0.1M sodium buffer and lyophilising, or as a suspension in saturated (NH4)2SO4 at 0º. [Hagihara et al. *Biochem Prep* 6 1 1958.] Purity of cytochrome c: This is checked by the ratio of the absorbance at 500nm (reduced form) to 280nm (oxidised form), i.e. e500/e280 should be between 1.1 and 1.28, although values of up to 1.4 have been obtained for pure preparations. For the preparation of the reduced form see Margoliash *Biochem Prep* 5 33 1957 and Yonetani *Biochem Prep* 11 1966.


**Cytochrome c oxidase** (from bovine heart mitochondria). [1001-16-5] Mr 100,000/haeme, [EC 1.9.3.1]. Purified by selective solubilisation with Triton X-100 and subsequently with lauryl maltoside; finally by sucrose gradient centrifugation [Li et al. *Biochem J* 242 417 1978].

Also purified by extraction in 0.02 M phosphate buffer (pH 7.4) containing 2% of cholic acid (an inhibitor which stabilises as well as solubilises the enzyme) and fractionated with (NH4)2SO4 collecting the 26-33% saturation cut and reprecipitation again and collecting the 26-33% saturation fraction. The pellet collected at 10,000xg appears as an oily paste. The cholate needs to be removed to activate the enzyme as follows: The ppte is dissolved in 10mL of 0.1M phosphate buffer pH 7.4, containing 1% of Tween-80 and dialysed against 1L of 0.01 M PO4 buffer (pH 7.4) containing 1% of Tween-80 for 10 h and aliquoted. The enzyme is
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stable at 0° for 2 weeks and at -15° for several months. It is assayed for purity (see reference) by oxidation of reduced cytochrome c (Km 10µM). [Yonetani Biochem Prep 11 14 1966; J Biol Chem 236 1680 1961.]

Cytokines see chemokines, interferons, interleukins.


Cytokines see chemokines, interferons, interleukins.

N-Decanoyl-N-methylglucamine (Mega-10, N-D-glucidyl-N-methyl deconamide) [85261-20-7] M 349.5, m 91-93°, 92°. Possible impurities are decanoic acid and N-methylglycamine. The former is removed by grinding the solid with Et2O and then with pet ether and dried over P2O5. Twice recrystd from MeOH-Et2O by dissolving in the minimum volume of MeOH and adding Et2O and drying in a vacuum. To remove the glycamine the solid (800 mg) is dissolved in hot H2O (10 mL) and set aside. Mega-10 crystallises in colourless needles. These are filtered off and dried in a vacuum to constant weight. It is a good non-ionic non-hygroscopic detergent with a critical micelle concentration (CMC) of 7.4 mM (0.26%) in 0.1M Tris-HCl pH 7.4 at 25°. [Hildreth Biochem J 207 363 1982.]


2'-Deoxyadenosine (adenine 2'-deoxyriboside) [16373-93-6] M 269.3, m 187-178°(dec, for sesquihydrate), [α]D20+258° (c 0.5, 0.1N H2SO4), pK 4.8. It forms needles from EtOH, n-BuOH and n-PrOH, and from H2O as the mono-hydrate. It has λmax 258 nm (pH 1), 260 nm (pH 7) and 261 nm (pH 13). [Ness and Fletcher J Am Chem Soc 81 4752 1959; Walker and Butler Can J Chem 34 1168 1956.]


2'-Deoxyguanosine monohydrate (9-[2-deoxy-β-D-ribofuranosyl]guanidine) [961-07-9] M 285.3, m ca 200°(dec), [α]$^D_{19}$ +37.5° (c 2, H$_2$O), [α]$^D_{19}$ -47.7° (c 0.9, N NaOH), PKEst(1) - 3.3, PKEst(2) - 9.2. Recrystd from H$_2$O as the monohydrate. [Brown and Lythgoe J Chem Soc 1990 1950; UV: Fox J Am Chem Soc 75 4315 1953; IR: Michelson and Todd J Chem Soc 3438 1954.1

2'-Deoxyinosine [890-38-0] M 252.2, m 206°(dec), 218-220°(dec), [α]$_{22}$ - 2 1° (c 2, N NaOH), [α]$_{22}$ - 9.3° (c 1, HzO), PKEst(i) - 8.9, PKEst(z) - 12.4. Purified by recrystn from H$_2$O. [Brown and Lythgoe J Chem Soc 1990 1950; UV: Fox Biochim Biophys Acta 269 41 1941]. The picrate has m 183°(dec) (from H$_2$O).

Deoxyribonucleic acid (from plasmids). Purified by two buoyant density ultracentrifugations using ethidium bromide-CsCl. The ethidium bromide was extracted with Et$_2$O and the DNA was dialysed against buffered EDTA and lyophilised. [Marmur and Doty J Mol Biol 5 109 1962; Guerry et al. J Bacteriol 116 1064 1973.]

Desthiobiotin [533-48-2] M 214.3, m 156-158°, [α]$^D_{19}$ +10.5° (c 2, H$_2$O), PKEst ~ 2.8. Crystd from H$_2$O or 95% EtOH.

Dextran [9004-54-0] M, 6,000-220,000. Solutions keeps indefinitely at room temperature if 0.2mL of Roccal (10% alkyldimethylbenzylammonium chloride) or 2mg phenyl mercuric acetate are added per 100mL solution. [Scott and Melvin Anal Biochem 25 1656 1953.]

Diacetone-D-Glucose (1,2:5,6-di-O-isopropylidene-α-D-glucofuranoside) [582-52-5] M 260.3, m 107-110°, 110.5°, 111-113°, 112°, [α]$^D_{19}$ -18.4° (c 1, H$_2$O). It crystallises from Et$_2$O, (needles), pet ether or *C$_6$H$_6$ and sublimes in vacuo. It is insol in 7 vols of H$_2$O and 200 vols of pet ether at their
boiling points. The solubility in H₂O at 17.5° is 4.3%. It pptes from aq solns on basification with NaOH. [Schmid and Karrer Helv Chim Acta 32 1371 1949; Fischer and Rund Chem Ber 49 90, 93 1916; IR: Kuhn Anal Chem 22 276 1950.]


**1,8-Diazafluorenone** (cyclopenta[1.2-b:4,3-b']dipyridin-9-one) [54078-29-4] M 182.2, m 205°, 229-231°, pKₐ -2.6. Recrystd from Me₂CO. The oxime has m 1 9-200°. [Druey and Schmid Helv Chim Acta 33 1080 1950.]

**Di- and tri-carboxylic acids.** Resolution by anion-exchange chromatography. [Bengtsson and Samuelson Anal Chim Acta 44 217b 1969.]

**Digitonin** [11024-24-1] M 1229.3, m >270°(dec), [α]D +63° (c 3, MeOH). Crystd from aqueous 85% EtOH or MeOH/diethyl ether.

**Digitoxigenin** [143-62-4] M 374.5, m 253°, [α]D +21° (c 1, MeOH). Crystd from aqueous 40% EtOH.


**Dihydrofolate reductase (from Mycobacterium phlei)** [9002-03-3] Mₙ ~18,000 [EC 1.5.1.3.]

Purified by ammonium sulfate pptn, then fractionated on Sephadex G-75 column, applied to a Blue Sepharose column and eluted with 1mM dihydrofolate. [Al Rubeai and Dole Biochem J 235 301 1986.]

**7,8-Dihydrofolic acid (7,8-dihydropteroyl-L-glutamic acid, DHFA)** [4033-27-6] M 443.4, pK₁ 2.0 (basic 10-NH), pK₂ 2.89 (2-NH₂), pK₃ 3.45 (α-CO₂H), pK₄ 4.0 (basic 5N), pK₅ 4.8 (γ-CO₂H), pK₆ 9.54 (acidic 3NH). Best purified by suspending (lg mostly dissolved)) in ice-cold sodium ascorbate (300mL of 10% at pH 6.0 [prepared by adjusting the pH of 30g of sodium ascorbate in 150mL of H₂O by adding 1N NaOH dropwise using a glass electrode till the pH is 6.0]). This gave a clear solution with pH ~5. While stirring at 0° add N HCl dropwise slowly (0.1mL/min) until the pH drops to 2.8 when white birefringent crystals separate. These are collected by centrifugation (1000xg for 5min), washed 3x with 0.001N HCl by centrifugation and decantation. The residue is then dried in a vacuum (0.02mm) over P₂O₅ (change the P₂O₅ frequently at first) and KOH at 25° in the dark. After 24hours the solid reaches constant weight.

For the assay of dihydrofolate reductase (see below) suspend ~66.5mg of DHFA in 10mL of 0.001M HCl containing 10mM dithiothreitol (DTT stock made from 154mg in 10mL H₂O making 0.1M), shake well and freeze in 400µL aliquots. Before use mix 400µL of this suspension with 0.1M DTT (200µL, also made in frozen aliquots), and the mixture is diluted with 200µL of 1.5M Tris-HCl pH 7.0 and 1.2mL of H₂O (making a total volume of ~2mL) to give a clear solution. To estimate the concentration of DHFA in this solution, dilute 20µL of this solution to 1mL with 0.1M Tris-HCl pH 7.0 and read the OD at 282nm in a 1cm pathlength cuvette. ε at 282nm is 28,000M⁻¹cm⁻¹. [Reyes and Rathod Methods Enzymol 122 360 1986.]

**Dihydropteridine reductase (from sheep liver)** [9074-11-7] Mₙ 52,000 [EC 1.6.99.7]. Purified by fractionation with ammonium sulfate, dialysed versus tris buffer, adsorbed and eluted from hydroxylapatite gel. Then run through a DEAE-cellulose column and also subjected to Sephadex G-100 filtration. [Craine et al. J Biol Chem 247 6082 1972.]

**Dihydropteridine reductase (from human liver)** [9074-11-7] Mₙ 52,000 [EC 1.6.99.7]. Purified to homogeneity on a naphthoquinone affinity adsorbent, followed by DEAE-Sephadex and CM-Sephadex...
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D.L-erythro-Dihydrosphingosine (dl-erythro-2-aminoocctadecan-1,3-diol) \[3102-56-5\] M 301.5, m 85-86\(^\circ\), 85-87\(^\circ\), \(pK_{\text{est}}\) ~ 8.8. Purified by recrystn from pet ether-EtOAc or CHCl\(_3\). The (\(\pm\))-N-dichloroacetyl derivative has m 142-144\(^\circ\) (from MeOH). [Shapiro et al. J Am Chem Soc 80 2170 1958; Shapiro and Sheradsky J Org Chem 28 2157 1963.] The D-isomer crystallises from pet ether-Et\(_2\)O and has m 78.5-79\(^\circ\), \[\alpha\]\(_D^{25}\) +6\(^\circ\) (CHCl\(_3\) + MeOH, 10:1). [Grob and Jenny Helv Chim Acta 35 2106 1953, Jenny and Grob Helv Chim Acta 36 1454 1953.]

Dihydrostreptomycin sesquisulfate \[5490-27-7\] M 461.4, m 250\(^\circ\)(dec), 255-265\(^\circ\)(dec), \[\alpha\]\(_D^{10}\) -92.4\(^\circ\) (c 1, H\(_2\)O), \(pK_{\text{est}}(1)^{\pm}\) 9.5 (NMe), \(pK_{\text{est}}(2,3)^{\pm}\) 13.4 (guanidino). It crystallises from H\(_2\)O with MeOH, n-BuOH or methyl ethyl ketone. The crystals are not hygroscopic like the amorphous powder, however both forms are soluble in H\(_2\)O but the amorphous solid is about 10 times more soluble than the crystals. The free base also crystallises from H\(_2\)O-Me\(_2\)CO and has \[\alpha\]\(_D^{10}\) -92.4\(^\circ\) (aqueous solution pH 7.0). [Solomons and Regina Science 109 515 1949; Wolf et al. Science 109 515 1949; McGilveray and Rinehart J Am Chem Soc 87 4003 1956].

3,4-Dihydroxyphenyl-L-alanine \([\text{DOPA, EUODOPA}\) \[59-92-7, 5796-17-8\] M 197.2, m 275\(^\circ\)(dec), 267-268\(^\circ\)(dec), 284-286\(^\circ\)(dec), -295\(^\circ\)(dec), \[\alpha\]\(_D^{10}\) -13.1\(^\circ\) (c 5.12, N HCl), \(pK_2^{25}\) 2.32 (CO\(_2\)H), \(pK_2^{25}\) 8.72 (NH\(_2\)), \(pK_2^{25}\) 9.96 (OH), \(pK_2^{25}\) 11.79 (OH). Likely impurities are vanillin, hippuric acid, 3-methoxytyrosine and 3-aminoctysosine. Recryst from large vols of H\(_2\)O as colourless white needles; solubility in H\(_2\)O is 0.165%, but it is insoluble in EtOH, C\(_6\)H\(_5\), CHCl\(_3\), and EtOAc. Also crystd from dissolving in dilute HCl and adding dilute ammonia to give pH 5, under N\(_2\). Alternatively, crystd from dI aqueous EtOH. It is rapidly oxidised in air when moist, and darkens; particularly in alkaline solution. Dry in a vacuum at 70\(^\circ\) in the dark, and store in a dark container preferably under N\(_2\). Lax 220.5nm (log \(\epsilon\) 3.79) and 280nm (log \(\epsilon\) 3.42) in 0.001N HC\(_1\). [Yamada et al. Chem Pharm Bull Jpn 29 2334 1981; Bretschneider et al. Helv Chim Acta 56 2857 1973; NMR: Jardetzky and Jardetzky J Biol Chem 248 2603 1973.]

3,5-Diiodo-L-tyrosine dihydrate \[300-39-0\] M 469.0, m 199-210\(^\circ\), 202\(^\circ\)(dec), \[\alpha\]\(_D^{25}\) +2.89\(^\circ\) (c 4.9, 4% HCl), \(pK_2^{25}\) 2.12, \(pK_2^{25}\) 6.48, \(pK_3^{25}\) 7.82. It forms crystals from H\(_2\)O [solubility (g/k): 0.204 at 0\(^\circ\), 1.86 at 50\(^\circ\), 5.6 at 75\(^\circ\) and 17.0 at 100\(^\circ\)]. Also recryst from 50% or 70% EtOH. When boiled in EtOH the crystals swell and on further boiling a gelatinous ppte is formed [Harrington Biochem J 22 1434 1928; Jurd J Am Chem Soc 77 5747 1955]. Also crystd from cold dilute ammonia by adding acetic acid to pH 6.
1,2-Dilauroyl-sn-glycero-3-phosphoethanolamine (dilauroyl-α-cephalin, 3-sn-phosphatidylethanolamine 1,2-didodecanoyl) [59752-57-7] M 579.8, m 210°, pK_{Est(1)} ~ 5.8 (PO₄H), pK_{Est(2)} ~ 10.5 (NH₂). Recryst from EtOH or tetrahydrofuran. [Bevan and Malkin J Chem Soc 2667 1951; IR: Bellamy and Beecher J Chem Soc 72 1953.]

1,2-Dilauroyl-sn-glycero-3-phosphatidylethanolamine (dilauroyl-α-ceilaphalin, 3-sn-phosphatidylethanolamine 1,2-didodecanoyl) [59752-57-7] M 579.8, m 210°, pK_{Est(1)} ~ 5.8 (PO₄H), pK_{Est(2)} ~ 10.5 (NH₂). Recryst from EtOH or tetrahydrofuran. [Bevan and Malkin J Chem Soc 2667 1951; IR: Bellamy and Beecher J Chem Soc 72 1953.]

1,2-Dimyristoyl-sn-glycero-3-phosphocholine monohydrate (dimyristoyl-L-α-lecithin) [18194-24-6] M 696.0, [α]_D^20 ~ +70° (c 8, EtOH-CHCl₃ 1:1 for α₁ form), pK_{Est(-)} ~ 5.8 (PO₄). Three forms α₁, α₂ and β'. Recryst from aqueous EtOH or EtOH-Et₂O. Solubility at 22-23° in Et₂O is 0.03%, in Me₂CO it is 0.06% and in pyridine it is 1.3%. [Baer and Kates J Am Chem Soc 72 942 1950; Baer and Maurakas J Am Chem Soc 74 158 1952; IR: Marinetti and Stotz J Am Chem Soc 76 1347 1954.]

1-(3-Dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (l-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride) see entry on p. 212 in Chapter 4.

1,2-Dimyristoyl-sn-glycero-3-phosphocholine monohydrate (dimyristoyl-L-α-lecithin) [18194-24-6] M 696.0, [α]_D^20 ~ +70° (c 8, EtOH-CHCl₃ 1:1 for α₁ form), pK_{Est(-)} ~ 5.8 (PO₄). Three forms α₁, α₂ and β'. Recryst from aqueous EtOH or EtOH-Et₂O. Solubility at 22-23° in Et₂O is 0.03%, in Me₂CO it is 0.06% and in pyridine it is 1.3%. [Baer and Kates J Am Chem Soc 72 942 1950; Baer and Maurakas J Am Chem Soc 74 158 1952; IR: Marinetti and Stotz J Am Chem Soc 76 1347 1954.]

1,2-Dimyristoyl-sn-glycero-3-phosphoethanolamine (dimyristoyl-α-cephalin) [998-07-2] M 635.9, m 207°, pK_{Est(1)} ~ 5.8 (PO₄H), pK_{Est(2)} ~ 10.5 (NH₂). Recryst from EtOH [Bevan and Malkin J Chem Soc 2667 19511.

The S-isomer with 1H₂O is recryst from 2,6-dimethylheptan-4-one and has m 226-227° (sintering at 90-95°), and [α]_D^20 ~ -70° (c 6, MeOH-CHCl₃ 1:1). [Baer and Martin J Biol Chem 193 835 1951.]

1,2-Dimyristoyl-sn-glycero-3-phosphoethanolamine (dimyristoyl-α-cephalin) [998-07-2] M 635.9, m 207°, pK_{Est(1)} ~ 5.8 (PO₄H), pK_{Est(2)} ~ 10.5 (NH₂). Recryst from EtOH [Bevan and Malkin J Chem Soc 2667 19511.

1,2-Dimyristoyl-sn-glycero-3-phosphoethanolamine (dimyristoyl-α-cephalin) [998-07-2] M 635.9, m 207°, pK_{Est(1)} ~ 5.8 (PO₄H), pK_{Est(2)} ~ 10.5 (NH₂). Recryst from EtOH [Bevan and Malkin J Chem Soc 2667 19511.

1,2-Dipalmitin [761-35-3] M 568.9, m 68-69° [α]_D^20 ~ +2.9° (c 8, CHCl₃), [α]_2540 ~ +1.0° (c 10, CHCl₃). Recryst from chloroform/pet ether. [Bevan and Malkin J Chem Soc 2667 1951.]

B-Dipalmitoyl-sn-glycero-3-phosphatidic acid [7091-44-3] M 648.9, +4° (c 10, CHCl₃), pK_{Est(-)} ~ 1.6, pK_{Est(2)} ~ 6.1. Recryst from Me₂CO at low temp. At 21° it is soluble in C₆H₆ (4.2%), pet ether (0.01%), MeOH (2%), EtOH (2.5%), AcOH (1.3%), Me₂CO (1.76%), and Et₂O (1.5%). [Baer J Biol Chem 189 235 1951.

R-Dipalmitoyl-sn-glycero-3-phosphatidic acid [7091-44-3] M 648.9, +4° (c 10, CHCl₃), pK_{Est(-)} ~ 1.6, pK_{Est(2)} ~ 6.1. Recryst from Me₂CO at low temp. At 21° it is soluble in C₆H₆ (4.2%), pet ether (0.01%), MeOH (2%), EtOH (2.5%), AcOH (1.3%), Me₂CO (1.76%), and Et₂O (1.5%). [Baer J Biol Chem 189 235 1951.


1,2-Distearoyl-sn-glycerol [1429-59-0] M 625.0. The dl-form recrystallises from CHCl₃-pet ether (b 40-60°), m 59.5° (α form) and 71.5-72.5° (β form). Recryst from solvents (e.g. EtOH, MeOH, toluene, Et₂O) gives the higher melting form and resolidification gives the lower melting forms. [IR: Chapman J Chem Soc 4680 1958, 2522 1956.] The S-isomer is recryst from CHCl₃-pet ether and has m 76-77°, [α]_D^20 ~ -2.8° (c 6, CHCl₃). [Baer and Kates J Am Chem Soc 72 942 1950.]

1,2-Distearoyl-sn-glycero-3-phosphoethanolamine (distearoyl-α-kephalin) [1069-79-0] M 748.1, m 180-182° (R-form, sintering at 130-135°), m 196° (α form), pK_{Est(1)} ~ 5.8 (PO₄H), pK_{Est(2)} ~ 10.5 (NH₂). The R-form is recryst from CHCl₃-MeOH and the ±-form is recryst from EtOH. [Bevan and Malkin J Chem Soc 2667 1951; Baer Can J Biochem Physiol 81 1758 1959.]
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Dolichol (from pig liver) \[\text{C}_{86}^\text{C}_{105}\text{poly}^\text{pre}^\text{nol}\]. Cryst 6 times from pet ether/EtOH at -20°C. Ran as entity on a paper chromatogram on paraffin impregnated paper, with acetone as the mobile phase. [Burgos Biochem J 88 470 1963.]

Domoic acid \[\text{[4-(2-carboxyhexa-3,5-dienyl)-3-carboxymethylproline]}\] \[\text{M 311.3, m} 215^\circ, 217^\circ, \alpha\text{C}^{128} - 108^\circ \text{ (c 1, H}_{2}\text{O)}, \text{pK}_{1} 2.20 (\text{2-CO}_{2}\text{H}), \text{pK}_{2} 3.72 (\text{CO}_{2}\text{H}), \text{pK}_{3} 4.93 (3-\text{CH}_{2}\text{CO}_{2}\text{H}), \text{pK}_{4} 9.82 (\text{NH})\]. The acid (~300 mg) is purified on a Dowex 1 column (3.5 x 40 mm, 200-400 mesh, acetate form), washed with H_{2}O until neutral, then eluted with increasing concentrations of AcOH (8L) from 0 to 0.25M. The fraction containing domoic acid (in 50mL) is collected, evaporated to dryness under reduced pressure and recryst from aqueous EtOH. Glutamate and Kainate receptor agonist. [Impellizzeri et al. Phytochemistry 14 1549 1975; Takemoto and Diago Arch Pharm 293 627 1960.]

DNA (deoxyribonucleic acids). The essential structures of chromosomes are DNA and contain the genetic "blue print" in the form of separate genes. They are made up of the four deoxyribonucleic acids (nucleotides): adenylic acid, guanylic acid, cytidylic acid and thymidylic acid (designated A, G, C, T respectively) linked together by their phosphate groups in ester bonds between the 3' and 5' hydroxy groups of the 2'-deoxy-D-ribose moiety of the nucleotides. The chains form a double stranded spiral (helix) in which the two identical nucleotide sequences run antiparallel with the heterocyclic bases hydrogen bonded (A..T, G..C) forming the "ladder" between the strands. Short sequences of DNA are available commercially, are commercially custom made or synthesised in a DNA synthesiser and purified by HPLC. Their purity can be checked by restriction enzyme cleavage followed by gel electrophoresis, or directly by gel electrophoresis or analytical HPLC. Commercial DNAs are usually pure enough for direct use but can be further purified using commercially available kits involving binding to silica or other matrices and eluting with tris buffers.

Dopamine-β-hydroxylase (from bovine adrenal medulla) \[\text{M}_{r} \sim 290,000, [EC 1.14.17.1].\] The Cu-containing glycoprotein enzyme has been isolated by two procedures. The first is an elaborate method requiring extraction, two (NH_{4})_{2}SO_{4} fractionations, calcium phosphate gel filtration, EtOH fractionation, DEAE-cellulose chromatography followed by two Sephadex-G200 gel filtrations giving enzyme with a specific activity of 65 Units/mg. [Friedman and Kaufman J Biol Chem 240 4763 1965; Rush et al. Biochem Biophys Res Commun 61 38 1974.] The second procedure is much gentler and provides good quality enzyme. Sedimented chromaffin vesicles were lysed in 10 volumes of 5mM K-phosphate buffer pH 6.5 using a loosely fitting Teflon-glass homogeniser. The mixture is centrifuged at 40,000xg/0.5 h and the supernatant is diluted with an equal volume of 100mM phosphate buffer (pH 6.5) containing 0.4M NaCl. This lysate is applied to a concanavalin A-Sepharose column (4 x 0.7cm) which had been equilibrated with 50 mM of phosphate buffer (pH 6.5 + 0.2M NaCl) with a flow rate of ~ 0.3 mL/min. The column is washed thoroughly with the buffer until OD_{280nm} is 0.005. The enzyme is then eluted with the same buffer containing 10% α-methyl-D-mannoside (flow rate 0.1 mL/min) and the enzyme is collected in twenty column volumes. The pooled eluate is concentrated by ultrafiltration in an Amicon Diaflo stirrer cell using an XM100A membrane. The concentrated enzyme is dialysed against 50 mM phosphate buffer (pH 6.5) containing 0.1% NaCl. The enzyme gives one band (+ two very weak band) on disc gel electrophoresis indicating better than 93% purity (67% fold purification) and has a specific activity of 5.4Units/mg. [Rush et al. Biochem Biophys Res Commun 57 1301 1974; Stewart and Klinman Ann Rev Biochem 57 551 1988.]

Ellipticin e \[[5,11-dimethylpyrido[4,3:b]carbazole]\] \[\text{M} 246.3, \text{m} 311-315^\circ, 312-314^\circ, \text{pK} 5.78 (80\% \text{aq methoxyethanol})\]. This DNA intercalator is purified by recryst from CHCl_{3} or MeOH and dried in vacuo. The UV \(\lambda_{\text{max}}\) values in aqueous EtOH-HCl are at 241, 249, 307, 335 and 426nm. [Marini-Bettolo and Schmutz Helv Chim Acta 42 2146 1959.] The methiodide has m 360°(dec), with UV \(\lambda_{\text{max}}\) (EtOH-KOH) 223, 242, 251, 311, 362 and 432nm. [Goodwin et al. J Am Chem Soc 81 1903 1959.]

Enniatin A \[\text{M} 681.9, \text{m} 122-122.5^\circ, \text{[a]} D^{18} - 92^\circ \text{ (c 0.9, CHCl}_{3}\). A cyclic peptidic ester antibiotic which is recryst from EtOH/water but is deactivated in alkaline soln. [Ovchinnikov and Ivanov in The Proteins (Neurath and Hill eds) Academic Press, NY, Vol V pp. 365 and 516 1982.]
(-)-Ephedrine (1R,2S-2-methylamino-1-phenylpropanol) [299-42-3] M 165.2, m -34°, 36°, 38.1°, b 126-129°/76mm, 225-227°/760mm, d2 1.0085, [α]D2 +15.1° (c 4, 3% HCl), [α]D2 +15.1° (c 0.8, H2O), -9.36° (c 3, MeOH), pK2 9.58 (pK5 8.84 in 80% aq methoxyethanol). Purified by vacuum distn (dehydrates) and forms waxy crystals or granules, and may pick up 0.5 H2O. The presence of H2O raises its m to 40°. [Moore and Taber J Amer Pharm Soc 24 211 1935.] The anhydrous base recrystd from dry ether [Fleming and Saunders J Chem Soc 4150 1955.] It gradually decomposes on exposure to light and is best stored in an inert atmosphere in the dark (preferably at -20°). Sol in H2O in 5%, in EtOH it is 1% and it is soluble in CHCl3, Et2O and oils. It has pKa values in H2O of 10.25 (0°) and 8.69 (60°) [Everett and Hyne J Chem Soc 1136 1958; Prelog and Häflinger Helv Chim Acta 33 2021 1950] and pKα25 8.84 in 80% aqueous methoxyethanol [Simon Helv Chim Acta 41 1835 1958]. The hydrochloride has m 220° (from EtOH-Et2O) and [α]D20 -38.8° (c 2, EtOH). [IR: Chatten and Levi Anal Chem 31 1581 1959.] The anhydrous base crystallises from Et2O [Fleming and Saunders J Chem Soc 4150 1955].

(+)-Ephedrine hydrochloride (1S-2R-2-methylamino-1-phenylpropan-1-ol hydrochloride) [24221-86-1] M 201.7, m 216-219°, [α]D2 +34° (c 11.5, H2O). Recrystd from EtOH-Et2O. The free base recrystallises from CH6 with m 40-41° [Skita et al. Chem Ber 66 974 1933].

Erythromycin A [114-07-8] M 733.9, m 133-135°(dec), 135-140°, 137-140°, [α]D2 +75° (c 2, EtOH), pK2 8.9. It recrystallises from H2O to form hydrated crystals which melt at ca 135-140°, resolidifies and melts again at 190-193°. The m after drying at 56°/12-13mm is that of the anhydrous material at 137-140°. Its solubility in H2O is 17% in EtOH, 25% in Et2O, 20% in CHCl3-hexane or 80% EtOH. It is stable in air and insoluble in H2O and is ppted by digitonin. UV λmax at 225 and 280 nm. [Oppolzer and Roberts Helv Chim Acta 63 1703 1980.]

β-Estradiol (1,3,5-estratrien-3,17β-diol) [50-28-2] M 272.4, m 173-179°, 176-178°, [α]D2 +76° to +83° (c 1, dioxane). Purified by chromatography on Si02 (toluene-EtOAc 4:1) and recrystd from CHCl3-hexane or 80% EtOH. It is stable in air and insoluble in H2O and is ppted by digitonin. UV λmax at 225 and 280 nm. [Oppolzer and Roberts Helv Chim Acta 63 1703 1980.]

β-Estradiol-6-one (1,3,5-estratriene-3,17β-diol-6-one) [571-92-6] M 359.4, m 278-280°, 281-283°, [α]D2 +4.2° (c 0.7, EtOH). It forms plates from EtOH. The 3,17-diacetate has m 173-175° after recrystn from aqueous EtOH. [Longwell and Wintersteiner J Biol Chem 133 219 1940.] The UV has λmax of 255 and 326nm in EtOH [Slaunwhite et al. J Biol Chem 191 627 1951].


Ethenoxyquin (1,2-dihydro-6-ethoxy-2,2,4-trimethylquinoline) [91-53-7] M 272.3, b 169°/12-13mm, d4 1.000, pK6 EtOH ~ 5.8. Purified by fractional distn in vacuo and solidifies to a glass. [Knoevenagel Chem Ber 54 1723, 1730 1921.] The methiodide has m 179° (from EtOH) and the 1-phenylcarbamoyl derivative has m 146-147° (from EtOH). [Beaver et al. J Am Chem Soc 79 1236 1957.]

17-α-Ethenylestradiol [57-63-6] M 296.4, m 141-146°, 145-146°, [α]D20 +4° (c 1, CHCl3). It forms a hemihydrate on recrystn from MeOH-H2O. It dehydrates on melting and re-melts on further heating at m 182-184°. UV λmax at 281nm (c 2040) in EtOH. Solubility is 17% in EtOH, 25% in Et2O, 20% in Me2CO, 25% in dioxan and 5% in CHCl3. [Petit and Muller Bull Soc Chim Fr 121 1951.] The diacetyl derivative has m 143-144° (from MeOH) and [α]D20 +1° (c 1, CHCl3) [Mills et al. J Am Chem Soc 80 6118 1958].

Exonucleases. Like the endonucleases they are restriction enzymes which act at the 3' or 5' ends of linear DNA by hydrolysing off the nucleotides. Although they are highly specific for hydrolysing nucleotides at the 3' or 5' ends of linear DNA, the number of nucleotides cleaved are time dependent and usually have to be estimated from the time allocated for cleavage. Commercially available exonucleases are used without further purification.
**Farnesol** *(trans-trans-3,7,11-trimethyl-2,6,10-dodecatrien-1-ol)* [106-28-5] M 222.4, b 111°/0.35mm, 126-127°/0.5mm, 142-143°/2mm, d_20^0 0.8871, n_0^2 1.4870. Main impurity is the cis-trans isomer. Purified by gas chromatography using a 4ft x 0.125in 3%OV-1 column at 150°. [Corey et al. *J Am Chem Soc* 92 6637 1970; Popjak et al. *J Biol Chem* 237 56 1962.] Also purified through a 14-in Podbielniak column at 110°/0.35mm (see p. 141). Alternatively it has been purified by gas chromatography using SP96 silicone on Fluoropak columns or Carbowax 20M on Fluoropak or base-washed 30:60 firebrick (to avoid decomp of alcohol, prepared by treating the firebrick with 5N NaOH in MeOH and washed with MeOH to pH 8) at 210° with Helium carrier gas at 60 m/min flow rate. The *diphenylcarbamoyl* derivative has m 61-63° (from MeOH) and has IR band at 3500 cm⁻¹. [Bates et al. *J Org Chem* 28 1086 1963.]

**Farnesyl pyrophosphate** [13058-04-3; E,E: 372-97-4] M 382.3, pK_{EtH(1)}<2, pK_{EtH(2)}<2, pK_{EtH(3)}=3.95, pK_{EtH(4)}=6.26. Purified by chromatography on Whatman No3 MM paper in a system of isopropanol-isobutanol-ammonia-water (40:20:1:30) (v/v). Stored as the Li or NH₄ salt at 0°.

**Ferritin (from human placenta)** [9007-73-2] M_r ~445,000 (Fe free protein). The purification of this major iron binding protein was achieved by homogenisation in water and precipitating with ammonium sulfate, repeating the cycle of ultracentrifuging and molecular sieve chromatography through Sephadex 4B column. Isoelectric focusing revealed a broad spectrum of impurities which were separated by ion-exchange chromatography on Sephadex A-25 and stepwise elution. [Konijn et al. *Anal Biochem* 144 423 1985.]

**Fibrinogen (from human plasma)** [9001-32-5] M_r 341,000. A protein made up of 2Aa,2Bβ and 2γ subunits connected by disulphide bridges. Possible impurity is plasminogen. Purified by glycine pptn [Mosesson and Sherry *Biochemistry* 5 2829 1966] to obtain fractions 1-2, then further purified [Blombäck and Blombäck *Arkiv Kemi* 10 415 1956] and contaminating plasminogen is removed by passage through a lysine-Sepharose column. Such preparations were at least 95% clottable as determined by Mosesson and Sherry's method (above ref.) in which the OD₂₈₀ was measured before and after clotting with 5 Units/mL of thrombin (> 3000U/mg). All fibrinogen preps were treated with calf intestinal alkaline phosphatase to convert any fibrinogen peptide-AP to fibrinogen peptide-A by removing serine-bound phosphate. Solutions are then lyophilised and stored at -20°. [Higgins and Shafer *J Biol Chem* 256 12013 1981.] It is sparingly soluble in H₂O. Aqueous solns are viscous with isoelectric point at pH 5.5. Readily denatured by heating above 56° or by chemical agents, e.g. salicylaldehyde, naphthoquinone sulfonates, ninhydrin or alloxan. [Edsall et al. *J Biol Chem* 237 5728 1962; Lorand and Middlebrook *Science* 118 515 1953; cf. Fuller in *Methods Enzymol* 163 474 1988.]

For plasminogen-deficient fibrinogen from blood plasma, the anticoagulated blood was centrifuged and the supernatant is discarded and the ppt is dissolved in 0.25M Tris-phosphate buffer (pH 7.0) and ppted by adding EtOH to 16% (v/v) at -40°. The ppt is centrifuged off, washed with small portions of cold EtOH, then with cold, peroxide-free diethyl ether. It is dried in the dark under vacuum over P₂O₅ at 50-60°. The uranyl complex is suspended in H₂O. Aqueous solns are viscous with isoelectric point at pH 5.5. Readily denatured by heating above 56° or by chemical agents, e.g. salicylaldehyde, naphthoquinone sulfonates, ninhydrin or alloxan. [Edsall et al. *J Biol Chem* 237 5728 1962; Lorand and Middlebrook *Science* 118 515 1953; cf. Fuller in *Methods Enzymol* 163 474 1988.]

**Flavin adenine dinucleotide (di-Na, 2H₂O salt, FAD)** [146-14-5] M 865.6, [α]_s46 -54° (c 1, H₂O). Small quantities, purified by paper chromatography using tert-buylalcohols/water, cutting out the main spot and eluting with water. Larger amounts can be ppted from water as the uranyl complex by adding a slight excess of uranyl acetate to a soln at pH 6.0, dropwise and with stirring. The soln is set aside overnight in the cold, and the ppt is centrifuged off, washed with small portions of cold EtOH, then with cold, peroxide-free diethyl ether. It is dried in the dark under vacuum over P₂O₅ at 50-60°. The uranyl complex is suspended in water and, after adding sufficient 0.1M NaOH to adjust the pH to 7, the ppt of uranyl hydroxide is removed by
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centrifugation [Huennekens and Felton Methods Enzymol 3 954 1957]. It can also be crysized from water. Should be kept in the dark. More recently it was purified by elution from a DEAE-cellulose (Whatman DE 23) column with 0.1M phosphate buffer pH 7, and the purity was checked by TLC. [Holt and Cotton, J Am Chem Soc 109 1841 1987.]

Flavin mononucleotide (Na, 2H2O salt, FMN) [130-40-5] M 514.4, pK1 2.1 (PO4H2), pK2 6.5 (PO4H+), pK3 10.3 (CONH), fluorescence λmax 530nm (870nm for reduced form). Purified by paper chromatography using tert-butanol-water, cutting out the main spot and eluting with water. Also purified by adsorption onto an apo-flavodoxin column, followed by elution and freeze drying. Crystd from acidic aqueous soln. [Mayhew and Strating Eur J Biochem 59 539 1976.]

4-Fluoro-7-nitrobenzofurazan (4-fluoro-7-nitrobenzo-2-oxa-1,3-diazole) [29270-56-2] M 183.1, m 52.5-53.5°, 53.5-54.5°. Purified by repeated recrystn from pet ether (b 40-60°). On treatment with MeONa in MeOH it gave 4-methoxy-7-nitrobenzo-2-oxa-l,3-diazole m 115-116°. [Nunno et al. J Chem Soc (C) 1433 1970.]

It is a very good fluorophore for amino acids [Imai and Watanabe Analyt Chim Acta 130 377 1981], as it reacts with primary and secondary amines to form fluorescent adducts with λmax 470nm and λem 530nm. It gives a glycine derivative with m 185-187° [Miyano et al. Anal Chim Acta 170 81 1985].

4-Fluoro-3-nitrophenylazide [28166-06-5] M 182.1, m 53-55°, 54-56°. Dissolve in Et2O, dry over MgSO4, filter, evaporate and recryst the residue from pet ether (b 20-40°) to give orange needles. Store in a stoppered container at -10°. The NMR has δ 7.75 (m 1H) and 7.35 (m 2H) in CDC13. [Hagedorn et al. J Org Chem 43 2070 1978.]

2-Fluorophenylalanine [R(+)- 97731-02-7; S(-) - 19883-78-4] M 183.2, m 226-232°, 231-234°, [α]D25 (+) and (-) 15° (c 2, H2O pH 5.5), pK1 24.12, pK2 9.01. Recryst from aqueous EtOH. The hydrochloride has m 226-231°(dec), and the N-acetyl derivative has m 147-149° (from aqueous EtOH). [Bennett and Nieman J Am Chem Soc 72 1800 1950.]

4-Fluoro-3-nitrophenylazide [28166-06-5] M 182.1, m 53-55°, 54-56°. Dissolve in Et2O, dry over MgSO4, filter, evaporate and recryst the residue from pet ether (b 20-40°) to give orange needles. Store in a stoppered container at -10°. The NMR has δ 7.75 (m 1H) and 7.35 (m 2H) in CDC13. [Hagedorn et al. J Org Chem 43 2070 1978.]


Fluram (Fluorescamine, 4-phenyl-spiro[furan-2(3H)-1-phthalan]-3,3'-dione) [38183-12-9] M 278.3, m 153-155°, 154-155°. A non-fluorescent reagent that reacts with primary amines to form highly fluorescent compounds. Purified by dissolving (-lg) in Et2O-C6H6 (l:l, 180 mL), wash with 1% aq NaHCO3 (50mL), dry (Na2SO4), evaporate in a vacuum. Dissolve the residue in warm CH2Cl2 (5mL), dilute with Et2O (12mL) and sublimed at 190-200/0.1mm or 210-230/0.5mm. UV: λmax 265-266nm (c 7070). [Barton et al. J Org Chem 37 329 1972; Duschinsky and Pleven J Am Chem Soc 79 4559 1957.]

Fluram (Fluorescamine, 4-phenyl-spiro[furan-2(3H)-1-phthalan]-3,3'-dione) [38183-12-9] M 278.3, m 153-155°, 154-155°. A non-fluorescent reagent that reacts with primary amines to form highly fluorescent compounds. Purified by dissolving (-lg) in Et2O-C6H6 (1:1, 180 mL), wash with 1% aq NaHCO3 (50mL), dry (Na2SO4), evaporate in a vacuum. Dissolve the residue in warm CH2Cl2 (5mL), dilute with Et2O (12mL) and sublimed at 190-200/0.1mm or 210-230/0.5mm. UV: λmax 265-266nm (c 7070). [Barton et al. J Org Chem 37 329 1972; Duschinsky and Pleven J Am Chem Soc 79 4559 1957.]

Fluram (Fluorescamine, 4-phenyl-spiro[furan-2(3H)-1-phthalan]-3,3'-dione) [38183-12-9] M 278.3, m 153-155°, 154-155°. A non-fluorescent reagent that reacts with primary amines to form highly fluorescent compounds. Purified by dissolving (-lg) in Et2O-C6H6 (l:l, 180 mL), wash with 1% aq NaHCO3 (50mL), dry (Na2SO4), evaporate in a vacuum. Dissolve the residue in warm CH2Cl2 (5mL), dilute with Et2O (12mL) and sublimed at 190-200/0.1mm or 210-230/0.5mm. UV: λmax 265-266nm (c 7070). [Barton et al. J Org Chem 37 329 1972; Duschinsky and Pleven J Am Chem Soc 79 4559 1957.]

Fluram (Fluorescamine, 4-phenyl-spiro[furan-2(3H)-1-phthalan]-3,3'-dione) [38183-12-9] M 278.3, m 153-155°, 154-155°. A non-fluorescent reagent that reacts with primary amines to form highly fluorescent compounds. Purified by dissolving (-lg) in Et2O-C6H6 (l:l, 180 mL), wash with 1% aq NaHCO3 (50mL), dry (Na2SO4), evaporate in a vacuum. Dissolve the residue in warm CH2Cl2 (5mL), dilute with Et2O (12mL) and sublimed at 190-200/0.1mm or 210-230/0.5mm. UV: λmax 265-266nm (c 7070). [Barton et al. J Org Chem 37 329 1972; Duschinsky and Pleven J Am Chem Soc 79 4559 1957.
Folic acid (FA, pteroyl-S-glutamic acid) \([75708-92-8]\) M 441.4, m >250º (dec), \([\alpha]D^{25} +23º\) (c 0.5, 0.1N NaOH), \(pK_1\) 2.35 (protonation N10), \(pK_2\) 2.75 (protonation N1), \(pK_3\) 3.49 (\(\alpha\)-CO\(_2\)H), \(pK_4\) 4.65 (\(\gamma\)-CO\(_2\)H), \(pK_5\) 8.80 (acidic N3). If paper chromatography indicates impurities then recrystallise from hot H\(_2\)O or from dilute acid [Walker et al. J Am Chem Soc 70 19 1948]. Impurities may be removed by repeated extraction with n-BuOH of a neutral aqueous soln of folic acid (by suspending in H\(_2\)O and adding N NaOH till the solid dissolves then adjusting the pH to -7.0-7.5) followed by pptn with acid, filtration, and recrystn form hot H\(_2\)O. [Blakley Biochem J 65 331 1975; Kalifa, Furrer, Bieri and Viscontini Helv Chim Acta 61 2739 1978.] Chromatography on cellulose followed by filtration through charcoal has also been used to obtain pure acid. [Sakami and Knowles Science 129 274 1959.] UV: \(\lambda_{max}\) 247 and 296nm (\(E\) 12800 and 18700) in H\(_2\)O pH 1.0; 282 and 346nm (\(E\) 27600 and 7200) in H\(_2\)O pH 7.0; 256, 284 and 366nm (\(E\) 24600, 24500 and 8600) in H\(_2\)O pH 13 [Rabinowitz in The Enzymes (Boyer et al. Eds 2 185 1960)].

Follicle Stimulating Hormone (FSH, follitropin) \([9002-68-0]\) M \(~36,000\). Purified by Sephadex G100 gel filtration followed by carboxymethyl-cellulose with NH\(_4\)OAc pH 5.5. The latter separates luteinising hormone from FSH. Solubility in H\(_2\)O is 0.5%. It has an isoelectric point of 4.5. A soln of 1mg in saline (100mL) can be kept at 60º for 0.5h. Activity is retained in a soln at pH 7-8 for 0.5h at 75º. The activity of a 50% aq EtOH soh is destroyed at 60º in 15 min. [Bloomfield et al. Biochim Biophys Acta 533 371 1978; Hartree Biochem J 100 754 1966; Pierce and Parsons Ann Rev Biochem 50 465 1981.]

Fructose-1,6-diphosphate (trisodium salt) \([38099-82-0]\) M 406.1, \(pK_1^{25} 6.14, pK_2^{25} 6.93\) (free acid). For purification via the acid strychnine salt, see Neuberg, Lustig and Rothenberg [Arch Biochem 3 33 1943]. The calcium salt can be partially purified by soln in ice-cold M HCl (1g per 10mL) and repptn by dropwise addition of 2M NaOH: the ppte and supernatant are heated on a boiling water bath for a short time, then filtered and the ppte is washed with hot water. The magnesium salt can be pptd from cold aqueous soln by adding four volumes of EtOH.

Fructose-6-phosphate \([643-13-0]\) M 260.1, \([\alpha]D^{11} +2.5\) (c 3, H\(_2\)O), \(pK_2^{25} 5.84\). Crystd as the barium salt from water by adding four volumes of EtOH. The barium can be removed by passage through the H\(^+\) form of a cation exchange resin and the free acid collected by freeze-drying.

6-Furfurylaminopurine (Kinetin) \([525-79-1]\) M 215.2, m 266-267º, 269-271º, 270-272º, 272º (sealed capillary), \(pK_1^{1} <1, pK_2 3.8, pK_3 10\). Platelets from EtOH and sublimes at 220º, but is best done at lower temperatures in a good vacuum. It has been extracted from neutral aqueous solns with Et\(_2\)O. [Miller et al J Am Chem Soc 75 3375 1953; Bullock et al. J Am Chem Soc 78 3693 1956.]

Fusaric acid (5-n-butyldpyridine-2-carboxylic acid) \([536-69-6]\) M 179.2, m 96-98º, 98º, 98-100º, 101-103º, \(pK_1 5.7, pK_2 6.16\) (80% aq methoxyethanol). Dissolve in CHCl\(_3\), dry (Na\(_2\)SO\(_4\)), filter, evaporate and recrystallise the residue from 50 parts of pet ether (b 40-60º) or EtOAc, then sublime in vacuo. The copper salt forms bluish violet crystals from H\(_2\)O and has m 258-259º. [Hardegger and Nikles Helv Chim Acta 39 505 1956; Schreiber and Adam Chem Ber 93 1848 1960; NMR and MS: Tschesche and Führer Chem Ber 111 3500 1978.]

Fuschin (Magenta I, rosaniline HCl) \([632-99-5]\) M 337.9, m >200º (dec). See rosaniline hydrochloride on p. 349 in Chapter 4.

D-Galactal \([21193-75-9]\) M 146.2, m 100º, 100-102º, 104º, 103-106º, \([\alpha]D^{20} -21.3º\) (c 1, MeOH). Recryst from EtOAc, EtOH or EtOAc + MeOH. [Overend et al. J Chem Soc 675 1950; Wood and Fletcher J Am Chem Soc 79 3234 1957; Distler and Jourdian J Biol Chem 248 6772 1973.]
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Gangcyclovir [9-{(1,3-dihydroxy-2-propoxy)methyl}guanidine; 2-amino-1,9-{(2-hydroxy-1-hydroxymethyl)-ethoxymethyl}-6H-purin-6-one; Cytothene; Cymevan(e)(e)] [82410-32-0] M 255.2, m >290° (dec), >300° (dec), monohydrate m 248-249° (dec), pK_{Est}(1)- -1.1, pK_{Est}(2)- 9.7. Recryst from MeOH. Alternatively dissolve ~90g of reagent in 700mL of distilled H_2O, filter and cool (ca 94% recovery). UV: λ_{max} in MeOH 254nm (ε 12,880), 270sh nm (ε 9040), solubility in H_2O at 25° is 4.3mg/mL at pH 7.0. ANTIVIRAL. [Ogilvie et al. Can J Chem 60 3005 1982; Ashton et al. Biochem Biophys Res Commun 108 1716 1982; Martin et al. J Med Chem 26 759 1983.]

Geranylgeranyl pyrophosphate [6699-20-3 (NH_4 salt)] M 450.5, pK_{Est}(1)- <2, pK_{Est}(2)- <2, pK_{Est}(3)- 3.95, pK_{Est}(4)- 6.26. Purified by counter-current distribution between two phases of a butanol/isopropyl ether/ammonia/water mixture (15:5:1:19) (v/v), or by chromatography on DEAE-cellulose (linear gradient of 0.02M KCl in 1mM Tris buffer, pH 8.9). Stored as a powder at 0°.

Geranyl pyrophosphate [763-10-0 (NH_4 salt)] M 314.2, pK_{Est}(1)- <2, pK_{Est}(2)- <2, pK_{Est}(3)- 3.95, pK_{Est}(4)- 6.26. Purified by paper chromatography on Whatman No 3 MM paper in a system of isopropyl alcohol/isobutyl alcohol/ammonia/water (40:20:1:39), RF 0.77-0.82. Stored in the dark as the ammonium salt at 0°.

Gitoxigenin (3β,14,16β,21-tetrahydroxy-20(22)norcholenic acid lactone) [545-26-6] M 390.5, m 223-226°, 234°, 239-240° (anhdyrous by drying at 60°), [α]_{D}^{20} +30° (c 1, MeOH). Recryst from aqueous EtOH produces plates of the sesquihydrate which dehydrate on drying at 100° in vacuo. It has also been recrystd from Me_2CO-MeOH and from EtOAc the crystals contain 1 mol of EtOAc with terminal thio-β-galactopyranosyl residues. [Distler and Jourdan J Biol Chem 248 6772 1973.]

Gliotoxin (3R-6-hydroxy-3-hydroxymethyl-2-methyl-(5α)-1,2,3,6,10-tetrahydro-5αH-3,10-epidisulfido[1,2-a]indol-1,4-dione) [67-99-2] M 326.4, m 191-218° (dec), 220° (dec), 221° (dec), [α]_{D}^{20} -254° (c 0.6, CHCl_3), [α]_{D}^{20} +270° (c 1.7, pyridine). Purified by recryst from MeOH. Its solubility in CHCl_3 is 1%. The dibenzoyl derivative has m 203° (from CHCl_3-MeOH). [Glister and Williams Nature 153 651 1944; Elvidge and Spring J Chem Soc Suppl 135 1949; Johnson et al. J Am Chem Soc 65 2005 1943; Bracken and Raisrick Biochem J 41 569 1947.]

Glucose oxidase (from Aspergillus niger) [9001-37-0] M_/ 186,000, [EC 1.1.3.4]. Purified by dialysis against deionized water at 6° for 48hours, and by molecular exclusion chromatography with Sephadex G-25 at room temperature. [Holt and Cotton J Am Chem Soc 109 1841 1987.]

Glucose-1-phosphate [59-56-3] M 260.1, [α]_{D}^{25} +120° (c 3, H_2O), [α]_{D}^{10} +78° (c 4, H_2O of di-K salt), pK_1 1.1, pK_2 6.13 [pK_{25} 6.50]. Two litres of 5%aq soln was brought to pH 3.5 with glacial acetic acid (+ 3g of charcoal, and filtered). An equal volume of EtOH was added, the pH was adjusted to 8.0 (glass electrode) and the soln was stored at 3° overnight. The ppt was filtered off, dissolved in 1.2L of distilled water, filtered and an equal volume of EtOH was added. After standing at 0° overnight, the crystals were collected at the centrifuge, and washed with 95% EtOH, then absolute EtOH, ethanol/diethyl ether (1:1), and diethyl ether. [Sutherland and Wosilait, J Biol Chem 218 459 1956.] Its barium salt can be freed from metal impurities by passage of an aqueous soln of Na salt is 5% in H_2O at 20°. Its barium salt can be purified by solution in dilute HCl and pptn by neutralising the soln. The ppt is washed with small volumes of cold water and dried in air.

Glucose-6-phosphate [acid 156-73-5; Ba salt 58823-95-3; Na salt 54010-71-8] M 260.1, m 205-207° (dec) mono Na salt, [α]_{D}^{24} -1° (c 5, H_2O), pK_1 1.65, pK_2 6.11, pK_{25} 11.71 [C_1(OH)O^-]. Can be freed from metal impurities as described for glucose-1-phosphate. Sol of Na Salt is 5% in H_2O at 20°. Its barium salt can be purified by solution in dilute HCl and pptn by neutralising the soln. The ppt is washed with small volumes of cold water and dried in air.
Glucose-6-phosphate dehydrogenase [9001-40-5] Mr 128,000 (from Baker's yeast), 63,300 (from rat mammary gland) [EC 1.1.1.49]. The enzyme is useful for measuring pyridine nucleotides in enzyme recycling. The enzyme from Baker's yeast has been purified by (NH₄)₂SO₄ fractionation, Me₂CO pptn, a second (NH₄)₂SO₄ fractionation, concentration by DEAE-SF chromatography, a third (NH₄)₂SO₄ fractionation and recrystn. Crystn is induced by addition of its coenzyme NADP, which in its presence causes rapid separation of crystals at (NH₄)₂SO₄ concentration much below than required to ppte the amorphous pptn, a second (NH₄)₂SO₄ fractionation, concentration by DEAE-SF chromatography, a third (NH₄)₂SO₄ fractionation and recrystn. The third gel adsorbed 50% of the activity. The gel is eluted with 0.2M phosphate (pH 7.4, 40mL/g). The yeast enzyme are 20µM for G-6P and 2µM for NADP, (from rat mammary gland) [EC 1.1.1.49].

Glucose-6-phosphate dehydrogenase [9001-40-5] Mr 128,000 (from Baker's yeast), 63,300 (from rat mammary gland) [EC 1.1.1.49]. The enzyme is useful for measuring pyridine nucleotides in enzyme recycling. The enzyme from Baker's yeast has been purified by (NH₄)₂SO₄ fractionation, Me₂CO pptn, a second (NH₄)₂SO₄ fractionation, concentration by DEAE-SF chromatography, a third (NH₄)₂SO₄ fractionation and recrystn. Crystn is induced by addition of its coenzyme NADP, which in its presence causes rapid separation of crystals at (NH₄)₂SO₄ concentration much below than required to ppte the amorphous pptn, a second (NH₄)₂SO₄ fractionation, concentration by DEAE-SF chromatography, a third (NH₄)₂SO₄ fractionation and recrystn. Crystn is induced by addition of its coenzyme NADP, which in its presence causes rapid separation of crystals at (NH₄)₂SO₄ concentration much below than required to ppte the amorphous pptn, a second (NH₄)₂SO₄ fractionation, concentration by DEAE-SF chromatography, a third (NH₄)₂SO₄ fractionation and recrystn. The third gel adsorbed 50% of the activity. The gel is eluted with 0.2M phosphate (pH 7.4, 40mL/g).

The gel is added in three steps (1 SmL of 0.4% geYmL per step) and the gel is removed by centrifugation after each addn. The third gel adsorbed 50% of the activity. The gel is eluted with 0.2M phosphate (pH 7.4, 40mL/g of gel; 60% recovery). The extract is ppted in 3volumes with (NH₄)₂SO₄ (adjusted to 4M) to give enzyme with an activity of 30pmoles/mg of protein x hour. [Lowry et al. Biochemistry 57:225 1958; Biochem Prep 2 87 1952.]


Glutathione S-transferase (human liver) [50812-37-8] Mr 25,000, [EC 2.5.1.18]. Purified by affinity chromatography using a column prepared by coupling glutathione to epoxy-saturated Sepharose. After washing contaminating proteins the pure transferase is eluted with buffer containing reduced glutathione. The solution is then concentrated by ultrafiltration, dialysed against phosphate buffer at pH ~7 and stored in the presence of dithiothreitol (2mM) in aliquots at <-20°. [Simons and Vander Jag Anal Biochem 52 334 1977.]

Glycerol kinase (from Candida mycoderma, E coli, rat or pigeon liver glycerokinase) [9030-66-4] Mr 251,000, [EC 2.7.1.30]. Commercial enzyme has been dialysed against 2mM Hepes, 5mM dithiothreitol and 0.3mM EDTA, followed by several changes of 20mM Hepes and 5mM dithiothreitol prior to storage under N₂ at -20°. [Knight and Cleland Biochemistry 28 5728 1989.] The enzyme from pigeon liver was purified by acid-pptn (acetate buffer at pH 5.1), (NH₄)₂SO₄ fractionation, heat treatment (60°/ 1 h),
L-Glycerol-3-phosphate dehydrogenase (GDH, from rabbit muscle) \[9075-65-4\] M₄ 78,000 [EC 1.1.1.8]. Recrystd by adding (NH₄)₂SO₄ till 0.45 saturation at pH 5.5 and the small amount of ppte is removed then satd (NH₄)₂SO₄ is added dropwise from time to time over several days in the cold room. The crystals are collected and recrystd until they have maximum activity. The enzyme is activated by Mg²⁺ and Mn²⁺ ions and is most stable in solutions of pH 5.5-5.5 range. The stability is greatly increased in the presence of glycerol. It has Km for glycerol of 60µM and for ATP 9µM in glycine buffer pH 7.0 and 25°C. [Kennedy Methods Enzymol 5 476 1962.]

Glycine anhydride \(\text{C}_2\text{H}_4\text{O}_3\) complex \[64681-08-9\] M 257.2 \(pK_{\text{Em}} \approx 5.5\). Glycine phosphocholine is purified via the CdCl₂ complex which is purified by four recrystns from 99% EtOH by standing at 0°C for 1h. The white ppte is collected, washed with EtOH, Et₂O and dried in a vacuum. The amorphous Cd complex can be converted to the crystalline form \(\text{C}_8\text{H}_{12}\text{O}_6\text{N}_2\cdot\text{CdCl}_2\cdot3\text{H}_2\text{O}\) by dissolving 34.4g in H₂O (410mL) and 99% EtOH (165mL total) added slowly with stirring and allowing the clear soh to stand at 25°C for 12h. The crystallised complex is filtered off, washed with cold 80% EtOH and dried in air. Glycerol phosphocholine can be recovered from the complex by dissolving in H₂O (2% soln), passing through an ion-exchange column (4.9 x 100cm, of lvol IRC-50 and 2vol of IR-45). The effluent is concentrated to a thick syrup at 45°C, dried further at 50°C/P₂O₅. It can be recrystd from 99.5% EtOH, long prisms) which are hygroscopic and must be handled in a H₂O-free atmosphere [Tattie and McArthur Biochem Prep 6 16 1958; Baer and Kates J Am Chem Soc 70 1394 1948; Acta Cryst 21 79, 87 1966]. Glycodeoxycholic acid monohydrate \(\text{C}_{24}\text{H}_{40}\text{O}_{7}\cdot\text{H}_2\text{O}\) complex \[19371\] M 467.6, m 186-177°(dec), 187-188°, \([\alpha]_D^{25} +45.9°\) (c 1, EtOH), \(pK_{\text{Em}} \approx 4.4\). Recrystallises from H₂O or aqueous EtOH with 1 mol of H₂O and dried at 100°C in vacuo. Solubility in EtOH is 5%. [UV: Lindstedt and Sjövall Acta Chem Scand 11 421 1957.] The Na salt is recrystd from EtOH/Et₂O, m 245-250°, \([\alpha]_D^{23} +441.2°\) (c 1, H₂O) [Wieland Hoppe Seyler's Z Physiol Chem 106 181 1919; Cortese J Am Chem Soc 59 2532 1937].
D(+)-Glycogen [9005-79-2] M 25,000-100,000, m 270-280°(dec), [α]D25 +216° (c 5, H2O). A 5% aqueous soln (charcoal) was filtered and an equal volume of EtOH was added. After standing overnight at 3° the ppte was collected by centriugation and washed with absolute EtOH, then EtOH/diethyl ether (1:1), and diethyl ether. [Sutherland and Wosilait J Biol Chem 218 459 1956.]

Glycogen synthase (from bovine heart) [9014-56-6] M, 60,000, [EC 2.4.1.11]. Purified by pptn of the enzyme in the presence of added glycogen by polyethylene glycol, chromatography on DEAE-Sephacel and high speed centrifugation through a sucrose-containing buffer. [Dickey-Dunkirk and Kollilea Anal Biochem 146 199 1985.]

Gramicidin A (a pentadecapeptide from Bacillus brevis) [11029-61-1] m ~229-230°(dec). Purified by countercurrent distribution from C6H6-CHCl3, MeOH-H2O (15: 15:23:7) with 5000 tubes. Fractions were examined by W (280nm) of small aliquots. Separation from Gramicidin C and other material occurred after 999 transfers. [Gross and Witkop Biochemistry 4 2495 1965; Bauer et al. Biochemistry 11 3266 1972. It has characteristic [α]D20 +27.3° (c 1.3, MeOH) and UV λmax 229-230nm. Almost insoluble in H2O (0.6%) but soluble in lower alcohols, dry Me2CO, dioxane, acetic acid and pyridine. The commercial material is more difficult to crystallise than the synthetic compound. [Sarges and Witkop J Am Chem Soc 86 1861, 187 201 1, 2020 1965.]

Gramicidin C (gramicidin S, a pentadecapeptide from Bacillus brevis) [9062-61-7]. Same as Gramicidin A since they are isolated together and separated. [Sarges and Witkop Biochemistry 4 2491 1965; Hunter and Schwartz "Gramicidins" in Antibiotics I (Gotlieb and Shaw Eds) Springer-Verlag, NY, p.642 1967; as well as references above for Gramicidin A.]

Gramicidin S 2HCl (from Bacillus brevis Nagano) [15207-30-4] M 1214.4, m 277-278° (dec), [α]D24 ^289° (c 0.4, 70% ac EtOH). Cryst in prisms from EtOH + ac HCl. Gramicidin S [113-73-5] M 1141.4, m 268-270°, [α]D25 ^260° (c 0.5, EtOH + 30mM ac HCl [7:3]). Crystd from EtOH. Di-HCl [15207-30-4] crysf from EtOH (+ few drops of HCl) has m 277-278°.

N-Guanyltyramine hydrochloride [60-20-8] M 215.7, m 218°, pK1 10.2 (phenolic OH), pK2 12.4 (guanidino N). Purified on a phosphocellulose column and eluted with a gradient of aqueous NH3 (0-10%). The second major peak has the characteristic tryptamine spectrum and is collected, lyophilised to give white crystals of the dihydrate which dehydrates at 100°. It has UV λmax at 274.5nm (ε 1310) in 0.1N NaOH and 274.5nm (ε 1330) at pH 7.0. Excitation λmax is at 280nm and emission λmax is at 330nm. [Mekalanos et al. J Biol Chem 254 5849 1979.]


Harmaline (7-methoxy-1-methyl-4,9-dihydro-3H-β-carboline, 4,9-dihydro-7-methoxy-1-methyl-3H-pyrido[3,4-b]indole) [304-21-2] M 214.3, m 229-230°, 229-231°, 235-237° (after distn at 120-140°/10-3), pK1 4.2. Recrystd from MeOH and sublimed at high vacuum. It has UV in MeOH has Amax 218, 260 and 376nm (log ε 4.27, 3.90 and 4.02 respectively); IR (Nujol) v 1620, 1600, 1570 and 1535cm⁻¹ and is CHCl3 v 1470 and 1629cm⁻¹. [Spenser Can J Chem 37 1851 1959; Marion et al. J Am Chem Soc 73 305 1951; UV Prukner and Witkop Justus Liebigs Ann Chem 554 127 1942.] The hydrochloride dihydrate has m 234-236°(dec), the picrate has m 228-229° (sinters at 215°) from aqueous EtOH, and the N-acetate forms needles m 204-205°.

Hematoporphyrin (3,3’-[7,12-bis-(1-hydroxyethyl)-3,8,13,17-tetramethyl-porphyrin-2,18-diyldi-]dipropionic acid) [14459-29-1] M 598.7, pK$_{a}$ -4.8. Purified by dissolving in EtOH and adding H$_2$O or Et$_2$O to give deep red crystals. Also recrystd from MeOH. UV has $\lambda_{max}$ at 615.5, 565, 534.4 and 499.5 nm in 0.1 N NaOH, and 597, 619, 634,653, 683 and 710 nm in 2 N HCl. [Falk Porphyrins and Metalloporphyrins Elsevier, NY, p 175 1964.] It is used in the affinity chromatographic purification of Heme proteins [Olsen Methods Enzymol 123 324 1986]. The $O$-methyl-dimethyl ester has $m$ 203-206° (from CHCl$_3$/MeOH) and the $O,O'$-dimethyl-dimethyl ester has $m$ 145° (from CHCl$_3$/MeOH). [Paul Acta Chem Scand 5 389 1951.]

Hematoporphyrin dimethyl ester [33070-12-1] M 626.7, m 212°. Crystd from CHCl$_3$/MeOH.

Hematoxylin (2-11bc-7,11b-dihydroindeno[2,1-c]-chromen-3,4-6ar-9,10-pentaol) [517-28-2] M 302.3, m 212° (dec), 210-212° (dec). Recrystd from H$_2$O (as trihydrate) in white-yellow crystals which become red on exposure to light and then melt at 100-120°. It has been recrystd from Me$_2$CO-*C$_6$H$_6$. Crystd also from dil aqueous NaHSO$_3$ until colourless. Soluble in alkali, borax and glycerol. Store in the dark below 0°. [Morsingh and Robinson Tetrahedron 26 182 1970; Dann and Hofmann Chem Ber 98 1498 1955.]

Hemin (ferriprotoporphyrin IX chloride) [16009-13-5] M 652.0, m sinters at 240°, pK$_{a}$ -4.8. It is purified by recrystn from AcOH. Also heme (5g) is shaken in pyridine (25mL) till it dissolves, then CHCl$_3$ (40mL) is added, the container is stoppered and shaken for 5min (releasing the stopper occasionally). The soln is filtered under slight suction, and the flask and filter washed with a little CHCl$_3$ (15mL). During this period, AcOH (300mL) is heated to boiling and saturated aqueous NaCl (5mL) and conc HCl (4mL) are added. The CHCl$_3$ filtrate is poured in a steady stream, with stirring, into the hot AcOH mixture and set aside for 12hours. The crystals are filtered off, washed with 50% aqueous AcOH (50mL), H$_2$O (100mL), EtOH (25mL), Et$_2$O and dried in air. [Fischer Org Synth Coll Vol I 111 442 1955.]

Heparin (from pig intestinal mucosa) [9005-49-6] $M_r$ ~3,000, amorphous, [α]$_D$ +55° (H$_2$O). Most likely contaminants are mucopolysaccharides including heparin sulfate and dermatan sulfate. Purified by pptn with cetylpyridinium chloride from saturated solutions of high ionic strength. [Cifonelli and Roden Biochem Prep 12 12 1968.]

Heparin (sodium salt) [9041-08-1] $M_r$ ~3000 (low Mol Wt, Bovine), amorphous, [α]$_D$ +47° (c 1.5, H$_2$O). Dissolved in 0.1M NaCl (lg/100mL) and ppted by addition of EtOH (150mL).

Histones (from S4A mouse lymphoma). Purification used a macroprocess column, heptafluorobutyric acid as solubilising and ion-pairing agent and an acetonitrile gradient. [McCroskey et al. Anal Biochem 163 427 1987.]

Hyaluronidase [9001-54-1, 37326-33-3] $M_r$ 43,000 (bovine testes), 89,000 (bacterial), [EC 3.2.1.35]. Purified by chromatography on DEAE-cellulose prior to use. [Distler and Jourdain J Biol Chem 248 6772 1973.]

Hydrocortisone (11β,17α,21-trihydroxy-pregn-4-ene-3,20-dione) [50-23-7] M 362.5, m 212-213°, 214-217°, 218-221°, 220-222°, [α]$_D$ +167° (c 1, EtOH). Recrystd from EtOH or isoPrOH. It is bitter tasting and has UV $\lambda_{max}$ at 242 nm (log ε 4.20). Its solubility at 25° is: H$_2$O (0.28%), EtOH (1.5%), MeOH (0.62%), Me$_2$CO (0.93%), CHCl$_3$ (0.16%), propylene glycol (1.3%) and Et$_2$O (0.35%). It gives an intense green colour with conc H$_2$SO$_4$. [Wendler et al. J Am Soc Chem 72 5793 1950.]

Hydrocortisone acetate (21-acetoxy-11β,17α-trihydroxy-pregn-4-ene-3,20-dione) [50-03-3] M 404.5, m 218-221°, 221-223°, 222-225°, [α]$_D$ +166° (c 0.4, dioxane), +150° (c 0.5, Me$_2$CO). Recrystd from Me$_2$CO-Et$_2$O or aqueous Me$_2$CO as somewhat hygroscopic monoclinic crystals. UV has $\lambda_{max}$ 242 nm (A1% 390) in MeOH. Its solubility at 25° is: H$_2$O (0.001%), EtOH (0.45%), MeOH (0.04%), Me$_2$CO (1.1%), CHCl$_3$ (0.5%), Et$_2$O (0.15%) and is very soluble in Me$_2$NCHO. [Wendler et al. J Am Chem Soc 74 3630 1952; Antonucci et al. J Org Chem 18 7081 1953.]
(±)-Ibotenic acid monohydrate (α-[3-hydroxy-5-isoxazolyl]-glycine, α-amino-3-hydroxy-5-isoxazoleacetic acid) [2552-55-8] M 176.1, m 144-146° (monohydrate), 151-152° (anhydrous), 148-151°, pK 2, pK 5.1, pK 8.2. It has been converted to the ammonium salt (m 121-123° dec) dissolved in H 2O and passed through an Amberlite IR 120 resin (H + form) and eluted with H 2O. The acidic fractions were collected, evaporated to dryness and the residue recrystd from H 2O as the monohydrate (m 144-146°). The anhydrous acid is obtained by making a slurry with MeOH, decanting and evaporating to dryness and repeating the process twice more to give the anhydrous acid (m 151-152°). Recryst from H 2O gives the monohydrate. [Nakamura Chem Pharm Bull Jpn 19 46 1971.] The ethyl ester forms needles when crystd from a small volume of Et 2O and has m 78-79° and IR (CHC 3 ) with v 3500-2300 (OH), 1742 (ester CO), 1628, 1528cm -1, and UV with λ max (EtOH) at 206nm (ε 7080). The hydrazide has m 174-175° (from MeOH) with IR (KBr) 1656 (C=O)cm -1.
2-Iminothiolane hydrochloride (2-iminotetrahydrothiophene) \[4781-83-3\] M 137.6, m 187-192\(^{\circ}\), 190-195\(^{\circ}\), 193-194\(^{\circ}\), 202-203\(^{\circ}\), pK <2 (free base). Recryst from MeOH-Et\(_2\)O (m 187-192\(^{\circ}\)) but after sublimation at -180\(^{\circ}\)/0.2mm the melting point rose to 202-203\(^{\circ}\). It has NMR with \(\delta\) 2.27 (2H, t), 3.25 (2H, t) and 3.52 (2H, t) in (CD\(_3\)\(_2\))\(_2\)SO. [King et al. Biochemistry 17 1499 1978.] The free base is purified by vacuum distn (b 71-72\(^{\circ}\)/6mm) with IR (film) with \(\nu\) 1700 (C=N)cm\(^{-1}\) and NMR (CDCl\(_3\)) with \(\delta\) at 3.58 (2H, t) and 2.10-2.8 (4H, m). The free base is stable on storage but slowly hydrolyses in aqueous solns with half lives at 25\(^{\circ}\) of 390h at pH 9.1, 210h at pH 10 and 18 h at pH 11. [Aragon and King Biochemistry 19 4343 1980.]

trans-Indol-3-ylacrylic acid \[1204-06-4\] M 187.2, m 190-195\(^{\circ}\)(dec), 195\(^{\circ}\)(dec), 196\(^{\circ}\)(dec), 195-196\(^{\circ}\)(dec), \(pK\textsubscript{Est} \sim 4.2\). Recryst from AcOH, H\(_2\)O or EtOAc-cyclohexane. UV in MeOH has \(\lambda\textsubscript{max}\) at 225, 274 and 325nm. [Shaw et al. J Org Chem 23 1171 1958; constitution: Rappe Acta Chem Scand 18 818 1964; Moffatt J Chem Soc 1442 1957; Kimmig et al. Hoppe Seyler's Z Physiol Chem 371 234 1958.]

3-Indolylbutyric acid \[133-32-4\] M 202.2, m 120-123\(^{\circ}\), 123-125\(^{\circ}\), 124\(^{\circ}\), pK 4.84. Recryst from H\(_2\)O. It is soluble in EtOH, Et\(_2\)O and Me\(_2\)CO but insoluble in CHCl\(_3\). [Bowman and Islip London 154 1971; Jackson and Manske J Am Chem Soc 52 5029 1930; Albaum and Kaiser Am J Bot 24 420 1937.] UV has \(\lambda\textsubscript{max}\) 278 and 320nm in isoPrOH [Elvidge J Phys Chem 89 7399 1985]. The ethyl ester has \(\lambda\textsubscript{max}\) 73-74\(^{\circ}\) (from \(^{\circ}\)C\(_6\)H\(_5\)-pet ether) and b 230\(^{\circ}\)/6mm [Bullock and Hand J Am Chem Soc 78 5854 1956]. Also recryst from EtOH/water (James and Ware J Phys Chem 89 5450 1985).

3-Indolylpyruvic acid \[392-12-1\] M 202.2, m 210\(^{\circ}\)(dec), 208-210\(^{\circ}\)(dec), 219\(^{\circ}\)(dec), \(pK\textsubscript{Est} \sim 2.4\). Recryst from Me\(_2\)CO-\(^{\circ}\)C\(_6\)H\(_6\), EtOAc-CHCl\(_3\), Me\(_2\)CO-AcOH (crystals with 1 molecule of AcOH) and dioxane-\(^{\circ}\)C\(_6\)H\(_6\) (with 0.5 molecule of dioxane) [Shaw et al. J Org Chem 23 1171 1958; Kaper and Veldstra Biochim Biophys Acta 30 401 1958]. The ethyl ester has \(\lambda\textsubscript{max}\) 139\(^{\circ}\) (from Et\(_2\)O) and its 2,4-dinitrophenylhydrazone has \(\lambda\textsubscript{max}\) 255\(^{\circ}\) (from Me\(_2\)CO). [Baker J Chem Soc 461 1946.]

myo-\(\text{Inositol (cyclohexane[1r,2c,3c,4i,5c,6f]-hexol) [87-89-8} M 180.2, m 218\(^{\circ}\) (dihydrate), 225-227\(^{\circ}\), 226-230\(^{\circ}\). Recryst from aq 50% ethanol or H\(_2\)O forming a dihydrate, or anhydrous crystals from AcOH. The dihydrate is efflorescent and becomes anhydrous when heated at 100\(^{\circ}\). The anhydrous crystals are not hygroscopic. Solubility in H\(_2\)O at 25\(^{\circ}\) is 14\%, at 60\(^{\circ}\) it is 28\%, slightly soluble in EtOH but insoluble in Et\(_2\)O. [Ballou and Anderson J Am Chem Soc 75 748 1953; Anderson and Wallis J Am Chem Soc 70 2931 1948.]

Interferons [\(\alpha\text{IFN}, \beta\text{IFN} \text{and } \gamma\text{IFN}]. Interferons are a family of glycosylated proteins and are cytokines which are produced a few hours after cells have been infected with a virus. Interferons protect cells from viral infections and have antiviral activities at very low concentrations (~3 \times 10^{-4} \text{M}, less than 50 molecules are apparently sufficient to protect a single cell). Double stranded RNA are very efficient inducers of IFNs. There are three main types of IFNs. The \(\alpha\) IFNs are synthesised in lymphocytes and the \(\beta\) IFNs are formed in infected fibroblasts. The \(\alpha\) and \(\beta\) families are fairly similar consisting of ca 166 to 169 amino acids. Although \(\gamma\) IFNs are also small glycosylated proteins (ca 146 amino acids), they are different because they are not synthesised after viral infections but are produced by lymphocytes when stimulated by mitogens (agents that induced cell division).

Several of these IFNs of mouse and human lymphocytes and fibroblasts are available commercially and have been best prepared in quantity by recombinant DNA procedures because they are produced in very small amounts by the cells. The commercial materials do not generally require further purification for their intended purposes. [Pestkas, Interferons and Interferon standards and general abbreviations, Methods Enzymol, Wiley & Sons, 119 1986, ISBN 012182019X; Lengyel, Biochemistry of interferons and their actions, Ann Rev Biochem 51 251-282 1982; De Maeyer and De Maeyer-Guignard, Interferons in The Cytokine Handbook, 3rd Edn, Thomson et al. Eds, pp. 491-516 1998 Academic Press, San Diego, ISBN 0126896623.]

Interleukin (from human source). Purified using lyophilisation and desalting on a Bio-Rad P-6DC desalting gel, then two steps of HPLC, first with hydroxylapatite, followed by a TSK-125 size exclusion column. [Kock and Luger J Chromatogr 296 293 1984.]
Interleukin-2 (recombinant human) \([94218-72-1]\) \(M_r \approx 15,000\), amorphous. Purified by reverse phase HPLC. [Weir and Sparks Biochem J 245 85 1987; Robb et al. Proc Natl Acad Sci USA 81 6486 1984.]

Interleukins (IL-1, IL-2 — IL-18). Interleukins are cytokines which cause a variety of effects including stimulation of cell growth and proliferation of specific cells, e.g. stem cells, mast cells, activated T cells, colony stimulating factors etc, as well as stimulating other ILs, prostaglandins release etc. They are small glycosylated proteins (ca 15 kD, 130-180 amino acids produced from longer precursors) and are sometimes referred to by other abbreviations, e.g. IL-2 as TCGF (T cell growth factor), IL-3 as multi-CSF (multilineage colony stimulating factor, also as BPA, HCSF, MCSF and PSF). They are produced in very small amounts and are commercially made by recombinant DNA techniques in bacteria or SF21 insect cells. Interleukins for human (h-IL), mouse (m-IL) and rat (r-IL) are available and up to E-18 are available commercially in such purity that they can be used directly without further refinement, particularly those that have been obtained by recombinant DNA procedures which are specific. As well as the interleukins, a variety of antibodies for specific IL reactions are available for research or IL identification. [Symons et al. Lymphokines and Interferons, A Practical Approach, Clemens et al. Eds, p. 272 1987; IRL Press, Oxford, ISBN 1852210354, 1852210362; Thomson et al. Eds, The Cytokine Handbook, 3rd Edn, 1998; Academic Press, San Diego, ISBN 0126896623.]

Iodonitrotetrazolium chloride \([146-68-9]\) \(M 505.7, m 505 O (dec), -245 O (dec).\) Recrystd. from H2O, aqueous EtOH or EtOH-Et2O. Alternatively dissolve in the minimum volume of EtOH and add Et2O; or dissolve in hot H2O (charcoal), filter and ppte by adding conc HCl. Filter solid off and dry at 100°C. Solubility in H2O at 25°C is 0.8%, and in hot MeOH-H2O (1:1) it is 5%. [Fox and Atkinson J Am Chem Soc 72 3629 1950.]

Iodonitrotetrazolium violet-Formazan \([7781-49-9]\) \(M 471.3, m 185-186°\). Dissolve in boiling dioxane (20g in 300mL), add H2O (100mL) slowly, cool, filter and dry in vacuo at 100°C. Its solubility in CHCl3 is -1%. [UV: Fox and Atkinson J Am Chem Soc 72 3629 1950.]

5-Iodouridine \([5-iodo-1-[\beta-D-ribofuranosyl]-pyrimidine-2,4(1H)-dione]\) \([1024-99-3]\) \(M 378.1, m 205-208°(dec), 210-215°(dec), [\alpha]_D^{20} -23.5° (c 1, HzO), pK2 8.5.\) Recrystd from H2O and dried in vacuo at 100°C. UV has \(\lambda_{max} 289\text{nm} (0.01\text{N HCl})\) and 278nm \(0.01\text{N NaOH}\). [Prusoff et al. Cancer Res 13 221 1953.]

3-Isobutyl-1-methylxanthine \([3-isobutyl-1-methylpurine-2,6-dione]\) \([28822-58-4]\) \(M 222.3, m 199-210°, 202-203°, pK_{Em} < 6.7\) (acidic NH). Recrystd from aqueous EtOH.

Isopentenyl pyrophosphate \([358-71-4]\) \(M 366.2, pK_{Em(1)}-<2, pK_{Em(2)}-<2, pK_{Em(3)}-3.95, pK_{Em(4)}-6.26.\) Purified by chromatography on Whatman No 1 paper using tert-butyl alcohol/formic acid/water (20:5:8, Rf 0.60) or 1-propanol/ammonia/water (6:3:1, Rf 0.48). Also purified by chromatography on a DEAE-cellulose column or a Dowex-1 (formate form) ion-exchanger using formic acid and ammonium formate as eluents. A further purification step is to convert it to the monocylohexylammonium salt by passage through a column of Dowex-50 (cyclohexylammonium form) ion-exchange resin. Can also be converted into its lithium salt.

DL-Isoserine \([\pm-3\text{-amino-2-hydroxypropionic acid}\] \([632-12-2]\) \(M 105.1, m 250-252°(dec), 235°(dec), 237°(dec), 245°(dec), pK_{2}^{13} 2.78 \) (acidic), \(pK_{2}^{13} 9.27 \) (basic). Recrystd from H2O or 50% aqueous EtOH. It has an isoelectric pH of 6.02. [Rinderknocht and Niemann J Am Chem Soc 75 6322 1953; Gundermann and Holtmann Chem Ber 91 160 1958; Emerson et al. J Biol Chem 92 451 1931.] The hydrobromide has \(m 128-130°\) (from aqueous HBr) [Schöberl and Braun Justus Liebigs Ann Chem 542 288 1939].

Isoxanthopterin \([2-amino-4,7-dihydroxypteridine]\) \([529-69-1]\) \(M 179.4, m \geq 300°, pK_{2}^{10} -0.5\) (basic), \(pK_{2}^{10} 7.34 \) (acidic), \(pK_{3}^{10} 10.06 \) (acidic). Purified by repeated pptn from alkaline solutions by acid (preferably AcOH), filter, wash well with H2O then EtOH and dried at 100°C. Purity is checked by paper chromatography \(R_f 0.15\) \((n-BuOH, AcOH, H_2O, 4:1:1)\); 0.33 \(3\%\text{aq NH}_4\text{OH}\). [Goto et al. Arch Biochem
Kanamycin B (Bekamycin, 4-O-[2,6-diamino-2,6-dideoxy-α-D-glucopyranosyl]-6-O-[3-amino-3-deoxy-α-D-glucopyranosyl]-2-deoxystreptamine) [4696-76-8, 29701-07-3 (sulfate salt)] M 483.5, m 170-179° (dec), 178-182° (dec), [α] D +130° (c 0.5, H 2O), pK 7.2. A small quantity (24 mg) can be purified on a small Dowex 1 x 2 column (6 x 50 mm), the correct fraction is evaporated to dryness and the residue crystallized from EtOH containing a small amount of H 2O. [Umezawa et al. Bull Chem SOC Jpn 42 537 1969.] It has been crystallized from H 2O by dissolving 1 g in H 2O (3 mL), adding Me 2NCHO (3 mL) setting aside at 4° overnight. The needles are collected and dried to constant weight at 130°. It has also been recrystallized from aq EtOH. It is slightly soluble in CHCl 3 and isoPrOH. [IR: Wakazawa et al. J Antibiot 14 A 180, 187 1961; Ito et al. J Antibiot 17 A 189 1964.]

Lactate dehydrogenase (from dogfish, Beef muscle) [9001-60-9] M 140,000 [EC 1.1.1.27]. 40-Fold purification by affinity chromatography using Sepharose 4B coupled to 8-(6-lactoferrin (from human whey). Purified by direct adsorption on cellulose phosphate by batch extraction, then eluted by a stepped salt and pH gradient. [Foley and Bates Anal Biochem 162 296 1987.]

Lactoferrin (from human whey). Purified by direct adsorption on cellulose phosphate by batch extraction, then eluted by a stepped salt and pH gradient. [Foley and Bates Anal Biochem 162 296 1987.]

Lectins (proteins and/or glycoproteins of non-immune origin that agglutinate cells, from seeds of Robinia pseudoacacia), M ~100,000. Purified by pptn with ammonium sulfate and dialysis; then chromatographed on DE-52 DEAE-cellulose anion-exchanger, hydroxylapatite and Sephacryl S-200. [Wantyghem et al. Biochem J 237 483 1986.]


DL-α-Lipoic acid (±-6,8-thioctic acid, 5-[1,2]-dithiolan-3-ylvaleric acid) [1077-28-7] M 206.3, m 59-61°, 60.5-61.5° and 62-63°, b 90°/10-4 mm, 150°/0.1 mm, pK 4.7. It forms yellow needles from cyclohexane or hexane and has been distilled at high vacuum, and sublimes at ~90° and very high vacuum. Insoluble in H 2O but dissolves in alkaline soln. [Lewis and Raphael J Chem Soc 4263 1962; Soper et al. J Am Chem Soc 76 4109; Reed and Niu J Am Chem Soc 77 416 1955; Tsuji et al. J Org Chem 43 3606 1978; Calvin Fed Proc USA 13 703 1954.] The S-benzyli thiouronium salt has m 153-154° (evacuated capillary; from MeOH), 132-134°, 135-137° (from EtOH). The d- and l- forms have m 45-47.5° and [α] D +113° (c 1.88, *C 6H 6) and have UV in MeOH with λ max at 330 nm (ε 140).
Lipoprotein lipase (from bovine skimmed milk) [9004-02-8] [EC 3.1.1.34]. Purified by affinity chromatography on heparin-Sepharose [Shirai et al. Biochim Biophys Acta 665 504 1981].

Lipoproteins (from human plasma). Individual human plasma lipid peaks were removed from plasma by ultracentrifugation, then separated and purified by agarose-column chromatography. Fractions were characterised immunologically, chemically, electrophoretically and by electron microscopy. [Rudel et al. Biochem J 13 89 1974.]

Lipoteichoic acids (from gram-positive bacteria) [56411-57-5]. Extracted by hot phenol/water from disrupted cells. Nucleic acids that were also extracted were removed by treatment with nucleases. Nucleic acid resistant acids, proteins, polysaccharides and teichoic acids were separated from lipoteichoic acids by anion-exchange chromatography on DEAE-Sephaloc or by hydrophobic interaction on octyl-Sepharose [Fischer et al. Eur J Biochem 133 523 1983].

D-Luciferin (firefly luciferin, 5-[6-hydroxybenzothiazol-2-yl]-4,5-dihydrothiazol-4-carboxylic acid), [2591-17-5]. M 280.3, m 189.5-190°(dec), 196°(dec), 201-204°, 205-210°(dec, browning at 170°), [α]D +2.36° (c 1.2, DMF), pK <1(1) ~1.2 (benzothiazole-N), pK <2(2) ~1.6 (thiazolidine-N), pK <3(3) ~6.0 (CO2H), pK <4(4) >8.5 (6OH). Recrystallises as pale yellow needles from H2O, or MeOH (83mg from 7mL). It has UV λmax at 263 and 327nm (log ε 3.88 and 4.27) in 95% EtOH. The Na salt has a solubility of 4mg in 1 mL of 0.05M glycine. [White et al. J Am Chem Soc 83 2402 1961, 85 337 1963; UV and IR: Bitler and McElroy Arch Biochem 72 358 1957; Review: Cormier et al. Fortschr Chem Org Naturst 30 1 1973.]

Lumiflavin (7,8,10-trimethylbenzo[g]pteridine-2,4(3H,10H)-dione) [1088-56-8]. M 256.3, m 330°(dec), 340°(dec), pK 10.2. Forms orange crystals upon recrystn from 12% aqueous AcOH, or from formic acid. It sublimes at high vacuum. It is freely soluble in CHCl3, but not very soluble in H2O and most organic solvents. In H2O and CHCl3 soln it has a green fluorescence. UV has Aλ,, at 269, 355 and 445nm (E 38,800, 11,700 and 11,800 respectively) in 0.1N NaOH and 264, 373 and 440nm (E 34,700, 11,400 and 10,400 respectively) in 0.1N HCl while UV in CHCl3 has h,, at 270, 312, 341, 360, 420, 445 and 470nm. [Hemmerich et al. Helv Chim Acta 39 1242 1956; Holiday and Stern Chem Ber 67 1352 1834; Yoneda et al. Chem Pharm Bull Jpn 20 1832 1972; Birch and Moye J Chem Soc 2622 1958; Fluorescence: Kuhn and Moruzzi Chem Ber 67 888 1934.]

Magnesium protoporphyrin dimethyl ester [14724-63-1]. M 580.7. Crude product dissolved in as little hot dry C6H6 as possible and left overnight at room temperature to crystall. [Fuhrhop and Graniek Biochem Prep 13 55 1971.]

α-Melanotropin [581-05-5] (13 amino acids peptide), [α]D +25° -58.5° (c 0.4, 10% aq AcOH). Extract separated by ion-exchange on carboxymethyl cellulose, desalted, evapd and lyophilised, then chromatographed on Sephadex G-25. [Lande et al. Biochem Prep 13 45 1971.]


6-Mercaptopurine-9-β-D-ribofuranoside \[574-25-4\]  M 284.3, m 208-210°(dec), 210-211°(dec), 220-223°(dec), 222-224°(dec), \([\alpha]_D^{25} -73° (c 1, 0.1\text{N} \text{NaOH}), pK 7.56.\] Johnson et al. 

Methadone hydrochloride (2-dimethylamino-4-ethoxycarbonyl-4,4-diphenylbutane HCl) \[1095-90-5\]  M 345.9, m 241-242°, \(pK_{1}^{15} 8.94, \ pK_{2}^{15} 10.12\) (free base). Crystd from EtOH.

Methoxanthin coenzyme (PQQ, pyrrolo quinoline quinone, carboxylic acid) \[72909-34-3\]  M 330.2, m 220°(dec). Efflorescent yellow-orange needles on recrystn from H₂O by addition of Me₂CO, or better from a supersaturated aqueous solution, as it forms an acetone adduct. [Forrest et al. *Nature* 280 843 1979.]

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When a soln in 10% aqueous MeCO is adjusted to pH 9 with aqueous NH₃ and kept at 25° for 30 min, the acetone adduct is formed; UV has \(\lambda_{max}\) at 247 and 330nm (shoulder at 270nm) in H₂O and \(\lambda_{max}\) at 250 and 340nm in H₂O at pH 2.5. With excitation at \(\lambda_{ex}\) 365nm it has a \(\lambda_{max}\) emission at 483nm. The \(^{13}\text{C}\) NMR has 

\[\begin{align*}
29.77, 51.06, 74.82, 111.96, 120.75, 121.13, 125.59, 126.88, 135.21, 139.19, 144.92, 161.01, 161.47, 165.17, 168.61, 190.16, \\
161.25, 165.48, 166.45, 173.30, 180.00. \\
\end{align*}\]

When a soln in 10% aqueous MeCO is adjusted to pH 9 with aqueous NH₃ and kept at 25° for 30 min, the acetone adduct is formed; UV has \(\lambda_{max}\) at 250, 317 and 360nm (H₂O, pH 5.5) and with \(\lambda_{ex}\) at 360nm it has \(\lambda_{max}\) fluorescence at \(\lambda_{max}\) of 465nm; and the \(^{13}\text{C}\) NMR [(CD₃)₂SO, TMS] has 

\[\begin{align*}
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161.25, 165.48, 166.45, 173.30, 180.00. \\
\end{align*}\]
Purification of Biochemicals and Related Products


5-Methyltetrahydrofolic acid disodium salt (prefolic A) [68792-52-9] M 503.4, pK1 2.4 (N10 protonation), pK2 2.7 (pyrimidine N1 protonation), pK3 3.5 (α-CO2H), pK4 4.9 (γ-CO2H), pK5 5.6 (N5-Me), pK6 8.5 (3NHCO acidic). Check purity by measuring UV at pH 7.0 (use phosphate buffer) and it should have Amax 290nm and Amin 245nm with a ratio of A290/A250 of 3.7. This ratio goes down to 1.3 as oxidation to the dihydro derivative occurs. The latter can be reduced back to the tetrahydro compound by reaction with 2-mercaptoethanol at room temp. If oxidation had occurred then the compound should be chromatographed on DEAE-cellulose (-0.9 milliequiv/g, in AcO- form) in (NH4)2CO3 (1.5 M) and washed with 1M NH4OAc containing 0.01M mercaptoethanol till free from UV absorption and then washed with 0.01M mercaptoethanol. All is done in a nitrogen atmosphere. The reduced folate is then eluted with a gradient between 0.0 1M mercaptoethanol and 1M NH4OAc containing 0.01M mercaptoethanol and the fractions with absorption at 290nm are collected. These are evapd under reduced pressure at 25O and traces of NH4OAc and H2O are removed at high vac~um/25~ (-24-48h). The product should have λmax 290nm (ε 32,000) in pH 7.0 buffer. [Sakami Biochem Prep 10 103 1963.]


4-Methylumbelliferone (7-hydroxy-4-methylcoumarin) [90-33-5] M 194.2, m 185-186°, 185-188°, 194-195°, pKEst(1)- 10.0 (phenolic OH). Purified by recrystn from EtOH. It is insoluble in cold H2O, slightly soluble in Et2O and CHC13, but soluble in MeOH and AcOH. It has blue fluorescence in aqueous EtOH, and has UV Amax 221, 251 and 322.5nm in MeOH. IR has v 3077 br, 1667, 1592, 1385, 1267, 1156, 1130 and 1066 cm⁻¹. The acetate has m 153-154O. [Woods and Sapp J Org Chem 27 3703 1962.]

4-Methylumbellifer-7-yl-α-D-glucopyranoside [17833-43-1] M 338.3, m 221-222°, [α]D 237° (c 3, H2O). Recrystd from hot H2O.

4-Methylumbellifer-7-yl-β-D-glucopyranoside [18997-57-4] M 338.3, m 210-212°, 211°, [α]D 20 -61.5° (c 2, pyridine), -89.5° (c 0.5, H2O for half hydrate). Recrystallises as the half hydrate from hot H2O. [Constantzas and Kocourek Collect Czech Chem Commun 24 1099 1959; De Re et al. Ann Chim (Rome) 49 2089 1959.]

1-Methyluric acid [708-79-2] M 182.1, m >350°, pK1 5.75 (basic), pK2 10.6 (acidic). Recrystd from H2O. [Bergmann and Dikstein J Am Chem Soc 77 691 1955.] It has UV λmax at 231 and 283. nm (pH 3) and 217.5 and 292.5nm (pH >12) [Johnson Biochem J 5 133 1952].

Mevalonic acid lactone [674-26-0] M 130.2, m 280, b 145-150°C/5mm. Purified via the dibenzyl-ethylenediammonium salt (m 124-125°) [Hofmann et al. J Am Chem Soc 79 2316 1957], or by chromatography on paper or on Dowex-1 (formate) column. [Bloch et al. J Biol Chem 234 2595 1959.] Stored as N,N'-dibenzylethylenediamine (DBED) salt, or as the lactone in a sealed container at 0°.

Mevalonic acid 5-phosphate [1189-94-2] M 228.1, pKEst(1)- 1.5 (PO4H2), pKEst(2)- 4.4 (CO2H), pKEst(3)- 6.31 (PO4H3). Purified by conversion to the tricyclohexylammonium salt (m 154-156°) by treatment with cyclohexyamine. Crystd from water/acetonitrile at -15°. Alternatively, the phosphate was chromatographed by ion-exchange or paper (Whatman No 1) in a system isobutyric acid/ammonia/water (66:3:30; Rp 0.42). Stored as the cyclohexylammonium salt.
**Mitomycin c**


Dowex-1 formate [Bloch et al.


**Mitomycin C** [50-07-7] M 334.4, m >360°, pKEm 8.0. Blue-violet crystals form C6H6-pet ether. It is soluble in Me2CO, MeOH and H2O, moderately soluble in C6H6, CCl4 and Et2O but insoluble in pet ether. It has UV λmax at 216, 360 and a weak peak at 560nm in MeOH. [Stevens et al. J Med Chem 8 1 1965; Shirahata and Hiyama J Am Chem Soc 105 7199 1983.]

**Muramic acid** [R-2-(2-amino-2-deoxy-D-glucose-3-xylo)-propionic acid] [1114-41-6] M 251.2, m 145-150°(dec), 152-154°(dec), 155°(dec), [α]D 10 +109° (c 2, H2O), +165°(0° extrapolated to 0 time) → +123° [after 3h (c 3, H2O)], pKEm(1) ~ 3.8 (CO2), pKEm(2) ~ 7.7 (NH2). It has been recrystd from H2O or aqueous EtOH as monohydrate which loses H2O at 80° in vacuo over P2O5. Sometimes contains some NaCl. It has been purified by dissolving 3.2g in MeOH (75mL), filtered from some insoluble material, concentrated to ~10mL and refrigerated. The colourless crystals are washed with absolute MeOH. This process does not remove NaCl, to do so the product is recrystd from a equal weight of H2O to give a low yield of very pure acid (0.12g). On paper chromatography 0.26pg give one ninhydrin positive spot after development with 75% phenol absolute MeOH. This process does not remove NaCl; to do so the product is recrystd from a equal weight of H2O or aqueous EtOH as monohydrate which loses H2O at 80° in vacuo over P2O5. Sometimes contains some NaCl. It has been purified by dissolving 3.2g in MeOH (75mL), filtered from some insoluble material, concentrated to ~10mL and refrigerated. The colourless crystals are washed with absolute MeOH. This process does not remove NaCl, to do so the product is recrystd from a equal weight of H2O to give a low yield of very pure acid (0.12g). On paper chromatography 0.26pg give one ninhydrin positive spot after development with 75% phenol (RF 0.51) or with sec-BuOH-HCO2O-H2O (7:1:2) (RF 0.30). [Matsushima and Park Biochem Prep 10 109 1963; J Org Chem 27 3581 1962.]

The acid has been also purified by dissolving 990mg in 50% aqueous EtOH (2mL), filtering, collecting the colourless needles on a sintered glass funnel and dried over P2O5 at 80°/0.1mm to give the anhydrous acid. [Lambert and Zilliken Chem Ber 93 2915 1960.] Alternatively the acid is dissolved in a small volume of H2O, neutralised to pH 7 with ion exchange resin beads (IR4B in OH- form), filtered, evaporated and dried. The residue is recrystd from 90% EtOH (v/v) and dried as above for 24h. [Strange and Kent Biochem J 71 333 1959.] The N-acetyl derivative has m ~ 125°(dec) and [α]D 41.2° after 24h (c 1.5, H2O). [Watanabe and Saito J Bacteriol 144 428 1980.]

**Muscimol** (pantherine, 5-aminoethyl-3[2h]-isoxazolone) [2763-96-4] M 114.1, m 170-172°(dec), 172-174°(dec), 172-175°, 175°, 176-178°(dec), pKEm(1) ~ 6 (acidic, ring 2-NH), pKEm(2) ~ 8 (CH3CH2NH2). Recrystd from MeOH-tetrahydrofuran or EtOH and sublimed at 110-140° (bath) at 10-4 mm and gives a yellow spot with ninhydrin which slowly turns purple [NMR: Bowden et al. J Chem Soc (C) 172 1968]. Also purified by dissolving in the minimum volume of hot H2O and adding EtOH dropwise until cloudy, cool, and colourless crystals separate; IR: ν 3445w, 3000-2560w br, 2156w, 1635s and 1475s cm⁻¹. [NMR: Jager and Frey Justus Liebigs Ann Chem 817 1982.] Alternatively it has been purified by two successive chromatographic treatments on Dowex 1 x 8 with the first elution with 2M AcOH and a second with a linear gradient between 0—2M AcOH and evaporating the desired fractions and recrystallising the residue from MeOH. [McCarr and Savard Tetrahedron Lett 22 5153 1981; Nakamura Chem Pharm Bull Jpn 19 46 1971.]

**Mycophenolic acid** (6-[1,3-dihydro-7-hydroxy-5-methoxy-4-methyl-1-oxoisobenzofuran-6-yl]-4-methylhex-4-enolic acid) [24280-93-1] M 320.3, m 141°, 141-143°, pKEm(1) ~ 2.5 (CO2H), pKEm(2) ~ 9.5 (phenolic OH). Purified by dissolving in the minimum volume of EtOAc, applying to a silica gel column (0.05-0.02 mesh) and eluting with a mixture of EtOAc + CHCl3 + AcOH (45:55:1) followed by recrystn from heptane-EtOAc, from aqueous EtOH or from hot H2O and drying in vacuo. It is a weak dibasic acid moderately soluble in Et2O, CHCl3 and hot H2O but weakly soluble in C6H6 and...

Myoglobin (from sperm whale muscle). [9047-17-0] M <17,000. purified by CM-cellulose chromatography and Sephadex G-50 followed by chromatography on Amberlite IRC-50 Type III or BioRex 70 (<400 mesh). The crystalline product as a paste in saturated (NH₄)₂SO₄ at pH 6.5-7.0 may be stored at 4°C for at least 4 years unchanged, but must not be kept in a freezer. [Anres and Atassi *Biochemistry* 12 942 1980; Edmundson *Biochem Prep* 12 41 1968.1]

Myricetin (Cannabis cetin, 3,3',4',5,7-hexahydroxyflavone) [529-44-2] M 318.2, m >300°, 357°(dec) (polyphenolic pKₐ 6.1). Recrystd from aq EtOH (m 357° dec, as monohydrate) or Me₂CO (m 350° dec, with one mol of Me₂CO) as yellow crystals. Almost insol in CHCl₃ and AcOH. The hexaacetate has m 213°. [Hergert *J Org Chem* 21 534 1956; Spada and Cameroni *Gauetta* 86 965, 975 1956; Kalff and Robinson *J Chem Soc* 127 181 1925.1

Nalidixic acid (1-ethyl-7-methyl-1,8-naphthyridin-4-one-3-carboxylic acid) [389-08-2] M 232.3, m 228.2-230.2°, 229-230°, pk 6.0. Crystd from H₂O or EtOH as a pale buff powder. It is soluble at 23°C in CHCl₃ (3.5%), toluene (0.16%), MeOH (0.13%), EtOH (0.09%), H₂O (0.01%) and Et₂O (0.01%). It inhibits nucleic acid and protein synthesis in yeast. [Lesher et al. *J Med and Pharm Chem* 5 1063 1962.1

Naloxone hydrochloride hydrate (Narcan, 1-N-propenyl-7,8-dihydro-14-hydroxymorphinan-6-one hydrochloride) [51481-60-8] M 399.9, m 200-205°, [α]D 164° (c 2.5, H₂O), pKₐ 6.0 (N-propenyl), pKₐ 9.6 (phenolic OH). This opiate antagonist has been recrystd from EtOH + Et₂O or H₂O. It is soluble in H₂O (5%) and EtOH but insoluble in Et₂O. The free base has m 184° (177-178°) after recrystn from EtOAc, [α]D 194.5° (c 0.93, CHCl₃). [Olofson et al. *Tetrahedron Lett* 1567 1977; Gold et al. *Med Res Rev* 2 211 1982.]

Naltrexone hydrochloride dihydrate (1-N-cyclopropylmethyl-7,8-dihydro-14-hydroxymorphinan-6-one hydrochloride) [16676-29-2] M 413.9, m 274-276°, [α]D 173° (c 1, H₂O), pKₐ 6.0 (N-cyclopropylmethyl), pKₐ 9.6 (phenolic OH). This narcotic antagonist has been purified by recrystn from MeOH and dried air. The free base has m 168-170° after recrystn from Me₂CO. [Cone et al. *J Pharm Sci* 64 618 1975; Gold et al. *Med Res Rev* 2 211 1982.]


Naphthol AS-acetate (3-acetoxynaphthoic acid anilide) [1163-67-3] M 305.3, m 152°, 160°. Recrystd from hot MeOH and dried in vacuo over P₂O₅. It is slightly soluble in AcOH, EtOH, CHCl₃ or C₆H₆. It is a fluorogenic substrate for albumin esterase activity. [Chen and Scott *Anal Lett* 17 857 1984.] At λₑₓ 320nm it had fluorescence at λₑₘ 500nm. [Brass and Sommer *Chem Ber* 61 1000 1928.]

1-Naphthyl phosphate di sodium salt [2183-17-7] M 268.1, pKₐ 0.97, pKₐ 5.85 (for free acid). Purified through an acid ion-exchange column (in H⁺ form) to give the free acid which is obtained by freeze drying and recryst from Me₂CO + C₆H₆ or by adding 2.5 vols of hot CHCl₃ to a hot soln of 1 part acid and 1.2 parts Me₂CO and cooling (m 155-157°, 157-158°). The acid is dissolved in the minimum volume of H₂O to which 2 equivalents of NaOH are added and then freeze dried, or by adding the equivalent amount of MeONa in MeOH to a soln of the acid in MeOH and collecting the Na salt, washing with cold MeOH then Et₂O and drying in a vacuum. [Friedman and Seligman *J Am Chem Soc* 72 624 1950; Chanley and Feageson J
2-Naphthyl phosphate monosodium salt \([14463-68-4]\) M 246.2, m 296° (sintering at 228°), pK\(_d^1\) 1.28, pK\(_d^2\) 5.53 (for free acid). The free acid is purified as for the preceding 1-isomer and has m 176-177°, 177-178° after recryst from CHCl\(_3\) + Me\(_2\)CO as the 1-isomer above. It is neutralised with one equivalent of NaOH and freeze dried or prepared as the 1-isomer above. Its solubility in H\(_2\)O is 1.5%.

\(\beta\)-Nicotinamide adenine dinucleotide (diphosphopyridine nucleotide, NAD, DPN) \([53-84-9]\) M 663.4, \([\alpha]_D^{25}\) -34.8° (c 1, H\(_2\)O), pK\(_1\) 2.2 (PO\(_4\))H, pK\(_2\) 4.0 (adenine NH\(_2\)), pK\(_3\) 6.1 (PO\(_4\)). Purified by paper chromatography or better on a Dowex-1 ion-exchange resin. The column was prepared by washing with 3M HCl until free of material absorbing at 260nm, then with water, 2M sodium formate until free of chloride ions and, finally, with water. NAD, as a 0.2% soln in water, adjusted with NaOH to pH 8, was adsorbed on the column, washed with water, and eluted with 0.1M formic acid. Fractions with strong absorption at 360nm were combined, acidified to pH 2.0 with 2M HCl, and cold acetone added slowly and with constant agitation. It was left overnight in the cold, then the ppte was collected in a centrifuge, washed with pure acetone and dried under vacuum over CaCl\(_2\) and paraffin wax shavings [Kornberg Methods Enzymol 3 876 1957]. Purified by anion-exchange chromatography [Dalziel and Dickinson Biochemical Preparations 11 84 1966.] The purity is checked by reduction to NADH (with EtOH and yeast alcohol dehydrogenase) which has \(\epsilon_{340nm} 6220 \text{ M}^{-1}\text{cm}^{-1}\). [Todd et al. J Chem Soc 3727,3733 1957.] [K\(\alpha\), Lamborg et al. J Biol Chem 231 685 1958.] The free acid crystallises fromaq Me\(_2\)CO with 3H\(_2\)O and has m 140-142°. It is stable in cold neutral aqueous solns in a desiccator (CaCl\(_2\)) at 25\(^\circ\), but decomposes at strong acid and alkaline pH. Its purity is checked by reduction with yeast alcohol dehydrogenase and EtOH to NADH and noting the OD at 340nm.

\(\beta\)-Nicotinamide adenine dinucleotide reduced di-Na salt trihydrate (reduced diphosphoryridine nucleotide sodium salt, NADH) \([606-68-8]\) M 763.5, pK as for NAD. This coenzyme is available in high purity and it is advised to buy a fresh preparation rather than to purify an old sample as purification will invariably lead to a more impure sample contaminated with the oxidised form (NAD). It has UV \(\lambda_{max}\) at 340nm (6,200 M\(^{-1}\)cm\(^{-1}\)) at which wavelength the oxidised form NAD has no absorption. At 340 nm a 0.161mM soln in a 1cm (pathlength) cell has an absorbance of 1.0 unit. The purity is best checked by the ratio \(A_{280nm}/A_{340nm}\) \(-2.1\), a value which increases as oxidation proceeds. The dry powder is stable indefinitely at -20°. Solutions in aqueous buffers at pH ~7 are stable for extended periods at ~20° and for at least 8h at 0°, but are oxidised more rapidly at 4° in a cold room (e.g. almost completely oxidised overnight at 4°). [UV: Drabkin J Biol Chem 175 563 1945; Fluorescence: Boyer and Thorrell Acta Chem Scand 10 447 1956; Redox: Rodney J Biol Chem 234 188 1959; Schlenk in The Enzymes 2 250, 268 1951; Kaplan in The Enzymes 3 105, 112 1960.] Deuterated NADH, i.e. NADH, has been purified through the anion exchange resin AG-1 x 8 (100-200 mesh, formate form) and through a Bio-Gel P-2 column. [Viola, Cook and Cleland Anal Biochem 96 334 1979.]

\(\beta\)-Nicotinamide adenine dinucleotide phosphate (NADP, TPN) \([53-59-8]\) M 743.4, pK\(_1\) 1.1 (PO\(_4\))H, pK\(_2\) 4.0 (adenine NH\(_2\)), pK\(_3\) 6.1 (PO\(_4\)). Purified by anion-exchange chromatography in much the same way as for NAD [Dalziel and Dickinson Biochem J 95 311 1965; Biochemical Preparations 11 87 1966]. Finally it is purified by dissolving in H\(_2\)O and precipitating with 4 volumes of Me\(_2\)CO and dried in
Vacuo over P₂O₅. It is unchanged by storing in vacuo at 20°. [Hughes et al. J Chem Soc 3733 1957, Schuster and Kaplan J Biol Chem 215 (1955).] Deuterated NADPH, i.e. NADPD, has been purified through the anion exchange resin AG-1 x 8 (100-200 mesh, formate form) and through a Bio-Gel P-2 column. \( \lambda_{\text{max}} \) 259 nm (€ 18 0000) at pH 7.0. [Viola, Cook and Cleland Anal Biochem 96 334 1979.]

\( \beta \)-Nicotinamide adenine dinucleotide phosphate reduced tetrasodium salt (reduced diphosphopyridine nucleotide phosphate sodium salt, NADPH) \([2646-71-1] \) M 833,4, pK as for NADP. Mostly similar to NADH above.

\( \beta \)-Nicotinamide mononucleotide (NMN) \([1094-61-7] \) M 334,2, \( [\alpha]_{\text{D}2}^\circ -38.3^\circ \) (c 1, \( \text{H}_2\text{O} \)), \( p_{\text{K}_{\text{Et}4}} \) 6.1 (PO₄°).\( p_{\text{K}_{\text{Et}4}} \) 6.1 (PO₄°). Purified by passage through a Dowex 1 (Cl- form), washed with \( \text{H}_2\text{O} \) until no absorbance at 260 nm. The tubes containing NMN are pooled, adjusted to pH 5.5-6 and evapd as for NADP.

This is adjusted to pH 3 with dilute \( \text{HNO}_3 \) in an ice bath and treated with 20 volumes of \( \text{Me}_2\text{CO} \) at 0-5°C. The gummy residue. It has

\[ \lambda_{\text{max}} \] 266 nm (€ 6400) and \( \lambda_{\text{min}} \) 249 nm (€ 3600) at pH 7.0 (i.e. no absorption at 340nm). It can be estimated by reaction with CN- or hydrosulfite which form the 4-adducts equivalent to NADH) which has UV \( \lambda_{\text{max}} \) 340 nm (€ 6200). Thus after reaction an OD₃₄₀ of one is obtained from a 0.1612 mM soln in a 1 cm path cuvette. [Plaut and Plaut Biochem Prep 5 56 1957; Maplan and Stolzenbach Methods Enzymol 3 899 1957; Kaplan et al. J Am Chem Soc 77 815 1955.]

\( (-)\)-Nicotine \( (1\text{-methyl}-2-[3\text{-pyridyl}]-\text{pyrroldine}) \) \([54-11-5] \) M 162,2, b 123-125°/17 mm, 246.1°/730.5 mm, 243-248°/atm (partial dec), d₄° 1.097, nD° 1.5280, \( [\alpha]_{\text{D}2}^\circ -169^\circ \) (c 1, \( \text{Me}_2\text{CO} \)), \( p_{\text{K}_{\text{Et}4}} \) 6.16 (pyridine N°), \( p_{\text{K}_{\text{Et}4}} \) 10.96 (pyrrolidine N°). Very pale yellow hygroscopic oil with a characteristic odour (tobacco extract) with browns in air on exposure to light. Purified by fractional distn. Its solubility in \( \text{EtOH} \) is 5%. The picrate forms yellow needles from hot \( \text{H}_2\text{O} \) and has \( m_\text{218}^\circ \) (from EtOH). POISONOUS.

\( (\pm)\)-Nicotine \( [22083-74-5] \) M 162,2, b 242.3°/atm, d₄° 1.082 (pK see above). Purified by dist. Its solubility in EtOH is 5%. The picrate forms yellow needles from hot \( \text{H}_2\text{O} \) and has \( m_\text{218}^\circ \). The methiodide has \( m_\text{219}^\circ \) (from MeOH).


2-Nitrophenyl-\( \alpha \)-D-galactopyranoside \([369-07-3] \) M 301,3, m 185-190°, 193°, 193-194°, \( [\alpha]_{\text{D}18}^\circ -51.9^\circ \) (c 1, \( \text{H}_2\text{O} \)). Purified by recrystn from EtOH. [Seidman and Link J Am Chem Soc 72 4324 1950; Snyder and Link J Am Chem Soc 75 1758 1953]. It is a chromogenic substrate for \( \beta \)-galactosidases [Jagota et al. J Food Sci 46 161 1981].

4-Nitrophenyl-\( \alpha \)-D-galactopyranoside \([7493-95-0] \) M 301,3, m 166-169°, 173°, \( [\alpha]_{\text{D}25}^\circ +248 \) (c 1, \( \text{H}_2\text{O} \)). Purified by recrystn from \( \text{H}_2\text{O} \) or aqueous EtOH. The monohydrate has \( m_\text{85}^\circ \) which resolidifies and melts at 151-152° (the hemihydrate) which resolidifies and melts again at 173° as the anhydrous form. Drying the monohydrate at 60° yields the hemihydrate and drying at 100° gives the anhydrous compound. The tetraacetate has \( m_\text{147}^\circ \) after drying at 100°. [Jermyn Aust J Chem 15 569 1962; Helfreich and Jung Justus Liebigs Ann Chem 589 77 1954]. It is a substrate for \( \alpha \)-galactosidase [Dangelmaier and Holmsen Anal Biochem 104 182 1980].

4-Nitrophenyl-\( \beta \)-D-galactopyranoside \([3150-24-1] \) M 301,3, m 178°, 178-181°, 181-182°, \( [\alpha]_{\text{D}28}^\circ -83^\circ \) (c 1, \( \text{H}_2\text{O} \)). Purified by recrystn from EtOH. [Horikoshi J Biochem (Tokyo) 35 39 1042;
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Nonactin [6833-84-7] M 737.0, m 147-148°, \([\alpha]D^20 +\) (c 1.2, CHC13). This macrotetrolide antibiotic was recrystd from MeOH as colourless needles, and dries at 90°/20h/high vacuum. [Helv Chim Acta 38 1445 1955, 1371 1972; Tetrahedron Lett 3391 1975.]


Nonyl-β-D-glucopyranoside [69984-73-2] M 306.4, m 67.5-70°, \([\alpha]D^20 -34.4°\) (c 5, H2O), \([\alpha]D^20 -5-28.8°\) (c 1, MeOH). Purified by recryst from Me2CO and stored in well stoppered containers as it is hygroscopic. [Pigman and Richtmyer J Am Chem Soc 64 369 1942.]


L-Noradrenaline hydrochloride (Arterenol) [329-56-6] M 205.6, m 145.2-146.4°, -150°(dec), \([\alpha]D^20 -40°\) (c 6, H2O), pK see above. Recryst from isopROH and stored in the dark as it is oxidised in the presence of light (see preceding entry). [Tullar J Am Chem Soc 70 2067 1948.]

Novobiocin (7-[O3-carbamoyl-5-O4-dimethyl-β-L-lyso-6-deoxyhexahydropyranosyloxy]-4-hydroxy-3-[4-hydroxy-3-[3-methylbut-2-enyl]-benzyl-amino]-8-methylcoumarin) [303-81-1] M 612.6, two forms m 152-156° and m 172-174°, 174-178°, \(\lambda_{\text{max}}\) at 330nm (acid EtOH), 305nm (alk EtOH), \([\alpha]D^20 -63°\) (c 1, EtOH), pK1 4.03 (4.2), pK2 9.16. Crystd from EtOH and stored in the dark. It has also been recryst from Me2CO-H2O. [Hoeksema et al. J Am Chem Soc 77 6710 1955; Kaczka et al. J Am Chem Soc 77 9404 1955.]

The sodium salt [1476-53-5] M 634.6, m 210-215°, 215-220°(dec), 222-229°, \([\alpha]D^20 -38°\) (c 1, H2O) has been recryst from MeOH, then dried at 60°/0.5mm. [Sensi, Gallo and Chiesa, Anal Chem 29 1611 1957; Kaczka et al. J Am Chem Soc 78 1426 1956.]

5'-Nucleotidase (from Electric ray, Torpedo sp) [9027-73-0] [EC 3.1.3.5], amorphous. Purified by dissolving in Triton X-100 and deoxycholate, and by affinity chromatography on concanavalin A-Sepharose and AMP-Sepharose [Grondal and Zimmerman Biochem J 245 805 1987].

Nucleotide thiophosphate analogues. The preparation and purification of [3H]ATP, [3H]GTP, s6TP, 6-thiophosphate, c16TP (6-chlorothiophosphate) and [3H]ATP are described and the general purification
was achieved by chromatography of the nucleotide thiophosphates in the minimum volume of H2O placed onto a DEAE-Sephadex A25 column and eluting with a linear gradient of triethylammonium bicarbonate (0.1 to 0.6M for G and I nucleotides and 0.2 to 0.5M for A nucleotides). [Biochim Biophys Acta 276 155 1972.]

**Nystatin dihydrate (Mycostatin, Fungicidin)** \([1400-61-9]\) M 962.1, m dec>160° (without melting by 250°), \([\alpha]_D^{15}+7°\) (0.1N HCl in MeOH), -10° (AcOH), +12° (Me2NCHO), +21° (pyridine). Light yellow powder with the following solubilities at -28°: MeOH (1.1%), ethylene glycol (0.9%), H2O (0.4%), CCl4 (0.12%), EtOH (0.12%), CHCl3 (0.05%) and C6H2 (0.03%). Could be ppted from MeOH soln by addition of H2O. Aqueous suspensions of this macrolide antifungal antibiotic are stable at 100°/10min at pH 7.0 but decomposes rapidly at pH <2 and >9, and in the presence of light and O2. [Birch et al. Tetrahedron Lett 1491, 1485 1974; Weiss et al. Antibiott Chemother 7 374 1957.]

**Octyl-β-D-glucopyranoside** \([29836-26-8]\) M 292.4, m 62-65°, 63.8-65°, -34° (c 4, MeOH). Purified by recryst from Me2CO. It is hygroscopic and should be stored in a well stoppered container. [Noller and Rockwell J Am Chem Soc 60 2076 1938; Pigman and Richtmyer J Am Chem Soc 64 369 1942.]


**Orotic acid Li salt H2O** (l-carboxy-4,6-dihydroxypyrimidine Li salt H2O) \([5266-20-6]\) M 180.0, m >300°, pK_1 2.8 (CO2H), pK_2 9.4 (OH), pK_3 >13 (OH) (for free acid). It is soluble in H2O at 17° and 100°. Best to acidify an aqueous soln, isolating the free acid which is recrystd from H2O (as monohydrate) m 345-347° (345-346°), then dissolving in EtOH, adding an equivalent amount of LiOH in EtOH and evaporating. Its solubility in H2O is 1.28% (17°) and 2.34% (100°). [Bachstez Chem Ber 63 1000 1930; Johnson and Shroeder J Am Chem Soc 54 2941 1932; UV: Shugar and Fox Biochim Biophys Acta 9 199 1952.]

**Oxacinil sodium salt** (5-methyl-3-phenyl-4-isoxazolylpenicillin sodium salt) \([1173-88-2]\) M 423.4, m 188°(dec), [α]_D^{10}+29° (c 1, H2O), pK_{Est} ~ 2.7. This antibiotic which is stable to penicillinase is purified by recrystn from isoPrOH and dried in vacuo. Its solubility in H2O at 25° is 5%. [Doyle et al. Nature 192 1183 1961.]

**Oxolinic acid** (5-ethyl-5,8-dihydro-8-oxo-1,3-dioxolo[4,5-g]quinoline-3-carboxylic acid) \([14698-29-4]\) M 261.2, m 313-314°(dec), 314-316°(dec), pK_{Est} ~ 2.3. Purified by recrystn from aqueous Me2CO or 95% EtOH. It has UV \(\lambda_{max} 220, (255.5sh), 259.5, 268, (298sh, 311sh), 321 and 326nm [\(\epsilon 14.8, (36.8sh), 38.4, 38.4, (6.4sh, 9.2sh), 10.8 and 11.2 \times 10^3\)]. [Kaminsky and Mettzer J Med Chem 11 160 1968.]

**Oxytocin** \([50-56-6]\) M 1007.2, m dec on heating, [α]_D^{20}-26.2° (c 0.53, N AcOH). A cyclic nonapeptide which was purified by countercurrent distribution between solvent and buffer. It is soluble in H2O, n-BuOH and isoBuOH. [Bodanszky and du Vigneaud J Am Chem Soc 81 2504 1959; Cash et al. J Med Pharm Chem 5 413 1962; Sakakibara et al. Bull Chem Soc Jpn 38 120 1965; solid phase synthesis: Bayer and...
It was also synthesised on a solid phase matrix and finally purified as follows: A Sephadex G-25 column was equilibrated with the aqueous phase of a mixture of 3.5% AcOH (containing 1.5% of pyridine) + n-BuOH + C6H6 (2:1:1) and then the organic phase of this mixture was run through. A soh of oxytocin (lag) in H2O (2mL) was applied to the column which was then eluted with the organic layer of the above mixture. The fractions containing the major peak [as determined by the Folin-Lowry protein assay [Fryer et al. Anal Biochem 153 262 19861 were pooled, diluted with twice their vol of H2O, evaporated to a small vol and lyophilised to give oxytocin as a pure white powder (20mg, 508 U/mg). [Ives Can J Chem 46 2318 1968.]

Palmitoyl coenzyme A [1763-10-6] M 1005.9. Possible impurities are palmitic acid, S-palmitoyl thioacid and S-palmitoyl glutathione. These are removed by placing ca 200mg in a centrifuge tube and extracting with Me2CO (20mL), followed by two successive extractions with Et2O (15mL) to remove S-palmitoyl thioacid and palmitic acid. The residue is dissolved in H2O (4 x 4 mL), adjusted to pH 5 and centrifuged to remove insoluble S-palmitoyl glutathione and other insoluble impurities. To the clear supernatant is added 5% HC104 (6mL) whereby S-palmitoyl CoA pptes. The ppte is washed with 0.8% HC104 (10mL) and finally with Me2CO (3 x 5mL) and dried in vacuum. It is stable for at least one year in dry form at -15°. Its solubility in H2O is 4%. The adenine content is used as the basis of purity with at 260 and 232nm (E 6.4 x 10^6 and 9.4 x 10^6 cm2/mol respectively). Higher absorption at 232nm would indicate other thio ester impurities, e.g. S-palmitoyl glutathione, which absorb highly at this wavelength. Also PO4 content should be determined and acid phosphate can be titrated potentiometrically. [Seubert Biochem Prep 7 80 1960; Srer et al. Biochim Biophys Acta 33 31 1959; Kornberg and Price J Biol Chem 204 329 , 345 1953.]

D-Panthenol (Provitamin B, R-2,4-dihydroxy-3,3-dimethylbutyryl acid 3-hydroxy-propylamide) [81-13-0] M 205.5, b 118-120°/0.02mm, d20^0 1.2, nD20^0 1.4935, [α]D^20^0 +37.5' (c 5, HzO). Purified by distn in vacuo. It is a slightly hygroscopic viscous oil. Soluble in H2O and organic solvent. It is hydrolysed by alkali and strong acid. [Rabin J Am Pharm Assoc (Sci Ed) 37 502 1948; Bonati and Pitré Farmaco Ed Scient 14 43 1959.]

R-(+)-Pantothenic acid sodium salt (N-[2,4-dihydroxy-3,3-dimethylbutyryl] β-alanine Na salt) [867-81-2] M 241.2, [α]D^20^0 +27.1° (c 2, H2O), pK^2.5 4.4 (for free acid). Crystd from EtOH, very hygroscopic (kept in sealed ampoules). The free acid is a viscous hygroscopic oil with [α]D^20^0 +37.5' (c 5, HzO), easily destroyed by acids and bases.

Papain [9001-73-4] \( \text{M}_r \approx 21,000 \), [EC 3.4.22.2], amorphous. A suspension of 50g of papain (freshly ground in a mortar) in 200mL of cold water was stirred at 4\(^\circ\) for 4h, then filtered through a Whatman No 1 filter paper. The clear yellow filtrate was cooled in an ice-bath while a rapid stream of \( \text{H}_2\text{S} \) was passed through it for 3h, and the suspension was centrifuged at 2000rpm for 20min. Sufficient cold MeOH was added slowly and with stirring to the supernatant to give a final MeOH concn of 70~01%. The ppte, collected by centrifugation for 20min at 2000rpm, was dissolved in 200mL of cold water, the soln was saturated with \( \text{H}_2\text{S} \), centrifuged, and the enzyme again ppted with MeOH. The process was repeated four times. [Bennett and Niemann J Am Chem Soc 72 1798 1950.] Papain has also been purified by affinity chromatography on a column of Gly-Gly-Tyr-Arg-agarose [Stewart et al. J Am Chem Soc 109 3480 1986].

Papaverine hydrochloride (6,7-dimethoxy-1-veratrylisouquinoline hydrochloride) [61-25-6] \( \text{M} 375.9, m 215-220^\circ, 222.5-223.5^\circ(\text{dec}), 231^\circ, \text{pK}^{25} 6.41. \) Recrystd from \( \text{H}_2\text{O} \) and sublimed at 140\(^\circ\)/0.1mm. Solubility in \( \text{H}_2\text{O} \) is 5%. [Saunders and Srivastava J Pharm Pharmacol 3 78 1951; Biggs Trans Faraday Soc 50 800 1954.] The free base has \( m 148-150^\circ \) [Bobbitt J Org Chem 22 1729 1957].

Pargyline hydrochloride (Eutonyl, \( N \)-methyl-\( n \)-propargylbenzylamine hydrochloride) [306-07-0] \( \text{M} 195.7, m 154-155^\circ, 155^\circ, \text{pK}^{25} 6.9. \) Recrystd from EtOH-Et\(_2\)O and dried in vacuo. It is very soluble in \( \text{H}_2\text{O} \), in which it is unstable. The free base has \( b 101-103^\circ/11\text{mm} \). It is a glucuronyl transferase inducer and a monoamine oxidase inhibitor. [von Braun et al. Justus Liebigs Ann Chem 445 205 1928; Yeh and Mitchell Experience 28 298 1972; Langstrom et al. Science 225 1480 1984.]

Pectic acid [9046-40-6] \( \text{M}_r (\text{C}_n\text{H}_{2n}\text{O}_{n+1})_m \approx 500,000 \), amorphous, \([\alpha]_D^2 +250^\circ \) (c 1, 0.1M \( \text{NaOH} \)). Citrus pectic acid (500g) was refluxed for 18h with 1.5L of 70% EtOH and the suspension was filtered hot. The residue was washed with hot 70% EtOH and finally with ether. It was dried in a current of air, ground and dried for 18h at 80\(^\circ\) under vacuum. [Morell and Link J Biol Chem 100 385 1933.] It can be further purified by dispersing in water and adding just enough dilute \( \text{NaOH} \) to dissolve the pectic acid, then passing the soln through columns of cation- and anion-exchange resins [Williams and Johnson Ind Eng Chem (Anal Ed) 16 23 1944], and precipitating with two volumes of 95% EtOH containing 0.01% HCl. The ppte is worked with 95% EtOH, then \( \text{Et}_2\text{O} \), dried and ground.

Pectin [9000-69-5] \( \text{M} 25,000-100,000 \), amorphous. Dissolved in hot water to give a 1% soln, then cooled, and made about 0.05M in HCl by addition of conc HCl, and ppted by pouring slowly, with vigorous stirring into two volumes of 95% \( \text{EtOH} \). After standing for several hours, the pectin is filtered onto nylon cloth, then redispersed in 95% EtOH and stood overnight. The ppte is filtered off, washed with EtOH-Et\(_2\)O, then \( \text{Et}_2\text{O} \), dried and air dried.

D-(-)-Penicillamine \( (R)-3\text{-mercapto-D-valine, 3,3-dimethyl-D-cysteine, from natural penicillin} \) [52-67-5] \( \text{M} 149.2, m 202-206^\circ, 214-217^\circ, [\alpha]_D^{25} -63^\circ \) (c 1, \( \text{NaOH} \) or pyridine), \( \text{pK}^{25} 2.4 \) (\( \text{CO}_2\text{H} \)), \( \text{pK}^{25} 8.0 \) (SH), \( \text{pK}^{25} 10.68 \) (NH\(_2\)). The melting point depends on the rate of heating (m 202-206\(^\circ\) is obtained by starting at 195\(^\circ\) and heating at 20/min). It is soluble in \( \text{H}_2\text{O} \) and alcohol but insoluble in Et\(_2\)O, CH\(_3\)Cl, CCl\(_4\) and hydrocarbons solvents. Purified by dissolving in MeOH and adding Et\(_2\)O slowly. Dried in vacuo and stored under \( \text{N}_2 \). [Weight et al. Angew Chem, Int Ed Engl 14 330 1975; Cornforth in The Chemistry of Penicillin (Clarke, Johnson and Robinson Eds) Princeton Univ Press, 455 1949; Polymorphism: Vidler J Pharm Pharmacol 28 663 1976.] The D-S-benzyl derivative has \( m 197-198^\circ \) (from \( \text{H}_2\text{O} \), [\( \alpha]_D^{17} -20^\circ \) (c 1, \( \text{NaOH} \), -70\(^\circ\) (N HCl)).

L-(-)-Penicillamine \( [1113-41-3] \) \( \text{M} 149.2, m 190-194^\circ, 202-206^\circ, 214-217^\circ, [\alpha]_D^{25} +63^\circ \) (c 1, \( \text{NaOH} \) or pyridine). Same as preceding entry for its enantiomer.

D-Penicillamine disulfide hydrate \( (S,S\text{-di-[penicillamine] hydrate}) [20902-45-8] \) \( \text{M} 296.4 + \text{aq}, m 203-204^\circ(\text{dec}), 204-205^\circ(\text{dec}), [\alpha]_D^{23} +27^\circ \) (c 1.5, \( \text{N HCl} \)), -82\(^\circ\) (c 0.8, \( \text{NaOH} \)), \( \text{pK}_{\text{Empl}}^{17} \) 2.4 (\( \text{CO}_2\text{H} \)), \( \text{pK}_{\text{Emt}}^{17} \) 10.7 (NH\(_2\)). Purified by recrystn from \( \text{EtOH} \) or aqueous EtOH. [Crooks in The Chemistry of Penicillin (Clarke, Johnson and Robinson Eds) Princeton Univ Press, 469 1949; Use as a thiol reagent for proteins: Garel Eur J Biochem 123 513 1982; Süs Justus Liebigs Ann Chem 561 31 1948.]

Pertussis toxin (from Bordetella pertussis) [(70323-44-3)] Mr 117,000. Purified by stepwise elution from 3 columns comprising Blue Sepharose, Phenyl Sepharose and hydroxylapatite, and SDS-PAGE [Svoboda et al. Anal Biochem 159 402 1986; Biochemistry 21 5516 1982; Biochem J 83 295 1978.]

2-Phenylethyl-β-D-thioglactoside [63407-54-5] M 300.4, m 108°, [α]D 32 -32.2° (c 5, MeOH). Recryst from H2O and dried in air to give the 1.5H2O and has m 80°. Anhydro surfactant is obtained by drying at 78° over P2O5. [Heilfrich and Turk Recryst from H2O and dried in air to give the 1.5H2O and has m 32 1856.]


Phenylmercuric acetate (PhHgOAc) [62-38-4] M 336.7, m 148-151°, 149°, 151.8-152.8°. Small colourless lustrous prisms from EtOH. Its solubility in H2O is 0.17% but it is more soluble in EtOH, Me2CO and *C6H6. [Maynard J Am Chem Soc 46 1510 1925; Coleman et al. J Am Chem Soc 59 2703 1937; J Am Pharm Assoc 25 752 1936.] See PhHgOH and PhHgN03.PhHgOH on p. 449 in Chapter 5.


Phosphatase alkaline (alkaline phosphatase) [9001-78-9] Mr ~40,000 (bovine liver), ~140,000 (bovine intestinal mucosa), 80,000 (E. coli) [EC 3.1.3.1]. The E. coli supernatant in sucrose (20%, 33mM) in Tris-HCl pH 8.0 was purified through a DEAE-cellulose column and recrystallised. To the column eluates in 0.125M NaCl is added MgCl2 (to 0.01M) and brought to 50% saturation in (NH4)2SO4 by adding the solid (0.20g/mL). The mixture is centrifuged to remove bubbles and is adjusted to pH 8.0 (with 2N NaOH). Saturated (NH4)2SO4 at pH 8.0 is added dropwise until the soln becomes faintly turbid (~61% saturation). It is set aside at room temp for lh (turbidity will increase). The mixture is placed in an ice bath for several minutes when turbidity disappears and a clear soln is obtained. It is then placed in a large ice bath at 0° (~5L) and allowed to warm slowly to room temperature in a dark room whereby crystals are formed appearing as a silky sheen. The crystals are collected by centrifugation at 25° if necessary. The crystalline solns are stable at room temperature for many months. They can be stored at Oo, but are not stable when frozen. Cysteine at 10-3M and thioglycolic acid at 10-4M are inhibitory. Inhibition is reversed on addition of Zn2+ ions. Many organic phosphates are good substrates for this phosphatase. [Molamy and Horecker Methods Enzymol 9 639 1966; Torriani et al. Methods Enzymol 12b 212 1968; Engstrom Biochim Biophys Acta 92 71 1964.]

Alkaline phosphatase from rat osteosarcoma has been purified by acetone pptn, followed by chromatography on DEAE-cellulose, Sephacryl S-200, and hydroxylapatite. [Nair et al. Arch Biochem Biophys 254 18 1987.]

3-sn-Phosphatidylethanolamine (L-α-cephalin, from Soya bean) [39382-08-6] Mr ~600-800, amorphous, pKa[H] 5.8 (PO4-), pKa[H] 10.5 (NH3). Purified by dissolving in EtOH, adding Pb(OAc)2.3H2O (30g in 100mL H2O) until excess Pb2+ is present. Filter off the solid. Pass CO2 gas through
the soln until pptn of PbCO₃ ceases. Filter the solid off and evaporate (while bubbling CO₂) under vacuum. An equal volume of H₂O is added to the residual oil extracted with hexane. The hexane extract is washed with H₂O until the aqueous phase is free from Pb [test with dithizone (2 mg in 100 mL CCl₄; Feigel Spot Tests Vol I, Elsevier p. 10 1954]. The hexane is dried (Na₂SO₄), filtered and evaporated to give a yellow waxy solid which should be dried to constant weight in vacuo. It is practically insoluble in H₂O and Me₂CO, but freely soluble in CHCl₃ (5%) and Et₂O, and slightly soluble in EtOH. [Schofield and Dutton Biochem Prep 55 1957.]

**O-Phosphocolamine 2-aminoethyl dihydrogen phosphate** \(\{1071-23-4\}\) M 141.1, m 237-240°, 242.3°, 234.5-244.5°, 244-245°(capillary), \(pK_{1}^{20} <1.5\) (PO₄H₂), \(pK_{2}^{20} 5.77\) (PO₄H⁻), \(pK_{3}^{20} 10.26\) (NH⁺). Purified by recryst from aqueous EtOH as a hydrate (m 140-141°). Its solubility in H₂O is 17% and 0.003% in MeOH or EtOH at 22°. [Fölich and Österberg J Biol Chem 234 2298 1959; Baer and Staucer Can J Chem 34 434 1956; Christensen J Biol Chem 135 399 1940.] It is a potent inhibitor of ornithine decarboxylase [Gilad and Gilad Biochem Biophys Res Commun 122 277 1984].

**Phosphoenolpyruvic acid monopotassium salt** (KPEP) \(\{4265-07-0\}\) M 206.1, \(pK_{1}^{25} 3.4\) (CO₂), \(pK_{2}^{25} 6.35\) (PO₄H⁻) (for free acid). It is purified via the monocyclohexylamine salt (see next entry). The salt (534mg) in H₂O (10mL) is added to Dowex 50WX4 H⁺ form (200-400 mesh, 2mL, H₂O washed) and stirred gently for 30min and filtered. The resin is washed with H₂O (6mL) and the combined solns are adjusted to pH 7.4 with 3N KOH (-1.4mL) and the volume adjusted to 18.4mL with H₂O to give a soln of 0.1M KPEP which can be lyophilised to a pure powder and is very good for enzyme work. It has been recrystd from MeOH-Et₂O. [Clark and Kirby Biochem Prep 11 103 1966; Wold and Ballou J Biol Chem 227 301 1957; Cherbuliez and Rabinowitz Helv Chim Acta 39 1461 1956.]

The triNa salt \(\{5541-93-5\}\) M 360.0, is purified as follows: the salt (1g) is dissolved in MeOH (40mL) and dry Et₂O is added in excess. The white crystals are collected and dried over P₂O₅ at 20°. [Chem Ber 92 952 1959.]

**Phosphoenolpyruvic acid tris(cyclohexylamine) salt** \(\{35556-70-8\}\) M 465.6, m 155-180°(dec). Recrystd from aqueous Me₂CO and dried in a vacuum. At 4° it is stable for >2 years and has IR at 1721cm⁻¹ (C=O). [Wold and Ballou J Biol Chem 227 301 1957; Clark and Kirby Biochem Prep 11 103 1966 for the monocyclohexylamine salt.]

**D-3-Phosphoglyceric acid disodium salt** (D-glycerate 3-phosphate di-Na salt) \(\{80731-10-8\}\) M 230.0, \(\left[\alpha\right]_{D}^{20} +7.7°\) (c 5, H₂O), -735° (in aq NH₄⁺ molybdate), \(pK_{Eh(1)}-1.0\) (PO₄H₂), \(pK_{Eh(2)} 6.66\) (PO₄H⁻) (for free acid). Best purified by conversion to the Ba salt by pptn with BaCl₂ which is recrystd three times before conversion to the sodium salt. The Ba salt (9.5g) is shaken with 200mL of a 1:1 slurry of Dowex 50 (Na⁺ form) for 2h. The mixture is filtered and the resin washed with H₂O (2 x 25mL). The combined filtrates (150mL) are adjusted to pH 7.0 and concentrated in vacuo to 30-40mL and filtered if not clear. Absolute EtOH is added to make 100mL and then n-hexane is added whereby a white solid and/or a second phase separates. When set aside at room temperature complete pptn of the Na salt as a solid occurs. The salt is removed by centrifugation, washed with Me₂CO, dried in air then in an oven at 55° to give a stable powder (4.5g). It did not lose weight when dried further over P₂O₅ at 78°/8h. The high rotation in the presence of (NH₄)₆Mo₇O₂₄ is not very sensitive to the concentration of molybdate or pH as it did not alter appreciably in 1/3 volume between 2.5 to 25% (w/v) of molybdate or at pH values ranging between 4 and 7. [Cowgill Biochim Biophys Acta 16 613 1955; Embdan, Deuticke and Kraft Hoppe Seyler's Z Physiol Chem 230 20 1934.]

**Phospholipids.** For the removal of ionic contaminants from raw zwitterionic phospholipids, most lipids were purified twice by mixed-bed ionic exchange (Amberlite AB-2) of methanolic solutions. (About 1g of lipid in 10mL of MeOH.) With both runs the first 1mL of the eluate was discarded. The main fraction of the solution was evaporated at 40°/ under dry N₂ and recryst three times from n-pentane. The resulting white powder was dissolved for about 4h at 50° under reduced pressure and stored at 3°. Some samples were purified by mixed-bed ion exchange of aqueous suspensions of the crystal/liquid crystal phase. [Kaatze et al. J Phys Chem 89 2565 1985.]
**Phosphoproteins (various).** Purified by adsorbing onto an iminodiacetic acid substituted agarose column to which was bound ferric ions. This chelate complex acted as a selective immobilised metal affinity adsorbent for phosphoproteins. [Muszyńska et al. *Biochemistry* 25 6850 1986.]


**0-Phospho-L-serine [407-41-0] M 185.1, c 3.2, H2O, +16.20 (c 2.8, H2O), pK<sub>1</sub> 5.65 (PO<sub>4</sub><sup>-</sup>), pK<sub>2</sub> 9.74 (NH<sub>4</sub><sup>+</sub>).** Recrystd by dissolving log in H2O (150mL) at 25°, stirring for up to 20min. Undissolved material is filtered off (Büchner) and 95% EtOH (85mL) is added dropwise during 4min, and set aside at 25° overnight. The crystals are washed with 95% EtOH (100mL) then dry Et<sub>2</sub>O (50mL) and dried in a vacuum (yield 6.5g). A further quantity (1.5mg) can be obtained by keeping the mother liquors and washings at -80° for 1 week. The DL-isomer has m 167-170°(dec) after recrystn from H2O + EtOH or MeOH. [Neuhaus and Korkes *Biochem Prep* 6 75 1958; Neuhaus and Byrne *J Biol Chem* 234 113 1959; IR: Folsch and Mellander *Acta Chem Scand* 11 1232 1957.]

**0-Phospho-L-threonine (L-threonine-0-phosphate) [1114-81-4] M 199.1, c 2.8, H2O, pK<sub>1</sub> 5.5' (C<sub>6</sub>H<sub>5</sub>OH), pK<sub>2</sub> 9.32 (C<sub>2</sub>H<sub>5</sub>OH), pK<sub>3</sub> 6.5 (C<sub>2</sub>H<sub>5</sub>N<sub>3</sub>OH).** Dissolve in the minimum volume of H2O, add charcoal, stir for a few min, filter and apply onto a Dowex 50W (H<sup>+</sup> form) then elute with 2N HCl. Evaporate the eluates under reduced pressure whereby the desired fraction produced crystals of the phosphate which can be recrystd from H2O- MeOH mixtures and the crystals are then dried in vacuo over P<sub>2</sub>O<sub>5</sub> at -80°. [Levene and Schonuller *J Biol Chem* 100 583 1933; Posternak and Graff *Helv Chim Acta* 28 1258 1945.]

**Phytol (d-3,7R,11R,15-tetramethylhexadec-2-en-1-ol) [150-86-7] M 296.5, c 1, H2O, -3.7° (c 2, H2O), pK<sub>1</sub> 8.497, n<sub>D</sub>,<sub>20</sub> 1.437.** Purified by distn under high vacuum. It is almost insoluble in H2O but soluble in most organic solvents. It has λ<sub>max</sub> at 212nm (log ε 3.04) in EtOH and IR ν at 3300 and 1670cm<sup>-1</sup>. [Demole and Lederer *Bull Soc Chim Fr* 1128 1958; Burrell *J Chem Soc* (C) 2144 1966; Bader *Helv Chim Acta* 34 1632 1951.]

**D-Pipecolinic acid (R-piperidine-2-carboxylic acid) [1723-00-8] M 129.2, c 2, H2O, -280°(dec), [α]<sub>D</sub> +26.2° (c 2, H2O), [α]<sub>20</sub> 2.29 (C<sub>2</sub>H<sub>5</sub>OH), pK<sub>1</sub> 10.77 (NH<sub>4</sub><sup>+</sub>).** Recrystallises as platelets from EtOH and is soluble in H2O. The hydrochloride has m 256-257°(dec) from MeOH and [α]<sub>25</sub> -10.8° (c 2, H2O). [Lukéš et al. *Collect Czech Chem Commun* 22 286 1957; Bayerman *Recl Trav Chim Pays-Bas* 78 134 1959; Asher et al. *Tetrahedron Lett* 22 141 1981.]

**L-Pipecolinic acid (S-piperidine-2-carboxylic acid) [3105-95-1] M 129.2, c 4, H2O, -280°(dec), [α]<sub>D</sub> -26° (c 4, H2O), [α]<sub>25</sub> -34.9° (H<sub>2</sub>O).** Recrystd from aqueous EtOH and sublimes as needles in a vacuum. It is sparingly soluble in absolute EtOH, Me<sub>2</sub>CO and CHCl<sub>3</sub> but insoluble in EtO<sub>2</sub>. The hydrochloride has m 258-259°(dec, from MeOH) and [α]<sub>25</sub> -10.8° (c 10, H<sub>2</sub>O). [Fujii and Myoshi *Bull Chem Soc Jpn* 48 1241 1975.]

**Piperidine-4-carboxylic acid (isonipecotic acid) [498-94-2] M 129.2, c 10, H<sub>2</sub>O, -300°(dec, darkens at ~300°), pK<sub>Eh</sub> 10.6 (NH<sub>4</sub><sup>+</sub>).** Recrystallises from H<sub>2</sub>O or EtOH as needles. The hydrochloride recrystallises from H<sub>2</sub>O or aqueous HCl and has m 293°(dec 298°dec, 300°dec). [Wibaut *Recl Trav Chim Pays-Bas* 63 141 1944; IR: Zacharius et al. *J Am Chem Soc* 76 2908 1954.]
Pituitary Growth Factor (from human pituitary gland) [336096-71-0]. Purified by heparin and copper affinity chromatography, followed by chromatography on carboxymethyl cellulose (Whatman 52). [Rowe et al. Biochemistry 25 6421 1986.]

Plasmids. These are circular lengths of DNA which invade bacteria or other cells e.g. insect cells, yeast cells, and have sequences which are necessary for their replication using enzymes and other ingredients, e.g. nucleotides, present in the cells. They contain engineered, or already have, genes which produce enzymes that provide the cells with specific antibiotic resistance and are thus useful for selecting bacteria containing specific plasmids. Plasmids have been extremely useful in molecular biology since they can be very easily identified (from their size or the sizes of the DNA fragments derived from their restriction enzyme digests) and can be readily engineered in vitro (outside the cells). Genes coding for specific enzymes or other functional proteins can be inserted into these plasmids which have DNA sequences that allow the expression of large quantities of bacteria or non-bacterial (e.g. human) proteins. They have also been engineered in such a way as to produce 'fusion proteins' (in which the desired protein is fused with a specific "reporter, marker or carrier protein" which will facilitate the isolation of the desired protein (e.g. by binding strongly to a nickel support) and then the desired protein can be cleaved from the eluted fusion protein and obtained in very pure form. A large number of plasmids with a variety of sequences for specific purposes are commercially available in very pure form. They can be used to infect cells and can be isolated and purified from cell extracts in large amounts using a number of available procedures. These procedures generally involve lysis of the cells (e.g. with alkaline sodium dodecylsulfate, SDS), separation from nuclear DNA, precipitation of plasmid DNA from the cell debris, adsorbing it on columns which specifically bind DNA, and then eluting the DNA from the column (e.g. with specific Tris buffers as recommended by the suppliers) and precipitating it (e.g. with Tris buffer in 70% EtOH at -70°C) The purity is checked in agarose gel (containing ethidium bromide to visualise the DNA) by electrophoresis. A large number of plasmids are now commercially available (see Clontech GmbH, http://www.clontech.com; Invitrogen http://www.invitrogen.com, among other suppliers) used as vectors for bacterial, mammalian, yeast and baculovirus expression.


Polyethylene glycol [25322-68-3] M1, various, from ~200 to ~35,000. May be contaminated with aldehydes and peroxides. Methods are available for removing interfering species. [Ray and Purathingal Anal Biochem 146 307 1985.]

Polypeptides. These are a string of α-amino acids usually with the natural S(L) [L-cysteine is an exception and has the R absolute configuration] or sometimes "unnatural" R(D) configuration at the α-carbon atom. They generally have less than ~100 amino acid residues. They can be naturally occurring or, because of their small size, can be synthesised chemically from the desired amino acids. Their properties can be very similar to those of small proteins. Many are commercially available, can be custom made commercially or locally with a peptide synthesiser. They are purified by HPLC and can be used without further purification. Their purity can be checked as described under proteins.

Porphobilinogen (5-amino-4-carboxymethyl-1H-pyrrole-3-propionic acid) [487-90-1] M 226.2, m 172-175°(dec), 175-180°(dec, darkening at 120-130°), pkf 3.70 (4-CH2CO2H), pkf 4.95 (3-CH3CH2CO2H), pkf 10.1 (NH+). Recrystallises as the monohydrate (pink crystals) from dil NH4 OAc solns of pH 4, and is dried in vacuo. The hydrochloride monohydrate has m 165-170°(dec) (from dilute HCl). [Jackson and MacDonald Can J Chem 35 715 1957, Westall Nature 170 614 1952; Bogarad J Am Chem Soc 75 3610 1953.]

Porphyrin a (from ox heart) [5162-02-1] M 799.0, m dec on heating. Purified on a cellulose powder column followed by extraction with 17% HCl and fractionation with HCl. [Morel et al. Biochem J 78

Prazosin hydrochloride (2-[4-((2-furyl)piperazin-1-yl)4-amine-6,7-dimethoxyquinazoline hydrochloride) [19237-84-4] M 419.9, m 278-280°, 280-282°, pK 6.5. It is recrystd by dissolving in hot MeOH adding a small volume of MeOH-HCl (dry MeOH saturated with dry HCl gas) followed by dry Et2O until crystn is complete. Dry in vacuo over solid KOH till odour of HCl is absent. It has been recrystd from hot H2O, the crystals were washed with H2O, and the H2O was removed azeotropically with CH2Cl2, and dried in a vacuum. [NMR and IR: Honkanen et al. J Heterocycl Chem 17 797 1980; cf Armarego and Reece Aust J Chem 34 1561 1981.] It is an antihypertensive drug and is an α,1-adrenergic antagonist [Brosnan et al. Proc Natl Acad Sci USA 82 5915 1985].


Prednisolone hydrochloride (Novocain, 2-dietyltiaminoethyl-4-aminobenzoate) [51-05-8] M 272.8, m 153-156°, 154-156°, 156°, pK(EtNH+)~ 3.38 (ring N+), pK(EtNH2)~ 10.8 NH3+). It forms yellow crystals from 90% aq EtOH and is moderately soluble in H2O. The oxalate salt has m 182.5-185° (from 80% aq EtOH) and the free base is a viscous liquid b 165-170°/0.002mm, 175-177°/2mm. [Elderfield et al. J Am Chem Soc 68 1526 1964; 77 4817 1955.]

Propidium iodide (3,8-diamino-5-(3-diethylaminopropyl)-6-phenylphenanthridinium iodide methiodide) [25535-16-4] M 668.4, m 210-230°(dec), pK(EtNH+)~ 3 (aniline NH2), pK(EtNH3)~ 8.5 (EtN2). Recryst as red crystals from H2O containing a little KI. It fluoresces strongly with nucleic acids. [Etkins J Chem Soc 3059 1952.] TOXIC.

R-Propranalol hydrochloride (R-1-isopropylamino-3-(1-naphthyloxy)-2-propanol HCl) [13071-11-9] M 295.8, m 192°, 193-195°, [α]D 25° -25° (c 1, EtOH), pK 9.5 (for free base). Recryst from n-PrOH or Me2CO. It is soluble in H2O and EtOH but is insoluble in Et2O. The racemate has m 163-164°, and the free base recryst from cyclohexane has m 96°. [Howe and Shanks Nature 210 1336 1966.] The S-isomer (below) is the physiologically active isomer.

Protamine kinase (from rainbow trout testes) [37278-10-7] [EC 2.7.1.70]. Partial purification by hydroxypatite chromatography followed by biospecific chromatography on nucleotide coupled Sepharose 4B (the nucleotide was 8-(6-amino-hexyl)amine coupled cyclic-AMP). [Jergil et al. Biochem J 139 441 1974.]

Protamine sulfate (from herring sperm) [9007-31-2] [α]22D-85.5° (satt H2O), pK 7.4-8.0. A strongly basic protein (white powder, see pH) used to ppte nucleic acids from crude protein extracts. It dissolved in hot H2O but separates as an oil on cooling. It has been purified by chromatography on an IRA-400 ion-exchange resin in the SO42- form and with dilute H2SO4. Eluates are freeze-dried under high vacuum below 20°. This method is used to convert protamine and protamine hydrochloride to the sulfate. [UV: Rasmussen Hoppe Seyler's Z Physiol Chem 224 97 1934; Ando and Sawada J Biochem (Tokyo) 49 252 1961; Felix and Hashimoto Hoppe Seyler's Z Physiol Chem 330 205 1963]


Proteins. These are usually naturally occurring (or deliberately synthesised in microorganisms, e.g. bacteria, insect cells, or animal tissues), and are composed of a large number of α-L(α)amino acids residues (except for L-cysteine which has the R absolute configuration), selected from the 20 or so natural amino acids, in specific sequences and in which the α-amino group forms an amide (peptide) bond with the α-carboxyl group of the neighboring amino acid. The number of residues are usually upwards of 100. Proteins with less than 100 amino acids are better referred to as polypeptides. Aqueous soluble proteins generally fold into ball-like structures mainly with hydrophilic residues on the outside of the "balls" and hydrophobic residues on the inside. Proteins can exist singly or can for dimers, trimers, tetramers etc., consisting of similar or different protein subunits. They are produced by cells for a large variety of functions, e.g. enzymology, reaction mediation as in regulation of DNA synthesis or chaperonins for aiding protein folding, formation of pores in membranes for transport of ions or organic molecules, or for intra or inter cellular signalling etc. The purity of proteins can be checked in denaturing (SDS, sodium dodecysulfate) or non-denaturing polyacrylamide gels using electrophoresis procedures for the individual protein (see specific proteins in the Methods Enzymol, Wiley series).


Prothrombin (Factor II, from equine blood plasma) [9001-26-7] M, 72,000. Purified by two absorptions on a barium citrate adsorbent, followed by decomposition of the adsorbents with a weak carboxylic cation-exchanger (Amberlite IRF-97), isoelectric pptn (pH 4.7-4.9) and further purification by chromatography on Sephadex G-200 or IRC-50. Finally recrystd from a 1% soln adjusted to pH 6.0-7.0 and partial lyophilisation to ca 1/5 to 1/10th vol and set aside at 2-5° to crystallise. Occasionally seeding is required. [Miller Biochem Prep 13 49 1971.]

Protoporphyrin IX (3,18-divinyl-2,7,13,17-tetramethylporphine-8,12-dipropionic acid, ooporphyrin) [553-12-8] M 562.7, pKw ~ 4.8. Purified by dissolving (4g) in 98-100% HCOOH (85mL), diluting with dry Et2O (700mL) and keeping at 0° overnight. The ppt is collected and washed with Et2O then H2O and dried in a vacuum at 50° over P2O5. It has been recrystd from aqueous pyridine and from Et2O as monoclinic, brownish-yellow prisms. UV λmax values in 25% HCl are 557.2, 582.2 and 602.4nm. It is freely soluble in ethanolic HCl, AcOH, CHCl3, and Et2O containing AcOH. It forms sparingly soluble diNa and diK salts. [Ramsey Biochem Prep 3 39 1953; UV: Holden Aust J. Exptl Biol and Med Sci 15 412 1937; Garnick J Biol Chem 175 333 1948; IR: Falk and Willis Aust J Sci Res [A] 4 579 1951.]

The Dimethyl ester [552-66-7] M 590.7, m 228-230°, is prepared by dissolving (0.4g) in CHCl3 (33mL) by boiling for a few min, then diluting with boiling MeOH (100mL) and refrigerating for 2 days. The crystals are collected, washed with CHCl3-MeOH (1:9) and dried at 50° in a vacuum (yield 0.3g). UV has λmax 631, 576, 541, 506 and 407nm in CHCl3 and 601, 556 and 406nm in 25% HCl. [Ramsey Biochem Prep 3 39 1953.]
Pyrminesin (toxic protein from phytoflagellate *Pyrmnesium parvum*) [11025-94-8]. Purified by column chromatography, differential soln and pptn in solvent mixtures and differential partition between diphasic mixtures. The product has at least 6 components as observed by TLC. [Ulitzur and Shilo *Biochim Biophys Acta* **301** 350 1970.]

Pterin-6-carboxylic acid (2-amino-4-oxo-3,4-dihydropteridine-6-carboxylic acid) [948-60-7] M 207.2, m >360°, pK1 4.23, pK2 8.7 (Pyridinium*). It has UV with λmax 207, 263 and 365nm by column chromatography, differential soln and pptn in solvent mixtures and differential partition between diphasic mixtures. The product has at least 6 components as observed by TLC. [Ulitzur and Shilo *Biochim Biophys Acta* **301** 350 1970.]

Purine-9-P-ribifuranoside (Nebularin) [550-33-4] M 252.2, m 178-180°, 181-182°, [a]D 25 -48.6° (c 1, H2O), -22° (c 0.8, 0.1N HCl) and -61° (c 0.8, 0.1N NaOH), pK 2.05. Recrystd from butanone and is practically insoluble in H2O, EtOH and Et2O. The crystals are washed with cold water, dried in a vacuum desiccator over P2O5 and stored in a brown bottle at room temperature. [Fleck and Alberty *J Biol Chem* **204** 1019 1953.]

Purifonia (from *Salmonella typhimurium*) [9001-59-6] M, 64,000, [EC 2.7.1.40], amorphous. Purified by (NH4)2SO4 fractionation and gel filtration, ion-exchange and affinity chromatography. [Garcia-Olalla and Garrido-Pertierra *Biochem J* **241** 573 1987.]
Quinacrine [Atebrine, 3-chloro-9(4-diethylamino-1-methyl)butylamino-7-methoxy)acridine] dihydrochloride. [69-05-6] M 472.9, m 248-250° (dec), \( pK_{a1} = 6.49 \) (aq H\(_2\)SO\(_4\)), \( pK_{a2} = 7.73 \) (ring NH\(^+\)), \( pK_{a3} = 10.18 \) (Et\(_2\)N). Cryst from H\(_2\)O (sol 2.8% at room temp) as yellow crystals. Slightly sol in MeOH and EtOH. Antimalarial, antiprotozoal and intercalates DNA. [Wolfe Antibiot 3 (Springer-Verlag) 203 1975.1

Quisqualic acid (3-[3,5-dioxo-1,2,4-oxadiazolin-2-yl]-L-alanine) [52809-07-1] M 189.1, m 190-191°, \( [\alpha]_{D}^{25} +17^\circ \) (c 2, 6M HCl), \( pK_{a1} = 2.1 \) (CO\(_2\)H), \( pK_{a2} = 8.9 \) (NH\(_2\)). It has been purified by ion-exchange chromatography on Dowex 50W (x 8, H\(^+\) form), the desired fractions are lyophilized and recrystd from H\(_2\)O-EtOH. It has IR (KBr) \( \nu: 3400-2750 \) br. 1830s, 1775s, 1745s and 1605s cm\(^{-1}\); and \( ^1H \) NMR (NaOD, pH 13) \( \delta: 3.55-3.57 \) (1H m, X of ABX, H-2), 3.72-3.85 (2H, AB of ABX, H-3), \( ^{13}C \) NMR (D\(_2\)O) \( \delta: 50.1t, 53.4d, 154.8s, 159.7s \) and 171.3s. [Baldwin et al. J Chem Soc, Chem Commun 256 1985.1

Renal dipeptidase (from porcine kidney cortex) [9031-96-3] M, 47,000 [EC 3.4.13.11]. Purified by homogenising the tissue, extracting with Triton X-100, elimination of insoluble material, and ion-exchange, size exclusion and affinity chromatography. [Hitchcock et al. Anal Biochem 163 219 1987.1

Restriction enzymes (endonucleases). These are enzymes which cleave double stranded DNA (linear or circular) at specific nucleotide sequences within the DNA strands which are then used for cloning (by ligating bits of DNA sequences together) or used for identifying particular DNA materials, e.g. plasmids, genes etc. A very large number of restriction enzymes are now available commercially and are extensively used in molecular biology. They are highly specific for particular nucleotide arrangements and are sensitive to the reaction conditions, e.g. composition of the medium, pH, salt concentration, temperature etc, which have to be strictly adhered to. The enzymes do not require further purification and the reaction conditions are also provided by the suppliers from which the necessary reaction media can also be purchased (see commercial catalogues).

Retinal (Vitamin A aldehyde), Retinoic acid (Vitamin A acid), Retinyl acetate, Retinyl palmitate see entries in Chapter 4.

Reverse transcriptase (from avian or murine RNA tumour viruses) [9068-38-6] [EC 2.7.7.49]. Purified by solubilising the virus with non-ionic detergent. Lysed virions were adsorbed on DEAE-cellulose or DEAE-Sephadex columns and the enzyme eluted with a salt gradient, then chromatographed on a phosphocellulose column and enzyme activity eluted in a salt gradient. Purified from other viral proteins by affinity chromatography on a pyran-Sepharose column. [Verna Biochim Biophys Acta 473 1 1977; Smith Methods Enzymol 65 560 1980; see commercial catalogues for other transcriptases.]

Riboflavin [83-88-5] M 376.4, m 295-300° (dec), \( [\alpha]_{D}^{25} -9.8^\circ \) (H\(_2\)O), -125° (c 5, 0.05N NaOH), \( pK_{a1} = 1.7, pK_{a2} = 9.69 \) (10.2, acidic NH). Cryst from 2M acetic acid, then extracted with CHCl\(_3\) to remove lumichrome impurity. [Smith and Metzler J Am Chem Soc 85 3285 1963.] Has also been crystallized from water. (See also p. 575.)


D-(+)-Ribonic acid-\( \gamma \)-lactone [5336-08-3] M 148.12, m 80°, 84-86°, \( [\alpha]_{D}^{25} +18.3^\circ \) (c 5, H\(_2\)O). Purified by recrystn from EtOAc. The tribenzoate has m 54-56° (from AcOH), \( [\alpha]_{D}^{25} +27^\circ \) (c 2.37, Me\(_2\)NCHO) and the 3.5-O-benzylidene derivative has m 230-231.5° (needles from Me\(_2\)CO-pet ether), \( [\alpha]_{D}^{25} -177^\circ \) (CHCl\(_3\)). [Chen and Joulié J Org Chem 49 2168 1984; Zinner and Voigt J Carbohydr Res 7 38 1968.]
Ribonuclease (from human plasma) [9001-99-4] Mr ~13,700, [EC 3.1.27.5], amorphous. Purified by (NH₄)₂SO₄ fractionation, followed by PC cellulose chromatography and affinity chromatography (using Sepharose 4B to which (G)₆ was covalently bonded). [Schmukler et al. J Biol Chem 250 2206 1975.]

RNA (ribonucleic acids). Ribonucleic acids are like DNA except that the 2'-deoxy-D-ribose moiety is replaced by a D-ribose moiety and the fourth nucleotide thymidylic acid (T) is replaced by uridylic acid (U). RNA does not generally form complete duplex molecules like DNA, i.e. it is generally monomeric, except in certain viruses. The two main classes of RNA are messenger-RNA (mRNA) and transfer-RNA (tRNA). mRNA transcribed from the DNA gene followed by the splicing out of the non-coding nucleotides (of the introns) and codes for a specific gene. There are many different tRNAs, at least one of which links to a specific α-amino acid, that bind to the mRNA via the ribosome (a set of proteins) to the RNA triplets (three nucleotides) which code for the particular α-amino acids. An enzyme then joins the α-amino acids of two adjacent tRNA-α-amino acid ribosome complexes bound to the mRNA to form a peptide bond. Thus peptide bonds and consequently polypeptides and proteins coded by the DNA via the respective mRNA are produced.

Martin et al. [Biochem J 89 327 1963] dissolved RNA (5g) in 90mL of 0.1mM EDTA, then homogenised with 90mL of 90% (w/v) phenol in water using a Teflon pestle. The suspension was stirred vigorously for 1h at room temperature, then centrifuged for 1h at 0°C at 25000rpm. The lower (phenol) layer was extracted four times with 0.1mM EDTA and the aqueous layers were combined, then made 2% (w/v) with respect to AcOK and 70% (v/v) with respect to EtOH. After standing overnight at -20°C, the ppt was centrifuged down, dissolved in 50mL of 0.1mM EDTA, made 0.3M in NaCl and left 3 days at 0°C. The purified RNA was then centrifuged down at 10000xg for 30min, dissolved in 100mL of 0.1mM EDTA, dialysed at 4°C against water, and freeze-dried. It was stored at -20°C in a desiccator. Michelson [J Chem Soc 1371 1959] dissolved log of RNA in water, added 2M ammonia to adjust the pH to 7, then dialysed in Visking tubing against five volumes of water for 24h. The process was repeated three times, then the material after dialysis was treated with 2M HCl and EtOH to ppt the RNA which was collected, washed with EtOH, ether and dried [see commercial catalogues for further examples].

Ricin (toxin from Castor bean Ricinus communis) [A chain 96638-28-7; B chain 96638-29-8] Mr ~60,000, amorphous. Crude ricin, obtained by aqueous extraction and (NH₄)₂SO₄ pptn, was chromatographed on a galactosyl-Sepharose column with sequential elution of pure ricin. The second peak was due to ricin agglutinin. [Simmons and Russell Anal Biochem 146 206 1985.] Inhibitor of protein synthesis. EXTREMELY DANGEROUS, USE EXTREME CARE [instructions accompany product].


Rifamycin B [13929-35-6] M 755.8, m 300°C (darkening at 160-164°C), [α]D₀ 11° (MeOH), pK₁ 2.60, pK₂ 7.76. It forms yellow needles from 0.08C₆H₆. It has solubility in H₂O (0.027%), MeOH (2.62%) and EtOH (0.44%). It has UV λₘₐₓ 223, 304 and 245nm (ε 555, 275 and 220). [Oppolzer and Prelog Helv Chim Acta 56 2287 1973; Oppolzer et al. Experientia 20 336 1964; X-ray: Brufani et al. Experientia 20 339 1964.]

Rifamycin SV sodium salt [15105-92-7] M 719.8, m 300°C(darkening >140°C), [α]D₀ 4° (MeOH), pKₑₐₙ ~ 7.8. Yellow orange crystals from Et₂O-pet ether or aq EtOH, very soluble in MeOH, EtOH, Me₂CO and EtOAc, soluble in Et₂O and HCO₃⁻, slightly soluble in H₂O and pet ether. Its UV has λₘₐₓ at 223, 314 and 445nm (ε 586, 322 and 204) in phosphate buffer pH 7. [NMR: Bergamini and Fowst Arzneim.-Forsch 15 951 1965.]

Sarcosine anhydride \([5076-82-4]\) M 142.2, m 146-147°, pK_Est(1)=--4.2, pK_Est(2)=--1.9. Crystd from water, EtOH or ethyl acetate. Dried in vacuum at room temperature.

(-)-Scopolamine hydrobromide \(3H_2O\) \((6\beta,7\beta\text{-epoxy}-3\alpha\text{-tropanyl \(S\)}\text{-tropane \(HBr\), hyoscine \(HBr\)}\) \([114-49-8]\) M 438.3, m 193-194°, 195°, 195-199°, \([\alpha]_D^{25}\text{-25°}(c 5, H_2O), pK^2 8.15.\] Recrystd from Me_2CO, H_2O or EtOH-Et_2O and dried. Soluble in H_2O (60%) and EtOH (5%) but insol in Et_2O and slightly in CHC_1_3. The hydrochloride has m 300° (from Me_2CO). The free base is a viscous liquid which forms a crystalline hydrate with m 59° and \([\alpha]_D^{20}\text{-28°}(c 2.7, H_2O).\] Readily hydrolysed in dilute acid or base. [Meinwald J Chem Soc 712 1953; Fodor Tetrahedron 1 86 1957.]

Seleno-DL-methionine \((±\text{-2-aminoo-4-methylselanylbutyric acid})\) \([2578-28-1]\) M 196.1, m 265°(dec), 267-269°(dec), 270° (see pKs of methionine). Crystallises in hexagonal plates from MeOH and H_2O. [Klosterman and Painter J Am Chem Soc 69 2009 1949.] The L-isomer is purified by dissolving in H_2O, adjusting the pH to 5.5 with aqueous NH_3, evaporating to near-dryness, and the residue is washed several times with absolute EtOH till solid is formed and then recrystd from Me_2CO. It has m 266-268°(dec), 275°(dec), \([\alpha]_D^{25}\text{+18.1°(c 1, N HCl).}\] [Pande et al. J Org Chem 35 1440 1970.]

Serotonin hydrochloride \((5\text{-HT}, 3\text{-[2-aminooethyl]-5-hydroxyindole \(HCl\)})\) \([153-98-0]\) M 212.7, m 167-168°, 178-180°, pK^2 4.9, pK^2 5.8 (10.0, NH_3), pK^3 11.1 (5-OH), pK^4 18.25 (acidic indole NH). Purified by recrystn from EtOH-Et_2O or Et_2O to give the hygroscopic salt. Store in the dark as it is light sensitive. The free base has m 84-86° (from Et_2O). The 5-benzoylxy derivative has m 84-85° (from Et_2O). [Ek and Witkop J Am Chem Soc 76 5579 1954; HamLin and Fischer J Am Chem Soc 73 5007 1951.] The picrate \(1H_2O\) has m 196-197.5° (dec with sintering at 160-165°) after recrystn from Et_2O. Serotonin is a natural neurotransmitter [Chuang Life Sci 41 1051 1987].


\(α\)-Solanine \((\text{solanc-5-en-3β-yl-\(O\)-3\text{-[3\text{-D-glucopyranosyl-\(O\)-2-\text{-L-rhamnopyranosyl-\(β\)-D-galacto-pyranside})}\})\) \([20562-02-1]\) M 868.1, m 285°(dec), 286°(dec) (sintering >190°), \([\alpha]_D^{20}\text{-58°(c 0.8, pyridine), pK^5 6.6.}\] Recrystd from EtOH, 85% aqueous EtOH, MeOH or aqueous MeOH as \(dihydrate\) m 276-278°. Solubility in H_2O is 25mg/L and 5% in pyridine, but it is very soluble in Et_2O and CHC_3. The hydrochloride is gummy or amorphous but has been crystd (m -212° dec). It has insecticidal properties. [Kuhn et al. Chem Ber 88 1492 1955.]

Somatostatin \([38916-34-6]\) M 1637.9, \([\alpha]_D^{25}\text{-36°(c 0.57, 1% AcOH).}\] A tetradecapeptide which is purified by gel filtration on Sephadex G-25, eluting with 2N AcOH, and then by liquid partition chromatography on Sephadex G-25 using n-BuOH-AcOH-H_2O (4:1:5) and has Rp= 0.4. It is a brain growth hormone releasing-inhibiting factor which has also been synthesised. [Burgus et al. Proc Natl Acad Sci USA 70 684 1973; Sorantakis and McKinley Biochem Biophys Res Commun 54 234 1973; Hartridt et al. Pharmazie 37 403 1982.]

Spectinomycin dihydrochloride pentahydrate \((\text{Actinospectacin})\) \([21736-83-4]\) M 495.3, m 205-207°(dec), \([\alpha]_D^{24\text{+14.8°(c 0.4, H_2O), pK^1 6.95, pK^2 8.70.}\] Purified from aqueous Me_2CO and is soluble in H_2O, MeOH and dilute acid and base but only slightly soluble in Me_2CO, EtOH, CHC_3 and \(^\text{4}^\text{C}_6\text{H}_6.\] The free base is an amorphous solid, m 184-194° with \([\alpha]_D^{20}\text{-20°(H_2O).}\] [Wiley et al. J Am Chem Soc 93 2652 1975; X-ray: Cochran et al. J Chem Soc Chem Commun 494 1972.] It is an aminoglycoside antibiotic which interacts with 16S ribosomal RNA [Moazet and Noller Nature 327 389 1987]; and is used for the treatment of gonorrhea [Rinehart J Infect Dis 119 345 1969].
D-Sphingosine (2S,3S-D-erythro-2-aminoocdec-4-en-1,3-diol from bovine brain) \[123-78-4\] M 299.5, m 79-820, 82° 82.5° (softens at -70°), \([\alpha]_{D}^{23} -3.4°\) (c 2, CHCl₃), pKₐ₈ ~ 8.8. Purified by recryst from EtOAc, Et₂O or pet ether (60-80°). It is insoluble in H₂O but soluble in Me₂CO, EtOH and MeOH. It has IR bands at 1590 and 875 cm⁻¹, and is characterised as the tribenzoate m 122-123° (from 95% EtOH). [Polgar et al. Arch Biochem Biophys 9 127 1962.]

Spirilloxanthin \[34255-08-8\] M 596.9, m 216-218°, \(\lambda_{\text{max}}\) 463, 493, 528 nm, \(\varepsilon_{\text{cm}} 2680\) (493 nm) in pet ether (b 40-70°). Cryst from CHCl₃/pet ether, acetone/pet ether, *C₆H₆/pet ether or *C₆H₆. Purified by chromatography on a column of CaCO₃/Ca(OH)₂ mixture or deactivated alumina. [Polgar et al. Arch Biochem Biophys 5 243 1944.] Stored in the dark in an inert atmosphere, at -20°.

Squalane (Cosobil, 2,6,10,15,19,23-hexamethyltetrasacosen, perhydroxysqualene) \[111-01-3\] M 422.8, m -38°, b 176°/0.05mm, 210-215°/1mm, 274°/10mm, -350°/760mm, d²9 0.80785, nD 1.416. Purified by fractional distn in vac or evap distn. Soluble in pet ether, *C₆H₆ and CHCl₃, slightly sol in alcohols, Me₂CO and AcOH but insol in H₂O [Staudinger and Leupold Helv Chim Acta 15 223 1932; Sax and Stross Anal Chem 29 1700 1951; Mandai et al. Tetrahedron Lett 22 763 1981].

Squalene \(\text{[all-trans-2,6,10,15,19,23-hexamethyl-2,6,10,14,18,22-tetracosahexaene]}\) \[111-02-4\] M 410.7, m -75°, b 203°/0.1mm, 213°/1mm, 285°/25mm, d²9 0.8670, n 1.4905. Cryst repeatedly from Me₂CO (1.4mWg) using a Dry-ice bath, washing the crystals with cold acetone, then freezing the squalene under vacuum. Squalene was further purified by passage through a column of silica gel or chromatographed on activated alumina, using pet ether as eluent and stored in vac in the dark. Dauben et al. [J Am Chem Soc 74 4321 1952] purified squalene via its hexachloride and is bactericidal. [Capstack et al. J Biol Chem 240 3258 1965; Krishna et al. Arch Biochem Biophys 114 200 1966; Heilbron and Thompson J Chem Soc 883 1929; Karrer et al. Helv Chim Acta 13 1084 1930; UV: Farmer et al. J Chem Soc 544 1943.]

Starch \[9005-84-9\] M (162.1)ₙ. Defatted by Soxhlet extraction with Et₂O or 95% EtOH. For fractionation of starch into "amylose" and "amylopectin" fractions, see Lansky et al. [J Am Chem Soc 71 4066 1949].

Sterigmatocystin \(\text{[3a,12c-dihydro-8-hydroxy-6-methoxy-3H-furo}[3',2',:4,5]\text{furo}[2,3-c]-xanthen-7-one]\) \[100487-13-2\] M 324.3, m 246°, 247-248°, \([\alpha]_{D}^{20} -398°\) (c 0.1, CHCl₃), pKₐ₈ ~ 8.0. Recryst from amyl acetate, Me₂CO or EtOH and sublimed in vacu. It has UV \(\lambda_{\text{max}}\) at 208, 235, 249 and 329nm (log ε 4.28, 4.39, 4.44 and 4.12). [UV: Bullock et al. J Chem Soc 4179, 1962; UV, IR: Holker and Mulheim J Chem Soc Chem Comm 1576, 1956; Birkinshaw and Hammad Biochem J 65 162 1957.] This mycotoxin induces bone marrow changes in mice [Curry et al. Mutation Res 137 111 1984].

Stigmatellin A \(\text{[2-[4,6-dimethoxy-3,5,11-trimethyltridecatri-7t,9t,11t-erythro]-8-hydroxy-5,7-dimethoxy-3-methyl-4H-1-benzopyran-4-one]}\) \[91682-96-1\] M 514.6, m 128-130°, \([\alpha]_{D}^{20} +38.5°\) (c 2.3, MeOH), pKₐ₈ ~ 7 (phenolic OH). It is stable in aqueous soln at neutral pH but decomposes at pH <5. Purified by recryst from toluene-hexane. It has UV \(\lambda_{\text{max}}\): nm (ε): 248sh (41000), 258 (59500) 267 (65500), 279 (41400) and 335 (5200) in MeOH; 249sh (45600), 258 (60000), 268 (72700), 277 (54100), 320 (2500) and 370 (3000) in MeOH + 1 drop of N KOH; 243sh (29300), 264 (63200), 274 (64100), 283sh (45800), 329 (4800) and 420 (21000) in MeOH + 6N HCl; and IR (CHCl₃): ν 3550m, 1645chs, 1635ss, 1620ss, 1590s, 1510m and 905m cm⁻¹. It gives colour reactions at 110° with vanillin/H₂SO₄ (grey), Ce(IV)/(NH₄)₂SO₄ (yellow) and phosphomolybdic acid (blue-grey). [Höfte et al. Justus Liebigs Ann Chem 1882 1884.] It inhibits electron transport [Jagow and Link Methods Enzymol 126 253 1986; Robertson et al. Biochemistry 32 1310 1993], and has antibiotic properties [Kunze et al. J Antibiot 37 454 1984]. The 71,9t,11t-isomer is Stigmatellin B.

Streptonigrin (nigrin, 5-amino-6-[7-amino-5,8-dihydro-6-methoxy-5,8-dioxo-2-quinolinyl]-4-[2-hydroxy-3,4-dimethoxyphenyl]-3-methyl-2-pyridinecarboxylic acid) [3930-19-6] M 506.5, m 262-263°C, 275°C(dec), pK 6.3 (1:1 aq dioxane). Purified by TLC on pH 7-buffered silica gel (made from a slurry of Silica Gel 60 and 400mL of 0.05M phosphate buffer pH 7.0) and eluted with 5% MeOH/KHC1. The extracted band can then be recrystd from Me2CO or dioxane as almost black plates or needles. It is soluble in pyridine, Me2NCHO, aqueous NaHCO3 (some dec), and slightly soluble in MeOH, EtOH, EtOAc and H2O. It has UV λmax 248, 375-380nm (E 38400 and 17400). [Weinreb et al. J Am Chem Soc 104 536 1982; Rao et al. J Am Chem Soc 85 2532 1963.] It is an antineoplastic and causes severe bone marrow depression [Wilson et al. Antibiot Chemother 11 147 1961].

Streptozotocin (N-[methylnitrosocarbamoyl]-α-D-glucosamine, streptozocin) [18883-66-4] M 265.2, m 111-114°C(dec), 114-115°C(dec with evolution of gas), [α]D +39° (HzO, may vary due to mutarotation). Recrystd from 95% EtOH and is soluble in H2O, MeOH and Me2CO. It has UV λmax 228nm (E 6360) in EtOH. The tetraacetate has m 111-114°C(dec), [α]D +41° (c 0.78, 95% EtOH) after recrystn from EtOAc. [Herr et al. J Am Chem Soc 89 4808 1967; NMR: Wiley et al. J Org Chem 44 9 1979.] It is a potent methylating agent for DNA [Bennett and Pegg Cancer Res 41 2786 1981].

Subtilisin (from Bacillus subtilis) [9014-01-1] [EC 3.4.21.62]. Purified by affinity chromatography using 4-(4-aminophenylazo)phenylarsonic acid complex to activated CH-Sepharose 4B. [Chandraskaren and Dhar Anal Biochem 150 141 1985].

Succinyl coenzyme A trisodium salt [108347-97-3] M 933.5. If it should be purified further then it should be dissolved in H2O (0.05g/mL) adjusted to pH 1 with 2M H2SO4 and extracted several times with Et2O. Excess Et2O is removed from the aqueous layer by bubbling N2 through it and stored frozen at pH 1. When required the pH should be adjusted to 7 with dilute NaOH and used within 2 weeks (samples should be frozen). Succinyl coenzyme A is estimated by the hydroxamic acid method [J Biol Chem 242 3468 1967]. It is more stable in acidic than in neutral aqueous solutions. [Methods Enzymol 128 435 1986.]

2-Sulfobenzoic cyclic anhydride (2,1-benzoxathiazol-3-one 1,1-dioxide) [81-08-3] M 184.2, m 126-127°C, 129.5°, 130°, b 184-186°/18mm. If the sample has hydrolysed extensively (presence of OH band in the IR) then treat with an equal bulk of SOCl2 reflux for 3h (CaC12 tube), evaporate and distil residue in a vacuum, then recrystd from *C6H6, Et20-*C6H,j or CHC13 (EtOH free by passing through Al2O3, or standing over CaC12). [Clarke and Breger Org Synth Coll Vol I 495 1948.] Used for modifying 6-amino functions of lysyl residues in proteins [Bagree et al. FEBS Lett 120 275 1980]. (see entry on p. 126.)

Syrexin (from bovine liver). Purified by (NH4)2SO4 pptn, then by pH step elution from chromatofocusing media in the absence of ampholytes. [Scott et al. Anal Biochem 149 163 1985.]

Taurodeoxycholic acid sodium salt monohydrate (n-[deoxycholyt)taurine Na salt H2O) [1180-95-6] M 539.7, m 171-175°C, [α]D23 +37° (c 1, H2O), pK 1.4 (free acid). The salt is recrystd from EtOH-Et2O. Its solubility in H2O is 10%. The free acid has m 141-144°. [Norman Ark Kemi 8 331 1956.] It forms mixed micelles and solubilises some membrane proteins [Hajjar et al. FEBS Lett 220 785 1980]. (see entry on p. 126.)

Terramycin (oxytetracycline) [79-57-2] M 460.4 (anhy), 496.5 (2H2O), sinters at 182°, melts at 184-185°C(dec), [α]D +196.6° (equilibrium in 0.1M HCl), -2.1° (equilibrium in 0.1M NaOH). Cryst (as dihydrate) from water or aqueous EtOH.

Tetracycline [60-54-8] M 444.4, m 172-174°(dec), [α]$_{D}^{25}$ +270° (c 1, MeOH), pK$_{a}^{1}$ 3.30, pK$_{a}^{2}$ 7.68, pK$_{a}^{3}$ 9.69. Crystd from toluene.

Tetracycline hydrochloride [64-75-5] M 489.9, m 214°(dec), 215-220°, [α]$_{D}^{20}$ -258° (c 0.5, 0.1N HCl), [α]$_{D}^{10}$ -245° (c 1, MeOH), pK$_{1}$ 1.4 (enolic OH), pK$_{2}$ 7.8 (phenolic OH), pK$_{3}$ 9.6 (Me$_{2}$N). Recrystd from MeOH + n-BuOH or n-BuOH + HCl. It is insoluble in Et$_{2}$O and pet ether. It has UV $\lambda_{max}$ at 270 and 360nm in MeOH. [Gottstein et al. J Am Chem Soc 81 1198 1959; Conover et al. J Am Chem Soc 84 3222 1962.]

6R-Tetrahydro-erythro-biopterin dihydrochloride (BH$_{4}$.2HCl, 6R-2-amino-4-hydroxy-6,[(1R,2S)-1,2-dihydroxypropyl]-5,6,7,8-tetrahydropteridine 2HCl) [69056-38-8] M 316.2, m 245-246°(dec), [α]$_{D}^{15}$ -6.8° (c 0.67, 0.1N HCl), pK$_{1}$ 1.37 (pyrimidine $+^{+}$), pK$_{2}$ 5.6 (5-NH$^{+}$), pK$_{3}$ 10.6 (acidic, 3NH). Recrystn from HCI enriches BH$_{4}$ in the natural 6R isomer. Dissolve the salt (~6g) in conc HCl (15mL) under gentle warming then add EtOH (30mL) dropwise, chill and collect the colourless needles (67%, up to 99% if mother liquors are concentrated), and dried in vacuo immediately over P$_{2}$O$_{5}$ and KOH. Stores indefinitely at -20O in a dry atmosphere. Better store in sealed ampoules under dry N$_{2}$. It can be recrystd from 6N aqueous HCl. It has UV $\lambda_{max}$ (2N HCl) 264nm (c 16770; pH 3.5 phosphate buffer) 265nm (c 13900); (pH 7.6) 297nm (c 9500) and 260nm sh (c 4690). It has been separated from the 6R-isomer by HPLC on a Partisil-10SCX column using 30mM ammonium phosphate buffer (pH 3.0) containing 3mM NaHSO$_{3}$ (2mL/min flow rate; 275nm detector) with retention times of 5.87min (6R) and 8.45min (6S). It is stable in acidic soln and can be stored for extended periods at -20O in 0.04M HCl. Above pH 7 the neutral species are obtained and these are readily oxidised by oxygen in the solvent to quinonoid species and then further oxidation and degradation occurs at room temperatures. These changes are slower at 0O. The sulfite salt can be obtained by recrystn from 2M H$_{2}$SO$_{4}$ and is less soluble than the hydrochloride salt. The 6R,2,5,1',2'-tetraacetylbiopterin derivative has m 292°(dec) after recrystn from MeOH (100 parts) and [α]$_{D}^{25}$ -144° (c 0.5, CHCl$_{3}$), [α]$_{D}^{25}$ +12.8° (c 0.39, Me$_{2}$SO). [NMR, UV: Matsuura et al. Heterocycles 23 3115 1983; Viscontini et al. Helv Chim Acta 62 2577 1979; Armarego et al. Aust J Chem 37 355 1984.]

Tetrahydrofolic acid dihydrochloride 2H$_{2}$O (THFA, 6S- or 6RS- 5,6,7,8-tetrahydrofolic acid 2HCl 2H$_{2}$O) [135-16-0] M 544.4, m >200°(dec), [α]$_{D}^{25}$ +16.9° (H$_{2}$O pH 7.0 + 2-mercaptoethanol), pK$_{1}$ 1.7 (pyrimidine $N^{+}$), pK$_{2}$ 2.4 (10N$^{+}$), pK$_{3}$ 3.5 (cis-CO$_{2}$H), pK$_{4}$ 4.9 (γ-CO$_{2}$H), pK$_{5}$ 5.6 (5-NH$^{+}$), pK$_{6}$ 10.4 (acidic, 3NH). Very high quality material is now available commercially and should be a white powder. It can be dried over P$_{2}$O$_{5}$ in a vacuum desiccator and stored in weighed aliquots in sealed ampoules. It is stable at room temp in sealed ampoules for many months and for much more extended periods at -20O. When moist it is extremely sensitive to moist air whereby it oxidises to the yellow 7,8-dihydro derivative. In soln it turns yellow in colour as it oxidises and then particularly in the presence of acids it turns dark reddish brown in colour. Hence aqueous solutions should be frozen immediately when not in use. It is always advisable to add 2-mercaptoethanol (if it does not interfere with the procedure) which stabilises it by depleting the soln of O$_{2}$. The sulfite salt is more stable but then it is much less soluble. The best way to prepare standard solns of this acid is to dissolve it in the desired buffer and estimate the concentration by absorption in N HCl where it has a peak at 265nm which drops sharply to zero having no absorption at 340nm. The presence of absorption at 340nm indicated oxidation to quinonoid or 7,8-dihydropterin. If the absorption is weak then dissolve in the minimum volume of anhydrous trifluoroacetic acid (fume hood) add charcoal, filter, then add one or two drops of N H$_{2}$SO$_{4}$ followed by dry Et$_{2}$O at 0O, allow the white tetrahydro
salt to settle and collect, and wash with dry Et₂O, by centrifugation. Dry the residue in a vacuum desiccator over P₂O₅ and KOH. Store in aliquots in the dark at 21°C.


Thiamphenicol (1R,2R-2-[2,2-dichloroacetylamino]-1-[4-methanesulfonylphenyl]-propan-1,3-diol) [15318-45-3] (D-threo), 90-91-5 M 356.2, m 163-166°, 165.2-165.6°, 165-166°, [α]D²⁵ +15.6° (c 2, EtOH), pK 7.2. Recrystd from H₂O or CHCl₃. UV λmax 224, 266 and 274nm (ε 13700, 800 and 700) in 95% EtOH. The 1S,2S-isomer [14786-51-7] has m 164.3-166.3° (from H₂O + EtOAc + pet ether) and [α]D²⁵ -12.6° (c 1, EtOH); and the racemate IRS,2RS Racefenical [15318-45-3] has m 181-183° (sinter at 180-183°) from CHCl₃-EtOAc-pet ether. [Cutler et al. J Am Chem Soc 74 5475, 5482 1952; UV: Nachod and Cutler J Am Chem Soc 74 1291 1952; Suter et al. J Am Chem Soc 75 4330 1953; Cutler et al. J Am Pharm Assoc 43 687 1954.]

Thiazolyl blue tetrazolium bromide (MTT, 3-[4,5-dimethyl-2-thiazolyl]-2,5-diphenyl-2H-tetrazolium bromide) [298-93-1, 2348-71-21 M 414.3, m 171°. It is recrystd by dissolving in MeOH containing a few drops of HBr and then adding dry Et₂O to complete the crystn, wash the needles with Et₂O and dry in a vacuum desiccator over KOH. [Beyer and Pyl Chem Ber 87 1505 1954.]


Thrombin (from bovine blood plasma) [9002-04-4] M₉ 32,600 [EC 3.4.4.13]. Purified by chromatography on a DEAE-cellulose column, while eluting with 0.1M NaCl, pH 7.0, followed by chromatography on Sephadex G-200. Final preparation was free from plasminogen and plasmin. [Yin and Wesslet J Biol Chem 243 112 1968.]

Thrombin from bovine blood was purified by chromatography using p-chlorobenzylamino-γ-aminocaproyl agarose, and gel filtration through Sephadex G-25. [Thompson and Davie Biochim Biophys Acta 250 210 1971.]

Thrombin from various species was purified by precipitation of impurities with rivanol. [Miller Nature 184 450 1959.]

L-Thyroxine sodium salt (5H₂O) [6106-07-6] M 888.9, [α]D²⁰ +29° (c 2, 1M HCl + EtOH, 1:4). Crystd from absolute EtOH and dried for 8h at 30°/1mm.

D-Thyroxine (D-[3,5-diiodo-4-oxophenyl]-3,5-diido-D-(±)-tyrosine, 3,3',5,5'-tetra-iodo-D-thyronine) [51-49-0] M 776.9, m 235°(dec), 235-236°(dec), 340°(dec), [α]D²⁰ +4.5° (c 3, aq
0.2N NaOH in 70% EtOH), \([a]_{D}^{20} -17^\circ\) (c 2, aq NaCl + EtOH 1:4), pK$_{D}^{25}$ 2.2 (CO$_2$H), pK$_{D}^{25}$ 8.40 (OH), pK$_{D}^{25}$ 10.1 (NH$_2$). Recrystd from H$_2$O as needles or from an ammonical soh by dilution with H$_2$O, MeOH or Me$_2$CO. Also purified by dissolving ~6.5 g in a mixture of MeOH (200mL) and 2N HCl (20mL), add charcoal, filter then add NaOAc soh to pH 6 and on standing the thyroxine separates, is washed with MeOH then Me$_2$CO and dried in vacuo. The N-formyl-D-thyroxine derivative has m 210° and \([a]_{D}^{25} -26.9^\circ\) (c 5, EtOH). The racemate N-thyroxine has m 256° and is purified in the same way. [Nahm and Siedel Chem Ber 96 1 1963; Salter Biochem J 24 471 1930.]

L-Thyroxine (O-[3,5-diiodo-4-oxyphenyl]-3,5-diiodo-L- (+)-tyrosine, 3,3',5,5'-tetraiodo-D-thyronine) \([51-48-9]\) M 776.9, m 229-230°(dec), -23S0(dec), 237O(dec), irx$_{\text{I}_{2}}$ -5.1O (c 2, aq N NaOH + EtOH 1:2), \([a]_{D}^{25} +1S0 (c 5, aq N HCl in 95% EtOH 1:2), \([a]_{D}^{25} +26O (EtOH/1M aq HCI; 1:1) (pK 6.6). Purification is the same as for the D-isomer above. Likely impurities are tyrosine, iodotyrosine, iodothyroxines and iodide. Dissolve in dilute ammonia at room temperature, then crystd by adding dilute acetic acid to pH 6. The N-formyl-L-thyroxine has m 214O(dec) and \([a]_{D}^{25} +27.8O (c 5, EtOH). [Harington et al. Biochem J 39 164 1945; Nahm and Siedel Chem Ber 96 1 1963; Reineke and Turner J Biol Chem 161 613 1945; Chalmers et al. J Chem Soc 3424 1949.]

Tissue inhibitor of metalloproteins (TIMP, from human blood plasma), M$_r$ -30,000. Purified by a [anti-human amniotic fluid-TIMP-Sepharose immuno-affinity column eluted with 50mM glycine/HCl pH 3.0 buffer that is 0.5M in NaCl then by gel fnlt [Cawston et al. Biochem J 238 677 1986].

dl- \(\alpha\)-Tocopherol (see vitamin E) \([59-02-9]\) M 430.7, A$_{1\%}$ 74.2 at 292 nm in MeOH. Dissolved in anhydrous MeOH (15mL/g) cooled to -6O for lh, then chilled in a Dry-ice/acetone bath, crystn being induced by scratching with a glass rod.

\(\gamma\)-Tocopherol (3,4-dihydro-2,7,8-trimethyl-2-(4,8,12-trimethyltridecyl)-2H-benzopyran-6-ol) \([54-28-4]\) M 416.7, m -30°, b 200-210°/0.1mm, d$_{25}^{0}$ 0.951, n$_{D}^{25}$ 1.505, \([\alpha]_{D}^{25} -2.4O (EtOH). Purified by distn at high vacuum and stored in dark ampoules under N$_2$. [IR: Uhle J Am Chem Soc 83 1460 1961; Kessar et al. Tetrahedron 27 2869 1971; Schreiber and Adams Experientia 17 13 1961.]

Tolylene-2,4-diisocyanate (toluene-2,4-diisocyanate). \([584-84-9]\) M 174.2, m 19.5-21.5°, 20-22°, 28°, b 126°/11mm, 124-126°/18mm, 250°/760mm. It is purified by fractionation in a vacuum and should be stored in a dry atmosphere. It is soluble in organic solvents but reacts with H$_2$O, alcohols (slowly) and amines all of which could cause explosive polymerisation. It darkens on exposure to light. It has a sharp pungent odour, is TOXIC and is IRRITATING TO THE EYES. [Siefken Justus Liebigs Ann Chem 562 75, 96, 127 1949; Bayer Angew Chem 59 257 1947. It is a reagent for covalent crosslinking of proteins [Wold Methods Enzymol 25 623 1972].

Tomatidine (5a,20B,22a,25B,27-azaspirostan-3a,5a-ol) \([77-59-8]\) M 415.7, m 202-206°, \([\alpha]_{D}^{25} -5.9O (c 1, MeOH), \([\alpha]_{D}^{25} +5.9O (CHCl$_3$). Forms plates from EtOAc. Also purified by distillation with *C$_6$H$_6$ and applying to an Al$_2$O$_3$ column (3.5 g) and eluting with *C$_6$H$_6$, evaporating and recrystalling three times from EtOAc. The hydrochloride has m 265-270° from EtOH and \([\alpha]_{D}^{25} -5O (MeOH). [IR: Uhle J Am Chem Soc 83 1460 1961; Kessar et al. Tetrahedron 27 2869 1971 ; Schreiber and Adams Experientia 17 13 1961.]

Tomatine (22S,25S-3B,5B-lycotecarboxyloxy-5a-spirosoolan) \([17406-45-0]\) M 1034.2, m 263-265°(dec), 290-291°(vac capillary), 283-5-287°(dec), 272-277°(dec), 300-305°(dec), \([\alpha]_{D}^{25} -18O to -34O (c 0.55, pyridine). Recrystd from MeOH, EtOH, aqueous EtOH or dioxane + NH$_3$. It is almost insoluble in pet ether, Et$_2$O or H$_2$O. [Reichstein Angew Chem 74 887 1962.]

N-Tosyl-L-lysine chloromethyl ketone (3S,1-chloro-3-tosylamino-7-amino-2-heptanone HCl) \([4272-74-6]\) M 569.3, m 150-153°(dec), 156-158°(dec), -165°(dec), \([\alpha]_{D}^{25} -7.3O (c 2, H$_2$O), pK$_{Est}$ ~ 10.6 (7-NH$_2$). The hydrochloride slowly crystallises from a conc soh in absolute EtOH,

Transferrin (from human or bovine serum) [11096-37-0] M₆=80,000. Purified by affinity chromatography on phenyl-boronate agarose followed by DEAE-Sephadex chromatography. The product is free from haemopexin. [Cook et al. Anal Biochem 149 349 1985; Aisen and Listowsky Ann Rev Biochem 49 357 1980.]

Trehalase (from kidney cortex) [9025-52-9] [EC 3.2.1.28]. Purified by solubilising in Triton X-100 and sodium deoxycholate, and submitting to gel filtration, ion-exchange chromatography, conA-Sepharose chromatography, phenyl-Sepharose CL-4B hydrophobic interaction chromatography, Tris-Sepharose 6B affinity and hydrolyapatite chromatography. Activity was increased 3000-fold. [Yoneyama Arch Biochem Biophys 255 168 1987.]

Trifluoperazine dihydrochloride (10-[3-\{4-methyl-1-piperazinyl\}propyl]-2-trifluoro-methylphenothiazine 2HCl) [440-17-5] M 480.4, m [240-243°, 242-243°, pK₁ 3.9, pK₂ 8.1. Recrystd from abs EtOH dried in vacuo and stored in tightly stoppered bottles because it is hygroscopic. It is soluble in H₂O but insoluble in C₆H₆, Et₂O and alkaline aqueous soln. It has UV λmax at 258 and 307.5nm (log ε 4.50 and 3.50) in EtOH (neutral species). [Craig et al. J Org Chem 22 709 1957.]

T4-RNA ligase (from bacteriophage-infected E.coli) M₄ 43,500 [EC 6.5.1.3 for RNA lyase]. Purified by differential centrifugation and separation on a Sephadex A-25 column, then through hydroxylapatite and DEAE-glycerol using Aff-Gel Blue to remove DNAase activity. (Greater than 90% of the protein in the enzyme preparation migrated as a single band on gradient polyacrylamide gels containing SDS during electrophoresis.) [McCoy et al. Biochim Biophys Acta 562 149 1979.]

Tubercidin (7-deazaadenosine) [69-33-0] M 266.3, m [247-248°, [α]D -67° (50% aq AcOH), pKᵯ 5.2-5.3. Forms needles from hot H₂O. It is soluble in H₂O (0.33%), MeOH (0.5%) and EtOH (0.05%). It has UV λmax 270nm (ε 12100) in 0.001N NaOH. The picrate has m 229-231°(dec). [Tolman et al. J Am Chem Soc 91 2102 1969; Mizuno et al. J Org Chem 28 3329 1963, IR: Anzai et al. J Antibiot (Japan) [9] 10 201 1957.]

Tunicamycin [11089-65-9] m 234-235°(dec), [α]D +52° (c 0.5, pyridine), pKₑ₄ ~ 9.4. The components are purified by recrystallising 3 times from hot glass-distilled MeOH and the white crystals are dissolved in 25% aqueous MeOH and separated on a Partisil ODS-10µ column (9.4 x 25 cm) [Magnum-9 Whatman] using a 260 nm detector. The column was eluted with MeOH:H₂O mixture adjusted to 1:4 (v/v) then to 2:4 (v/v). The individual components are recovered and lyophilised. Ten components were isolated and all were active (to varying extents) depending on the lengths of the aliphatic side-chains. The mixture has UV λmax 205 and 260nm (A½cm 230 and 110). Stable in H₂O at neutral pH but unstable in acidic soln. It inhibits protein glycosylation. [Mahoney and Duskin J Biol Chem 254 6572 1979; Elnein Trends Biochem Sci 6 219 1981; Takatsuki J Antibiot 24 215 1971.]

Ubiquinol-cytochrome c reductase (from beef heart mitochondria) [9027-03-6] [EC 1.6.2.2]. Purified in Triton X-100 by solubilising the crude enzyme with Triton X-100, followed by hydroxylapatite and gel chromatography. The minimum unit contains nine polypeptide subunits of M₆ 6000 - 49000 kD. [Engel et al. Biochim Biophys Acta 592 211 1980.]

Uracil, uridine and uridine nucleotides. Resolved by ion-exchange chromatography AGI (Cl⁻ form). [Lindsay et al. Anal Biochem 24 506 1968.]
Purification of Biochemicals and Related Products

Uridine 5'-diphosphoglucose pyrophosphorylase (from rabbit skeletal muscle) [9029-22-6] M$_r$ 350,000, [EC 2.7.7.9]. Purified by two hydrophobic chromatographic steps and gel filtration. [Bergamini et al. Anal Biochem 143 35 1984.] Also purified from calf liver by (NH$_4$)$_2$SO$_4$ (40-58%) pptn, Ca$_3$(PO$_4$)$_2$ gel filtration, DEAE-cellulose chromatography and recrystn against increasing concentrations of (NH$_4$)$_2$SO$_4$ (from 10%) in 0.02M TEA (at 2.5% increments) until at 20% (NH$_4$)$_2$SO$_4$ it crystallises out [Hansen et al. Methods Enzymol 8 248 1966].

Uridine 5'-(-1-thio) monophosphate [15548-52-4, 18875-72-4 (Abs Stereochem specified)] and Uridine 5'-(-a-thio) diphosphate [RS(a-P)$_2$ 27988-67-6; R(a-P)$_2$ 72120-52-6, PKE$_{125}$ (~) 6.4, PKE$_{133}$ (~) 9.5 The Et$_3$N salt was purified by dissolving ~4g in 500mL of H$_2$O (add a drop or two of Et$_3$N if it does not dissolve) and chromatographed by applying to a column (3 x 30cm) of DEAE-Sephadex A-25 and eluted with a 1.4L linear gradient of Et$_3$NH.HC$_2$O from 0.05 to 0.55M, pH 7.8 and 4O. The product eluted between 0.2-0.3M Et$_3$N.HC$_2$O. Pooled fractions were evaporated and the residue was twice taken up in EtOH and evaporated to dryness to remove the last traces of Et$_3$NH.HC$_2$O. 31P NMR: Pa is a doublet at -40.81 and -40.33, and Pp at 7.02ppm, J$_{pp}$ 32.96Hz. [Biochemistry 18 5548 1979.]

Uric acid (di-Na salt) [27821-45-0] M 368.2, m 198S0, pK$_{25}$ 6.63, pK$_{36}$ 9.71. Crystd from MeOH.

Urokinase (from human urine) [9039-53-6] M, 53,000, [EC 3.4.21.31]. Crystn of this enzyme is induced at pH 5.0 to 5.3 (4O) by careful addition of NaCl with gentle stirring until the soln becomes turbid (silky sheen). The NaCl concentration is increased gradually (over several days) until 98% of saturation is achieved whereby the urokinase crystallises as colourless thin brittle plates. It can be similarly recrystd to maximum specific activity [104K CTA units/mg of protein (Sherry et al. J Lab Clin Med 64 145 1964)]. [Lesuk et al. Science 147 880 1965; NMR: Bogusky et al. Biochemistry 28 6728 1989.]

(+) Usnic acid (2,6-diacetyl-7,9-dihydroxy-8,9b-dimethyldibenzofuran-1,3(2H,9bH)-dione) [7562-61-0, 125-46-2] M 344.3, m 201-204°, 203-206°, [a]$_D$ 1546 +630° (c 0.7, CHCl$_3$), pK$_1$ 4.4, pK$_2$ 8.8, pK$_3$ 10.7. This very weak acid is the natural form which is recrystd from Me$_2$CO, MeOH or C$_6$H$_6$. At 25° it is soluble in H$_2$O (<0.01%), Me$_2$CO (0.77%), EtOAc (0.88%), MeOCH$_2$CH$_2$OH (0.22%) and furfural (7.32%). [Curd and Robertson J Chem Soc 894 1937; Barton and Brunn J Chem Soc 603 1953; resolution: Dean et al. J Chem Soc 1250 1953; synthesis: Barton et al. J Chem Soc 262 1989].

(-)-Usnic acid (2,6-diacetyl-7,9-dihydroxy-8,9b-dimethyldibenzofuran-1,3(2H,9bH)-dione) [6159-66-6, 7562-61-0] M 344.3, m 201-204°, 204°, [a]$_D$ -495° (c 0.9, CHCl$_3$). Properties almost similar to those of the preceding entry.

Ustilagic acid (Ustizea j B, di-D-glucosyldihydroxyhexadecanoic acid) [8002-36-6] M -780, m 146-147°, [a]$_D$ +70° (c 1, pyridine), pK ~ 4.9. It is a mixture of partly acetylated di-D-glucosyldihydroxyhexadecanoic acid which crystallises from diethyl ether. Also purified from the culture by dissolving in hot MeOH, filtering and concentrating by blowing a current of air until the soln becomes turbid, then heating to 50° and adding 4 vols of H$_2$O (also at 50°) and allowing to cool very slowly. Filter off the white solid and dry in air. [Lemieux et al. Can J Chem 29 409, 415 1951; Can J Biochem Physiol 33 289 1955.]

Valinomycin (Potassium ionophore I) [2001-95-8] M 111.3, m 186-187°, 190°, [a]$_D$ +31.0° (c 1.6, C$_6$H$_6$). Recryst from dibutyl ether or Et$_2$O. Dimorphic, modification A crystallises from n-octane, and modification B crystallises from EtOH/H$_2$O. Soluble in pet ether, CHCl$_3$, AcOH, BuOAc and Me$_2$CO. [J Am Chem Soc 97 7242 1975; UV, IR and NMR see Chem Ber 88 57 1955.]

(±)-Verapramil hydrochloride (5-[N-(3,4-dimethoxyphenylethyl)methylamino]-2-[3,4-dimethoxyphenyl]-2-isopropylvaleronitrile HCl) [23313-68-0] M 491.1, m 138.5-140.5°,
MeOH), pK_{15.4}, pK_{2 7.4}. It is a Ca channel antagonist and is a coronary vasodilator. [Ramuz Hely Chtm Acta 58 2050 1975; Harvey et al. Biochem J 257 95 1989.]


Vinblastine sulfate (vinleucoblastine) [143-67-9] M 909.1, m 284-285°, [α]_{D}^{25}-28° (c 1, MeOH), pK_{1} 5.4, pK_{2} 7.4. Purified by recrystn from H_{2}O and dried in vacuo. [Neuss et al. J Am Chem Soc 86 1440 1964.] The free base is recrystd from MeOH or EtOH and has m 210-212°, 211-216°, [α]_{D}^{25} +420° (CHCl_{3}); and has UV λ_{max} 214 and 259nm (log ε 4.73 and 4.21). The dihydrochloride dihydrate has m 244-246°. [Bommer et al. J Am Chem Soc 86 1439 1964.] It is a monoamine oxidase inhibitor [Keun Son et al. J Med Chem 33 1845 1990].

Vincristine sulfate (22-oxovinleucoblastine sulfate) [2068-78-2] M 925.1, m 218-220°, [α]_{D}^{25}+26.2° (CH_{2}Cl_{2}), pK_{1} 5.0, pK_{2} 7.4 (in 33% aq Me_{3}NCHO). Recryst from MeOH. It has UV λ_{max} 220, 255 and 296nm (log ε 4.65, 4.21 and 4.18). It is a monoamine oxidase inhibitor and is used in cancer research [Son et al. J Med Chem 33 1845 1990; Horio et al. Proc Natl Acad Sci USA 85 3580 1988].

Viomycin sulfate (Viocin, Tuberaclinomycin B) [37883-00-4] M 685.7, m 266°(dec), [α]_{D}^{17} -29.5° (c 1, H_{2}O), pK_{1} 7.2 (8.2), pK_{2} 10.3. Crystd from H_{2}O-EtOH and dried in a vacuum. Dry material is hygroscopic and should be stored dry. The UV has λ_{max} at 268 and 285nm (log ε 4.4 and 4.2) in H_{2}O. [Kitigawa et al. Chem Pharm Bull Jpn 20 2176 1972.] The hydrochloride forms hygroscopic plates with m 270°(dec), [α]_{D}^{15} -16.6° (c 1, H_{2}O) with λ_{max} 268nm (log ε 4.5) in H_{2}O; 268nm (log ε 4.4) in 0.1N HCl and 285nm (log ε 4.3) in 0.1N NaOH.

Vitamin A acid [Retinoic acid, 3,7-dimethyl-9-(2,6,6-trimethyl-1-cyclohexenyl)-2,4,6,8-nonatetraen-1-oic acid] [302-79-4] M 300.4, m 180-181°, 180-182°, pK_{Est} ~2.4. Purified by chromatography on silicic acid columns, eluting with a small amount of EtOH in hexane. Dissolve in EtOH, wash with H_{2}O, dry (Na_{2}SO_{4}), evaporate and the solid residue crystd from MeOH (0.53g /3.5mL MeOH to give 0.14g) or EtOH. Also recrystd from i-PrOH, or as the methyl ester from MeOH. UV in MeOH has A_{max} 268 and 285nm (log ε 3.8). It is an irritant and is light sensitive. Store in an inert atmosphere, at 0°. [Robeson et al. J Am Chem Soc 77 4111 1955.]

Vitamin A alcohol (retinol) [68-26-8] M 286.5, A_{1cm}^{41\%}(λ_{max})(all-trans) 1832 (325 nm), (13-cis) 1686 (328nm), (11-cis) 1230 (319 nm), (9-cis) 1480 (323 nm), (9,13-di-cis) 1379 (324 nm), (11,13-di-cis) 908 (311 nm) in EtOH. Purified by chromatography on columns of water-deactivated alumina eluting with 3-5% acetone in hexane. Separation of isomers is by TLC plates on silica gel G, developed with pet ether (low boiling)/methyl heptanone (1 1:2). Store in the dark, under nitrogen, at 0°. [See Guenghaly et al. Arch Biochem Biophys 38 75 1952.]
Vitamin B1 Hydrochloride  [Aneurine hydrochloride, Thiamine hydrochloride, 3{(4-amino-2-methyl-5-pyrimidinyl)methyl}-4-methylthiazolium chloride monohydrochloride] [67-03-8] M 337.3, m 248°(dec), 249-250°, monohydrate m 135°(dec), pK1 5.4, pK2 9.2. Crystallises from 95% EtOH (sol, ca 1%). The monohydrate is dehydrated by drying at 100° in vacuo over H2SO4, but is hygroscopic and picks up one mol. of H2O readily. It can be sterilised at 100° if the pH of the solution is below 5.5. The nitrate has m 196-200°(dec) and is more stable than the hydrochloride. The picrolonate crystallises from H2O and is dimorphic, m 164-165° and 228-229°(dec). [Todd and Bergel J Chem Soc 364, 367 1937; J Am Chem Soc 58 1063, 1504 1936, 59 526 1937.]

Vitamin B2  [Riboflavin, Lactoflavin, 6,7-dimethyl-9-(D-1'-ribityl)isoalloxazine] [83-88-5] M 376.4, m 278-282°(dec with darkening at 240°), 281-282°, [α]D 112° to -122° (c 2.5, 0.02M NaOH), [α]D 59° (c 0.23, AcOH), pK1 1.7, pK2 9.69 (10.2). It crystallises from H2O as a yellow-orange powder in three different forms with differing amounts of H2O. It melts if placed in an oil bath at 250°, but decomposes at 280° if heated at a rate of 50/min. Solubility in H2O is lg in 3000-15000mL depending on the crystal structure. Sol in EtOH at 25° is 4.5mg in 100mL. Store in the dark because it is decomposed to lumichrome by UV light.

Vitamin B6 hydrochloride  (adrenaline, pyridoxine HCl, 3-hydroxy-4,5-bis[hydroxymethyl]2-methylpyridine HCl) [58-56-0] M 205.6, m 208-208.5°, 208-209°(dec), 209-210°(dec), 205-212° (sublimines), pK1 5.0 (3-OH), pK2 8.96 (pyridinium+). Purified by recrystn form EtOH-Me2CO, n-BuOH or MeOH-Et20. Its solubility in H2O is 22% and in EtOH it is 1.1%. It is insoluble in Et2O and CHCl3. Acidic aqueous solns are stable at 120°/30 min. The free base has m 159-160° after recrystn from Me2CO and sublimation at 140-145°/0.0001mm. It has UV λmax at 290nm (ε 84000) in 0.1N aqueous HCl and 253 and 325nm (ε 3700 and 7100). [Khua and Wendt Chem Ber 71 780 1938, 72 311 1939; Harris and Folkers J Am Chem Soc 61 1242 1939; Harris et al. J Am Chem Soc 62 3198 1940.] See also Pyridoxal-5'-phosphate H2O above.

Vitamin B12  (cyanocobalamine, α-(5,6-dimethylbenzimidazoly]cyano cobamide) [68-19-9] M 1355.4, m darkens at 210-220° and does not melt below 300°, [α]D 55°-59° (H2O). Cryst from de-ionized H2O, solubility in H2O is 1g/80g and dried under vacuum over Mg(ClO4)2. The dry red crystals have m 195-200° after dehydration at 100° with an 8-9% weight loss. [Barker et al. Biochem Prep 10 33 1963.] This material gives a single spot of paper chromatography [see Weissbach et al. J Biol Chem 235 1462 1960. The vitamin is soluble in H2O (16.4mM at 24°, 6.4mM at 19°), in EtOH and PhOH but insol in Me2CO, Et2O, CH2Cl2 and dioxane. UV: λmax 260, 375 and 522nm (ε 34.7 x 106, 10.9 x 106 and 8.0 x 106 / mole) in H2O. The dry crystals are stable for months in the dark, but aqueous solns decompose on exposure to VIS or UV light or alkaline CN-, but stable in the dark at pH 6-7. The vitamin is inactivated by strong acids or alkalies. [Barker et al. J Biol Chem 235 480 1960; see also Vitamin B12 (Zagala and Friedrich Eds) W de Gruyter, Berlin 1979.]

Vitamin C  see ascorbic acid entry on p. 116 in Chapter 4.
Vitamin D_2 [50-14-6] M 396.7, m 114-116°, [\(\alpha\)]_D\(^{25}\) +122° (c 4, EtOH). Converted into their 3,5-dinitrobenzoyl esters, and crystd repeatedly from acetone. The esters were then saponified and the free vitamins were isolated. [Laughland and Phillips Anal Chem 28 817 1956.]

Vitamin D_3 [67-97-0] 384.6, m 83-85°, [\(\alpha\)]_D\(^{25}\) +126° (c 2, EtOH). Converted into their 3,5-dinitrobenzoyl esters, and crystd repeatedly from acetone. The esters were then saponified and the free vitamins were isolated. [Laughland and Phillips Anal Chem 28 817 1956.]

Vitamin E (2R,4'R,8'R-\(\alpha\)-tocopherol, natural active isomer) [59-02-9] M 430.7, m 2.5-3.5°, b 200-220°/0.1mm, 200°/0.005mm, d\(_D\)\(^{25}\) 0.950, n\(_D\)\(^{25}\) 1.5045, [\(\alpha\)]\(_D\)\(^{25}\) +3.58° (c 1.1, \(\text{C}_6\text{H}_6\)). Viscous yellow oil which is distd at high vacuum. It has \(A_{\lambda\text{max}}\) 294nm 71). It is oxygen and light sensitive and is best stored as its stable acetate which is purified by evaporative distn at b 180-200°(bath temp)/0.7mm, [\(\alpha\)]_D\(^{10}\) +3.3° (c 5.1, EtOH). [NMR: Cohen et al. Helv Chim Acta 64 1158 1981; Burton and Ingold Acc Chem Res 19 1986; Karrer et al. Helv Chim Acta 21 520 1938.]

Vitamin E acetate (DL-\(\alpha\)-tocopheryl acetate) [7695-91-2] M 472.8, m -27°, b 194-196°/0.01mm, 222-224°/0.3mm, d\(_D\)\(^{20}\) 0.958, n\(_D\)\(^{20}\) 1.4958. It is a viscous liquid which is purified by distn under high vacuum in an inert atm and stored in sealed ampoules in the dark. It is considerably more stable to light and air than the parent unacetylated vitamin. It is insoluble in H_2O but freely soluble in organic solvents. All eight stereoisomers have been synthesised. The commercially pure d-\(\alpha\)-tocopheryl acetate (2R,4'R,8'R) has b 180-200°/0.7mm and [\(\alpha\)]_D\(^{20}\) +3.9° (c 5, EtOH). [Cohen et al. Helv Chim Acta 64 1158 1981.]

Vitamin K_1 (2-methyl-3-phytyl-1,4-na~$\text{thoquinone}) [84-80-0] M 450.7, m -20°, b 141-140°/0.01mm, b 140-145°/10-3 mm, d\(_D\)\(^{25}\) 0.967, n\(_D\)\(^{25}\) 1.527, [\(\alpha\)]\(_D\)\(^{25}\) -0.4° (c 57.5, \(\text{C}_6\text{H}_6\)). Yellow viscous oil, which can be distd at high vacuum practically unchanged. Insoluble in H_2O, but soluble in common organic solvents. Store in the dark under N_2, oxygen sensitive. A\(_{\lambda\text{max}}\) 328 at 248nm. [J Am Chem Soc 61 2557 1939, 76 4592 1954; Helv Chim Acta 27 225 1954.]

Vitamin K_3 (2-methyl-1,4-naphthoquinone, Menadione, Menaphthone) [58-27-5] M 172.2, m 105-106°, 105-107°. Recrystd from 95% EtOH, or MeOH after filtration. Bright yellow crystals which are decomposed by light. Solubility in EtOH is 1.7% and in \(\text{C}_6\text{H}_6\) it is 10%. It IRRITATES the mucous membranes and skin. [Fieser J Biol Chem 133 391 1940.]

Xanthine (2,6-dihydroxypurine, purine-2,6(1H,3H)dione) [69-89-6] M 152.1, pK\(_1\) 0.8 [protonation of imidazole 7(9)NH], pK\(_2\) 7.44 [monoanion 1(3)NH], pK\(_3\) 11.12 [dianion 1,3-N\(_2\)-]. The monohydrate separates in a microcryst form on slow acidification with acetic acid of a solution of xanthine in dil NaOH. Also pptd by addition of conc NH_3 to its soln in hot 2N HCl (charcoal). After washing with H_2O and EtOH, it is dehydrated on heating above 125°. Sol in H_2O is 1 in 14,000 at 16° and 1 in 1,500 and separates as plates from boiling H_2O. It has no m, but the perchlorate has m 262-264°. [Lister Heterocyclic Compounds, Fused Pyrimidines—Purines Part II, Ed. Brown, J.Wiley & Sons, 1971.]

Xanthopterin monohydrate (2-amino-4,6-dihydroxypteridine, 2-amino-pteridin-4,6(1H,5H)-dione) [5979-01-1] (H_2O), 119-48-8 (anhydr) M 197.2, m <300°, pK\(_1\) 1.6 (basic), pK\(_2\) 6.59 (acidic), pK\(_3\) 9.31 (acidic)(anhydrous species), and pK\(_1\) 1.6 (basic), pK\(_2\) 8.65 (acidic), pK\(_3\) 9.99 (acidic)(7,8-hydrated species). Purification as for isoxanthopterin. Crystd by acidifying an ammoniacal soln, and collecting by centrifugation followed by washing with EtOH, ether and drying at 100° in vacuo. Paper chromatography Rp 0.15 (n-PrOH, 1% aq NH_3, 2:1), 0.36 (n-BuOH, AcOH, H_2O, 4:1:1) and 0.47 (3% aq NH_3). [Inoue and Perrin J Chem Soc 260 1962; Inoue Tetrahedron 20 243 1964; see also Blakley Biochemistry of Folic Acid and Related Pteridines North Holland Publ Co, Amsterdam 1969.]
Xanthotoxin (Methoxalen, 9-methoxyfuro[3,2-g][1]benzopyran-7-one) [298-81-7] M 216.2, m 146-148º, 148º, 148-149º. Purified by recrystn from C6H6-pet ether (b 60-80º) as silky needles, EtOH-Et2O as rhombic prisms or hot H2O as needles. It is soluble in aqueous alkali due to ring opening of a lactone but recyclises upon acidification. It has UV λmax in EtOH at 219, 249 and 300nm (log ε 4.32, 4.35 and 4.06) and 1H NMR in CDCl3 with δ at 7.76 (d, 1H, J 10 Hz), 7.71 (d, 1H, J 2.5 Hz), 7.38 (s, 1H), 6.84 (d, 1H, J 2.5 Hz), 6.39 (d, 1H, J 10 Hz) and 4.28 (s, 3H). [Nore and Honkanen J Heterocycl Chem 17 985 1980.] It is a DNA intercalator and is used in the treatment of dermal diseases [Tessman et al. Biochemistry 24 1669 1985.]

Xylanase (from Streptomyces lividans) [37278-89-0] M 43,000 [EC 3.2.1.8]. Purified by anion-exchange chromatography on an Accell QMA column and finally by HPLC using a ProteinPak DEAE 5PW anion-exchange column. Solutions were stored frozen at -70º. [Morosoli et al. Biochem J 239 587 1986; Wong et al. Microbiol Rev 52 305 1988.]

GENERAL INDEX

For individual organic chemicals, listed alphabetically, see Chapter 4, beginning on Page 80; or inorganic and metal-organic chemicals see Chapter 5, beginning on Page 389, and for biochemicals and related products see Chapter 6, beginning on Page 500. It is much faster to use the CAS Registry Numbers Index on p 585 for locating specific compounds irrespective of which chapter they are in.

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Purification of Laboratory Chemicals

Fifth Edition

Wilfred L.F. Armarego
John Curtin School of Medical Research, Australian National University, Canberra

Christina L.L. Chai
Department of Chemistry, Australian National University, Canberra

- The only complete source that covers the purification of laboratory chemicals that are commercially available in such an easy-to-use format
- Provides purification procedures for commercially available chemicals and biochemicals
- Includes an extremely useful compilation of ionisation constants

Now in its fifth edition, Purification of Laboratory Chemicals continues to provide laboratory scientists with a manual for purifying and increasing the purity of, modern commercially available chemical substances.

The authors have written and revised six chapters that describe the aspects of purification and properties of chemical substances. In addition to detailing physical methods and procedures such as crystallization, distillation, chromatography, etc., the authors also address chemical methods and procedures used in purification including conversion to specific derivatives or complexes and regeneration of the original material in a much-purified form.

The book also outlines recent developments in synthesis (e.g., combinatorial chemistry, solid support chemistry, fluorous chemistry) and the corresponding purification procedures that will provide many of the commercially supplied chemical substances in years to come. Additionally, interesting perspective about the future of purification is provided by the authors, based on their years of experience.

The bulk of the book contains purification procedures (taken from the literature) of individual entries for commercially available organic compounds, inorganic and metal-organic compounds, and biochemical and related compounds respectively. The entries are accessible in alphabetical order, and in most cases synonymous names and/or abbreviations are included as well as the CAS (Chemical Abstracts Service) Registry Numbers. The physical properties have been entered, such as the molecular weight, melting and boiling points, and specific rotations if substances are optically active. Rapid purification procedures for common solvents have also been included after the respective extensive procedures.

New to this edition, the ionisation constants in the form of pK have been entered for ionisable compounds. These are followed by procedures, used to purify the substances, in most cases to analytical purity. An index of CAS Registry Numbers with the respective page numbers of the entries has been added as well, making it easy to locate any substance irrespective of which chapter it is in, and also rapidly telling the reader whether there is a purification procedure for that substance in this book.