KIRK-OTHMER

ENCYCLOPEDIA OF CHEMICAL TECHNOLOGY

FOURTH EDITION

VOLUME 1

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A
TO
ALKALOIDS

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PREFACE

The Fourth Edition of the *Encyclopedia of Chemical Technology* is built on the solid foundation of the previous editions and also looks forward into the 21st century. The First Edition, published between 1949 and 1956, demonstrated the enormous progress the American chemical industry made during World War II and the postwar period. The Second Edition, published between 1963 and 1972, reflected the chemical industry as an international enterprise with the interchange of experience and know-how on a global scale. The Third Edition, published between 1978 and 1984, continued the presentation of the best worldwide practices in the process technologies and emphasized topics of great concern to all scientists and engineers, ie, energy, safety, and the environment.

The Fourth Edition is in many ways an entirely new encyclopedia in a format familiar to those acquainted with the earlier editions. All of the articles in this new edition have been rewritten and updated and many new subjects have been added, reflecting changes in chemical technology since the Third Edition. The results, however, will be familiar to the users of the earlier editions: comprehensive, authoritative, accessible, lucid.

The use of SI units as well as common units, Chemical Abstracts Services Registry Numbers, and complete indexing based on automated retrieval from a machine-readable composition system continue. The *Encyclopedia* is an indispensible information source for all producers and users of chemical products and materials.

New subjects have been added, especially in biotechnology, computer topics, analytical techniques and instrumentation, environmental concerns, fuels and energy, inorganic and solid state chemistry, composite materials and materials science in general, and pharmaceuticals.

The Fourth Edition could not be published without the assistance of the many advisors, reviewers, chemists, and engineers who have given their advice and guidance. To all of them our thanks is due.

PREFACE

INTRODUCTION

The main subject of the *Encyclopedia* is chemical technology, and about one-half of all the articles deal with chemical substances, either single substances, such as Sulfuric acid, or groups of substances, such as Aluminum compounds. There are also articles on industrial processes, such as Alkylation; on uses, such as Abrasives; Adhesives; on pharmaceuticals, dyes, fibers; on foods and other human uses, such as Cosmetics. There are articles on the unit operations and unit processes of chemical engineering; on fundamentals, such as Absorption; Mass transfer; and on scientific and technological subjects, such as Catalysis, Color, Electrochemical processing, Magnetic materials, and Ultrasonics. Still other articles deal with such general subjects as Computer technology, Information retrieval, Patents, Regulatory agencies, Technical service, and Transportation.

In general, the properties and manufacture of any substance are given in one article, which makes cross reference to one or more articles where the uses of that substance are described. Thus the manufacture of fused alumina is described under Aluminum compounds, but for its uses the reader will be directed to such articles as Abrasives and Refractories.

For inorganic compounds, in some cases it is the anion, in others the cation that has the greater industrial significance. Thus calcium phosphate, sodium phosphate, and ammonium phosphate are important primarily as phosphates and are discussed under Phosphoric acid and phosphates. Similarly, chromates and borates are under Chromium compounds and Boron compounds, respectively, and salts of organic acids (except acetates and formates) are discussed with the acids. On the other hand, barium chloride, barium nitrate, and barium sulfate would be thought of together and are therefore described in Barium compounds. In general, compounds of the following anions are dealt with in articles such as Aluminum compounds and Calcium compounds: acetates; carbonates; formates; chlorides, bromides, and iodides (under halides); nitrates; nitrites; oxides (including hydroxides and oxygen acids and their salts, but excluding true peroxides); sulfates; sulfites; and sulfides. The organic compounds of a metal, containing a metal-to-carbon bond, are also discussed with the compounds of that metal or under

Organometallics. However, fluorine, in its industrial applications, is so different from the other halogens that the metallic fluorides are usually grouped together under Fluorine compounds, inorganic.

Organic compounds containing fluorine (with or without other halogens) are discussed under Fluorine compounds, organic. There are also articles on Bromine compounds and Iodine compounds. Chlorine is treated somewhat differently. The article Chlorocarbons and chlorohydrocarbons covers a large number of industrially important compounds; compounds containing other elements as well as carbon, hydrogen, and chlorine are sometimes grouped together (as, Chlorophenols; Chlorohydrins), sometimes treated as derivatives under a parent compound (thus chloroanilines appear as derivatives under Amines, aromatic, aniline).

In general, the treatment of a compound will be found either under its own name, or under a group of substances (for example, ethyl acetate under Esters, organic), or as a derivative under a parent compound (for example, ethyl acrylate under Acrylic acid and derivatives). The cross references provided will, it is hoped, in almost all cases direct the reader to the appropriate part of the *Encyclopedia*.

NOTE ON CHEMICAL ABSTRACTS SERVICE REGISTRY NUMBERS AND NOMENCLATURE

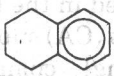
Chemical Abstracts Service (CAS) Registry Numbers are unique numerical identifiers assigned to substances recorded in the CAS Registry System. They appear in brackets in the *Chemical Abstracts* (CA) substance and formula indexes following the names of compounds. A single compound may have synonyms in the chemical literature. A simple compound like phenethylamine can be named *β*-phenylethylamine or, as in *Chemical Abstracts*, benzeneethanamine. The usefulness of the *Encyclopedia* depends on accessibility through the most common correct name of a substance. Because of this diversity in nomenclature careful attention has been given to the problem in order to assist the reader as much as possible, especially in locating the systematic CA index name by means of the Registry Number. For this purpose, the reader may refer to the CAS Registry Handbook—Number Section which lists in numerical order the Registry Number with the *Chemical Abstracts* index name and the molecular formula; eg, **458-88-8**, Piperidine, 2-propyl-, (*S*)-, $C_8H_{17}N$; in the *Encyclopedia* this compound would be found under its common name, coniine [*458-88-8*]. Alternatively, this information can be retrieved electronically from CAS Online. In many cases molecular formulas have also been provided in the *Encyclopedia* text to facilitate electronic searching. The Registry Number is a valuable link for the reader in retrieving additional published information on substances and also as a point of access for on-line data bases.

In all cases, the CAS Registry Numbers have been given for title compounds in articles and for all compounds in the index. All specific substances indexed in *Chemical Abstracts* since 1965 are included in the CAS Registry System as are a large number of substances derived from a variety of reference works. The CAS Registry System identifies a substance on the basis of an unambiguous computer-language description of its molecular structure including stereochemical detail. The Registry Number is a machine-checkable number (like a Social Security number) assigned in sequential order to each substance as it enters the registry system. The value of the number lies in the fact that it is a concise and unique means of substance identification, which is independent of, and therefore bridges,

many systems of chemical nomenclature. For polymers, one Registry Number may be used for the entire family; eg, polyoxyethylene (20) sorbitan monolaurate has the same number as all of its polyoxyethylene homologues.

Cross-references are inserted in the index for many common names and for some systematic names. Trademark names appear in the index. Names that are incorrect, misleading, or ambiguous are avoided. Formulas are given very frequently in the text to help in identifying compounds. The spelling and form used, even for industrial names, follow American chemical usage, but not always the usage of *Chemical Abstracts* (eg, *coniine* is used instead of *(S)-2-propylpiperidine, aniline* instead of *benzenamine,* and *acrylic acid* instead of *2-propenoic acid*).

There are variations in representation of rings in different disciplines. The dye industry does not designate aromaticity or double bonds in rings. All double bonds and aromaticity are shown in the *Encyclopedia* as a matter of course. For example, tetralin has an aromatic ring and a saturated ring and its structure



appears in the *Encyclopedia* with its common name, Registry Number enclosed in brackets, and parenthetical CA index name, ie, tetralin [*119-64-2*] (1,2,3,4-tetrahydronaphthalene). With names and structural formulas, and especially with CAS Registry Numbers, the aim is to help the reader have a concise means of substance identification.

CONVERSION FACTORS, ABBREVIATIONS, AND UNIT SYMBOLS

SI Units (Adopted 1960)

The International System of Units (abbreviated SI), is being implemented throughout the world. This measurement system is a modernized version of the MKSA (meter, kilogram, second, ampere) system, and its details are published and controlled by an international treaty organization (The International Bureau of Weights and Measures) (1).

SI units are divided into three classes:

BASE UNITS

length	meter[†] (m)
mass	kilogram (kg)
time	second (s)
electric current	ampere (A)
thermodynamic temperature[‡]	kelvin (K)
amount of substance	mole (mol)
luminous intensity	candela (cd)

SUPPLEMENTARY UNITS

plane angle	radian (rad)
solid angle	steradian (sr)

[†]The spellings "metre" and "litre" are preferred by ASTM; however "-er" is used in the *Encyclopedia*.

[‡]Wide use is made of Celsius temperature (t) defined by

$$t = T - T_0$$

where T is the thermodynamic temperature, expressed in kelvin, and $T_0 = 273.15$ K by definition. A temperature interval may be expressed in degrees Celsius as well as in kelvin.

DERIVED UNITS AND OTHER ACCEPTABLE UNITS

These units are formed by combining base units, supplementary units, and other derived units (2–4). Those derived units having special names and symbols are marked with an asterisk in the list below.

Quantity	Unit	Symbol	Acceptable equivalent
*absorbed dose	gray	Gy	J/kg
acceleration	meter per second squared	m/s^2	
*activity (of a radionuclide)	becquerel	Bq	1/s
area	square kilometer	km^2	
	square hectometer	hm^2	ha (hectare)
	square meter	m^2	
concentration (of amount of substance)	mole per cubic meter	mol/m^3	
current density	ampere per square meter	A/m^2	
density, mass density	kilogram per cubic meter	kg/m^3	g/L; mg/cm^3
dipole moment (quantity)	coulomb meter	C·m	
*dose equivalent	sievert	Sv	J/kg
*electric capacitance	farad	F	C/V
*electric charge, quantity of electricity	coulomb	C	A·s
electric charge density	coulomb per cubic meter	C/m^3	
*electric conductance	siemens	S	A/V
electric field strength	volt per meter	V/m	
electric flux density	coulomb per square meter	C/m^2	
*electric potential, potential difference, electromotive force	volt	V	W/A
*electric resistance	ohm	Ω	V/A
*energy, work, quantity of heat	megajoule	MJ	
	kilojoule	kJ	
	joule	J	N·m
	electronvolt†	eV†	
	kilowatt-hour†	kW·h†	
energy density	joule per cubic meter	J/m^3	
*force	kilonewton	kN	
	newton	N	$kg·m/s^2$

†This non-SI unit is recognized by the CIPM as having to be retained because of practical importance or use in specialized fields (1).