ENCYCLOPEDIA OF CHEMICAL TECHNOLOGY

Edited by **RAYMOND E. KIRK**
Head, Department of Chemistry, Polytechnic Institute of Brooklyn
and **DONALD F. OTHMER**
Head, Department of Chemical Engineering, Polytechnic Institute of Brooklyn

Assistant Editors
JANET D. SCOTT *and* **ANTHONY STANDEN**

VOLUME 13

STILBITE
to
THERMOCHEMISTRY

EDITORIAL STAFF FOR VOLUME 13

Janet D. Scott — **Anthony Standen**

James A. Lecky — **Annette Stern**

CONTRIBUTORS TO VOLUME 13

J. J. Ayo, Jr., General Aniline & Film Corporation, Dyestuff and Chemical Division, *Sulfur dyes*

J. S. Ball, Bureau of Mines, U.S. Department of the Interior, *Sulfur compounds, organic*

C. K. Banks, Metal and Thermit Corp., *Thermit process*

R. F. Benenati, Polytechnic Institute of Brooklyn, *Stoichiometry*

H. Blanchet, Freeport Sulphur Company, *Sulfur*

R. F. Boyer, The Dow Chemical Company, *Styrene resins and plastics*

E. E. Campaigne, Indiana University, *Sulfides, organic*

H. L. Carolan, Carbide and Carbon Chemicals Company, A Division of Union Carbide and Carbon Corporation, "Dynel and Vinyon" under *Textile fibers* (*acrylic and vinyl*)

B. M. Carter, General Chemical Division, Allied Chemical & Dye Corporation, *Sulfuric acid*

K. A. Clark, Research Council of Alberta, *Tar sands*

P. de Mayo, Birkbeck College, University of London, *Terpenes* (*sesqui-; tri-*)

C. H. Demos, Lederle Laboratories Division, American Cyanamid Company, *Tetracyclines* (*chlortetracycline*)

P. H. Dike, Leeds & Northrup Company, *Temperature measurement*

E. F. Domino, University of Michigan, *Stimulants and depressants of the nervous system*

John Ehrlich, Parke, Davis & Company, *Streptomyces antibiotics* (*chloramphenicol*)

E. M. Elkin, Canadian Copper Refiners Limited, *Tellurium and tellurium compounds*

R. C. Ellingson, Mead Johnson and Company, "D-Fructose" under *Sugars* (*commercial*)

A. C. Finlay, Chas. Pfizer & Co., Inc., *Streptomyces antibiotics* (*carbomycin; viomycin*)

Lawrence H. Flett, National Aniline Division, Allied Chemical & Dye Corporation, *Succinic acid and succinic anhydride*

Gregory Flint, General Chemical Division, Allied Chemical & Dye Corporation, *Sulfuric acid* (*sulfur trioxide*)

CONTRIBUTORS TO VOLUME 13

E. H. Flynn, The Lilly Research Laboratories, *Streptomyces antibiotics (erythromycin)*

Wm. Howlett Gardner, National Aniline Division, Allied Chemical & Dye Corporation, *Succinic acid and succinic anhydride*

E. E. Gilbert, General Chemical Division, Allied Chemical & Dye Corporation, *Sulfonation and sulfation*

L. B. Gittinger, Jr., Freeport Sulphur Company, *Sulfur*

W. C. Goggin, The Dow Chemical Company, *Styrene resins and plastics*

J. A. Grant, Owens-Corning Fiberglas Corporation, *Textile fibers (glass)*

A. A. Harban, Standard Oil Company (Indiana), *Sulfonic acids.*

G. C. Harris, Hercules Powder Company, *Terpenes (di-)*

J. E. Hawkins, University of Florida, *Terpenes (mono-, acyclic)*

Karl M. Herstein, Herstein Laboratories, Inc., *Thallium and thallium compounds*

J. L. Hickson, Sugar Research Foundation, Inc., *Sugars (survey)*; *Sugars (commercial)* (in part); *Sugars (derivatives)*

F. L. Hilbert, U. S. Process Corp., *Tanning materials (vegetable)*

Mary F. Hughes, Refined Syrups & Sugars, Inc., "Invert sugar" under *Sugars (commercial)*

M. E. Hultquist, Research Division, American Cyanamid Company, *Sulfa drugs*; *Sulfonamides*

F. L. Jackson, Freeport Sulphur Company, *Sulfur*

C. E. Johnson, Standard Oil Company (Indiana), *Sulfonic acids*

L. V. Jones, Saran Yarns Co., "Saran" under *Textile fibers (acrylic and vinyl)*

George Jura, University of California, *Surface properties*

Ernest R. Kaswell, Fabric Research Laboratories, Inc., *Textile testing*

Ernest Kuhn, General Aniline & Film Corporation, Dyestuff and Chemical Division, *Sulfur dyes*

H. A. Lechevalier, Institute of Microbiology, Rutgers University, *Streptomyces antibiotics (survey; streptomycin; neomycin)*

P. M. Levin, E. I. du Pont de Nemours & Co., Inc., Textile Fibers Department, "Acrilon, Orlon, X-51," under *Textile fibers (acrylic and vinyl)*; *Textile fibers (tetrafluoroethylene)*

Pat Macaluso, Stauffer Chemical Company, *Sulfur compounds—structures*; *Sulfur compounds, inorganic*

Emma J. McDonald, National Bureau of Standards, U.S. Department of Commerce, *Sugar analysis*

J. M. McGuire, The Lilly Research Laboratories, *Streptomyces antibiotics (erythromycin)*

J. L. Margrave, University of Wisconsin, *Tellurium and tellurium compounds*

George F. Mitchell, General Foods Corporation, *Tea*

H. H. Mosher, Arkansas Chemical Company, *Textile technology*

L. A. Nelson, Jr., Freeport Sulphur Company, *Sulfur*

Mark Nickerson, University of Michigan, *Stimulants and depressants of the nervous system*

Richard Pasternack, Chas. Pfizer & Co., Inc., *Tartaric acid*

Louise L. Phillips, Refined Syrups & Sugars, Inc., "Invert sugar" under *Sugars (commercial)*

O. S. Plantinga, Johnson & Johnson, *Surgical dressings*

Louis Preisman, Barium Reduction Corporation, *Strontium compounds*

Donald Price, Oakite Products, Inc., *Surface-active agents*

L. M. Pruess, Research Division, Lederle Laboratories, American Cyanamid Company, *Tetracyclines (chlortetracycline)*

Peter P. Regna, Chas. Pfizer & Co., Inc., *Streptomyces antibiotics* (*carbomycin*; *viomycin*); *Tetracyclines* (*oxytetracycline*; *tetracycline*)

Desmond M. C. Reilly, Food Machinery and Chemical Corporation (Chemical Divisions), "Strontium hydroxide" under *Strontium compounds*

E. O. Rhodes, Koppers Company, Inc., *Tar and pitch*

E. G. Rietz, Chicago City Colleges, Wright Branch, *Sulfones*; *Sulfoxides*; *Terpenes* (*mono-, acyclic*)

W. J. Roberts, Pennsylvania Industrial Chemical Corporation, *Styrene*; *Terpene resins*

W. S. Ropp, Hercules Powder Company, *Terpenes* (*mono-, cyclic*)

S. A. Rossmassler, E. I. du Pont de Nemours & Co., Inc., Textile Fibers Department, *Textile fibers* (*polyester*)

J. S. Ruhoff, Monsanto Chemical Company, *Sweetening agents*

L. F. Samler, Saran Yarns Co., "Saran" under *Textile fibers* (*acrylic and vinyl*)

Alvin Schallis, Stauffer Chemical Company, *Sulfur compounds, inorganic*

G. B. Shea, Bureau of Mines, U.S. Department of the Interior, "U.S. deposits" under *Tar sands*

F. J. Soday, The Chemstrand Corporation, *Textile fibers, synthetic* (*survey*)

H. C. Speel, Consultant, *Textile technology*

J. A. Stavrolakis, Armour Research Foundation, *Thermal analysis*

R. H. Stevens, Herty Foundation, *Tall oil*

A. A. Stonehill, Ethicon Suture Laboratories, Incorporated, *Surgical sutures*

James M. Straley, Tennessee Eastman Company, Division of Eastman Kodak Company, *Sulfuric and sulfurous esters*

J. A. Struthers, The Dow Chemical Company, *Styrene resins and plastics*

R. L. Stubbings, Lehigh University, *Tanning materials* (*chemistry*; *synthetic*)

Michael Szwarc, College of Forestry, State University of New York, *Thermochemistry*

D. F. Taylor, Fansteel Metallurgical Corporation, *Tantalum and tantalum compounds*

E. H. Thaete, Jr., Freeport Sulphur Company, *Sulfur*

J. J. Throssel, College of Forestry, State University of New York, *Thermochemistry*

Hans Thurnauer, American Lava Corporation, *Talc*

Gilberta G. Torrey, E. I. du Pont de Nemours & Co., Inc., Grasselli Chemicals Department, *Sulfamic acid*

W. E. Truce, Purdue University, *Sulfinic acids*

Selman A. Waksman, Institute of Microbiology, Rutgers University, *Streptomyces antibiotics* (*survey*; *streptomycin*; *neomycin*)

A. L. Ward, Pennsylvania Industrial Chemical Corporation, *Styrene*; *Terpene resins*

L. A. Wills, Consultant, *Sugar manufacture*

ABBREVIATIONS AND SYMBOLS

A.	Ångström unit(s)
A	anion; as, H*A*
abs.	absolute
a.c.	alternating current
ac-	alicyclic; as, *ac*-derivatives of tetrahydronaphthalene
A.C.S.	American Chemical Society
addn.	addition
A.G.A.	American Gas Association
A.I.Ch.E.	American Institute of Chemical Engineers
A.I.M.E.	American Institute of Mining and Metallurgical Engineers
alc.	alcohol, alcoholic
alk.	alkaline (not alkali)
Alk	alkyl
amp.	ampere(s)
amp.-hr.	ampere-hour(s)
amt.	amount (noun)
anhyd.	anhydrous
A.P.I.	American Petroleum Institute
app.	apparatus
approx.	approximate (adj.), approximately
aq.	aqueous
Ar	aryl
ar-	aromatic; as, *ar*-derivatives of tetrahydronaphthalene
as-	asymmetric; as, *as-m*-xylidine
ASA	American Standards Association
A.S.M.	American Society for Metals
A.S.M.E.	American Society of Mechanical Engineers
A.S.T.M.	American Society for Testing Materials
atm.	atmosphere(s), atmospheric
at. no.	atomic number
at. wt.	atomic weight
av.	average
b. (as, b_{11})	boiling (at 11 mm.)
B	base; as, *B*.2HCl
bbl.	barrel(s)
Bé.	Baumé
b.p.	boiling point
B.t.u.	British thermal unit(s)
bu.	bushel(s)
C.	centigrade
C-	denoting attachment to carbon; as, *C*-alkyl derivatives of aniline
cal.	calorie(s)
calcd.	calculated
c.f.m.	cubic foot (feet) per minute
cg.	centigram(s)
c.g.s.	centimeter-gram-second
chem.	chemical
C.I.	*Colour Index* no.
cks.	centistokes
c.l.	car lots
cm.	centimeter(s)
coeff.	coefficient
com.	commercial
compd.	compound (noun)
compn.	composition
concd.	concentrated
concn.	concentration
cond.	conductivity
const.	constant
cor.	corrected

c.p.	chemically pure
cps.	centipoise
crit.	critical
cryst.	crystalline
crystd.	crystallized
crystn.	crystallization
cu.	cubic
d (as, d_4^{20})	density (conveniently, specific gravity)
d	differential operator
d-	*dextro-*, dextrorotatory
D-	denoting configurational relationship, as to *dextro*-glyceraldehyde
d.c.	direct current
dec., decomp.	decompose(s)
decompn.	decomposition
deriv.	derivative
detd.	determined
detn.	determination
diam.	diameter
dielec.	dielectric (adj.)
dil.	dilute
distd.	distilled
distn.	distillation
DL-, *dl-*	racemic
dm.	decimeter
e	electron
ed.	edition, editor
elec.	electric, electrical
elev.	elevated
e.m.f.	electromotive force
eng.	engineering
eq.	equation
equil.	equilibrium
equiv.	equivalent
esp.	especially
estd.	estimated
estn.	estimation
e.s.u.	electrostatic unit(s)
e.u.	entropy unit(s)
e.v.	electron volt(s)
expt.	experiment
exptl.	experimental
ext.	extract
extd.	extracted
extn.	extraction
F.	Fahrenheit
Fedl.	Federal
ff.	following (pages)
fl.oz.	fluid ounce(s)
f.o.b.	free on board
f.p.	freezing point
ft.	foot (feet)
ft.-lb.	foot-pound(s)
g.	gram(s)
gal.	gallon(s)
g.p.d.	grams per denier
g.p.m.	gallons per minute
hp.	horsepower
hr.	hour(s)
hyd.	hydrated, hydrous
i.	insoluble
i-	inactive; as, *i*-methionine
i.b.p.	initial boiling point
I.C.C.	Interstate Commerce Commission
I.D.	inner diameter
in.	inch(es)
insol.	insoluble
I.P.T.	Institute of Petroleum Technologists
I.U.	International Unit(s)
I.U.C., I.U.P.A.C.	International Union of Chemistry, International Union of Pure and Applied Chemistry
j.	joule
K.	Kelvin
K	dissociation constant
Kev	kilo electron volt
kg.	kilogram(s)
kg.-cal.	kilogram-calorie(s)
kv.	kilovolt(s)
kv.-amp.	kilovolt-ampere(s)
kw.	kilowatt(s)
kw.-hr.	kilowatt-hour(s)
l.	liter(s)
l-	*levo-*, levorotatory
L-	denoting configurational relationship, as to *levo*-glyceraldehyde
lb.	pound(s)
LC_{50}	concentration lethal to 50% of animals tested

l.c.l.	less than car lots
LD_{50}	dose lethal to 50% of animals tested
ln	logarithm (natural)
log	logarithm (common)
m.	meter(s)
m-	meta; as, *m*-xylene
M	metal
M	molar (as applied to concn.; not molal, which is written out)
ma.	milliampere(s)
manuf.	manufacture
manufd.	manufactured
manufg.	manufacturing
max.	maximum
M.C.A.	Manufacturing Chemists' Association
m.c.f.	million cubic feet
m.e., meq.	milliequivalent(s)
mech.	mechanical
M.e.v.	million electron volts
mg.	milligram(s)
m.g.d.	million gallons per day
min.	minimum; minute(s)
misc.	miscellaneous
mixt.	mixture
ml.	milliliter(s)
M.L.D.	minimum lethal dose
mm.	millimeter(s)
mM	millimole(s)
mol.	molecule, molecular
m.p.	melting point
m.p.h.	miles per hour
M.R.	molar refraction
mv.	millivolt(s)
mμ	millimicron(s)
n (as, n_D^{20})	index of refraction (for 20°C. and sodium light)
n-	normal; as, *n*-butyl
N	normal (as applied to concn.)
N-	denoting attachment to nitrogen; as, *N*-methylaniline
neg.	negative (adj.)
no.	number
N.O.I.B.N.	not otherwise indexed by name
o-	ortho; as, *o*-xylene
O-	denoting attachment to oxygen; as, *O*-acetylhydroxylamine
O.D.	outer diameter
oz.	ounce(s)
p., pp.	page, pages
p-	para; as, *p*-xylene
pos.	positive (adj.)
powd.	powdered
p.p.m.	parts per million
ppt.	precipitate
pptd.	precipitated
pptn.	precipitation
prepd.	prepared
prepn.	preparation
Pr. no.	Foreign Prototype no (for dyes)
p.s.i.(g.), (a.)	pound(s) per square inch (gage), (absolute)
pt.	point
pts.	parts
quad. pt.	quadruple point
qual.	qualitative
quant.	quantitative
q.v.	"which see"
R	univalent hydrocarbon radical (or hydrogen)
R.	Rankine
ref.	reference
resp.	respectively
r.h.	relative humidity
R.I.	*Ring Index* no.
r.p.m.	revolutions per minute
r.p.s.	revolutions per second
s.	soluble
s-	symmetric(al); as, *s*-*m*-xylidine
S-	denoting attachment to sulfur; as, *S*-methylcysteine
S.A.E.	Society of Automotive Engineers
satd.	saturated
satn.	saturation

S.C.F.	standard cubic foot (feet)	t.s.i.	tons per square inch
Sch.	Schultz no. (for dyes)	Twad.	Twaddell
sec.	second(s)	u.v.	ultraviolet
sec-	secondary; as, *sec*-butyl	v.	volt(s)
S.F.s.	Saybolt Furol second(s)	var.	variety
sl.s.	slightly soluble	*vic-*	vicinal; as, *vic-m*-xylidine
sol.	soluble	vol.	volume(s) (not volatile)
soln.	solution	v.s.	very soluble
soly.	solubility	w.	watt(s)
sp.	specific	wt.	weight
sp., spp.	species	X.U. (10^{-10} mm.)	X-unit
spec.	specification	yd.	yard(s)
sp.gr.	specific gravity	yr.	year(s)
sq.	square	$[\alpha]_D^{20}$	optical rotation (for 20°C. and sodium light)
S.T.P.	standard temperature and pressure	γ	microgram(s)
subl.	sublime(s), subliming	∂	differential operator (partial)
S.U.s.	Saybolt Universal second(s)	Δ	finite difference
sym-	symmetric(al); as, *sym-m*-xylidine	η	viscosity
T.A.P.P.I.	Technical Association of the Pulp and Paper Industry	λ	wave length
		μ	micron(s)
tech.	technical	Ω	ohm(s)
temp.	temperature	$<$	less than
tert-	tertiary; as, *tert*-butyl	$>$	more than
theoret.	theoretical	$\sim$	cycle(s)
t.p.h.	tons per hour	$\approx$	approximately equal to

Other letter symbols may be found in "Standard System of Nomenclature for Chemical Engineering Unit Operations" adopted by the American Institute of Chemical Engineers.

SHIPPING REGULATIONS

Complete information for the U.S. is given in "Tariff No. 9 Publishing Interstate Commerce Commission Regulations for Transportation of Explosives and Other Dangerous Articles by Land and Water in Rail Freight Service and by Motor Vehicle (Highway) and Water Including Specifications for Shipping Containers," with supplements, issued by H. A. Campbell, Agent, 30 Vesey Street, New York 7, N.Y. (1954). The following terms for labeling explosives and other dangerous articles have been used in the Encyclopedia:

Red label (for inflammable liquids)
Yellow label (for inflammable solids and oxidizing materials)
White label (for acids and corrosive liquids)
Red label (for inflammable compressed gases)
Green label (for noninflammable compressed gases)
N.O.I.B.N. (not otherwise indexed by name)

In the text of the Encyclopedia the preferred terms "flammable" and "nonflammable" are used in place of "inflammable" and "noninflammable," respectively.

STANDARD REFERENCE WORKS

The titles of the following reference works have usually been abbreviated when they are given in the bibliographies. See also *Literature of chemical technology*, Vol. 8, p. 418.

Adams, R. (ed.), *Organic Reactions*, Wiley, N.Y., 7+ Vols., 1942–.

Allen, A. H., *Commercial Organic Analysis*, 5th ed., Blakiston, New York, Vols. I–X, 1923–33.

American Association of Textile Chemists and Colorists (A.A.T.C.C.), *1954 Technical Manual and Year Book*, Howes Pub. Co., N.Y., 1954.

American Society for Testing Materials, *1952 Book of A.S.T.M. Standards*, Philadelphia, 7 Parts, 1952–53.

American Standards Association (ASA), *American Standards*, N.Y.

Annual Tables of Constants and Numerical Data, C. Marie (ed.), McGraw-Hill, N.Y., 1912–34.

Association of Official Agricultural Chemists (A.O.A.C.), *Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists*, 7th ed., Collegiate Press, Menasha, Wis., 1950.

Badger, W. L., and McCabe, W. L., *Elements of Chemical Engineering*, 2nd ed., McGraw-Hill, N.Y., 1936.

Beilstein, F. K., *Handbuch der organischen Chemie*, 4th ed., Springer, Berlin and Heidelberg, 71+ Vols., 1918–. (64 Vols. photo-lithoprinted by Edwards Bros., Ann Arbor, Mich.)

Brauer, G. (ed.), *Handbuch der präparativen anorganischen Chemie*, Enke, Stuttgart.

Clark, B. L., and Kolthoff, I. M. (eds.), *Chemical Analysis*, Interscience, N.Y., 7+ Vols., 1945–.

Cook, E. F., and Martin, E. W. (eds.), *Remington's Practice of Pharmacy*, 9th ed., Mack Pub. Co., Easton, Penna., 1948.

Elderfield, R. C. (ed.), *Heterocyclic Compounds*, Wiley, N.Y., 6 Vols., 1950–.

Faith, W. L., Keyes, D. B., and Clark, R. L., *Industrial Chemicals*, Wiley, N.Y., 1950.

Friedländer, P., *Fortschritte der Teerfarbenfabrikation und verwandter Industriezweige*, Springer, Berlin, Vols. I–XXV, 1888–1942.

Friend, J. N. (ed.), *Textbook of Inorganic Chemistry*, Griffin, London, Vols. I–XI, 1914–38.

Gmelins Handbuch der anorganischen Chemie, 8th ed., Verlag Chemie, Weinheim/Bergstrasse, System-Nummern 1–70, 1924–.

Great Britain General Medical Council, *British Pharmacopœia*, Constable, London, 1948; Addendum, 1951.

Handbook of Chemistry and Physics, C. D. Hodgman (ed.), 36th ed., Chem. Rubber Pub. Co., Cleveland, 1954.

Heilbron, I. M., and Bunbury, H. M., *Dictionary of Organic Compounds*, Oxford Univ. Press, N.Y., Vols. I–IV, new rev. ed., 1953.

Houben, J. (ed.), *Methoden der organischen Chemie* (*Weyls Methoden*), 3rd ed., Thieme, Leipzig, Vols. I–IV, 1925–41. (Photo-lithoprinted by Edwards Bros., Ann Arbor, Mich.) For new edition see under Müller, E.

Houben, J., *Fortschritte der Heilstoffchemie*. Erste Abteilung: *Das deutsche Patentschriftwesen*, Vols. I–VI; Zweite Abteilung: *Die Ergebnisse der wissenschaftlichen Literatur*, Vols. I–III; de Gruyter, Berlin, 1926–39. (Photo-lithoprinted by Edwards Bros., Ann Arbor, Mich.)

Huntress, E. H., *Organic Chlorine Compounds*, Wiley, N.Y., 1948.

Inorganic Syntheses, McGraw-Hill, N.Y., 4+ Vols., 1939–.

International Critical Tables of the Numerical Data of Physics, Chemistry, and Technology (I.C.T.), E. W. Washburn (ed.), McGraw-Hill, N.Y., Vols. I–VIII, 1926–33.

STANDARD REFERENCE WORKS

Landolt-Börnstein, *Physikalisch-chemische Tabellen*, 5th ed., Springer, Berlin, 8 Vols., 1923–36 (photo-lithoprinted by Edwards Bros., Ann Arbor, Mich.); 6th ed., *Zahlenwerte und Funktionen aus Physik, Chemie, Astronomie, Geophysik, Technik*, A. Eucken (ed.), Vols. I–IV, 1950–.

Lange, N. A., and Forker, G. M. (eds.), *Handbook of Chemistry*, 8th ed., Handbook Publishers, Sandusky, Ohio, 1952.

Lunge, G., and Berl, E., *Chemisch-technische Untersuchungsmethoden*, 8th ed., Springer, Berlin, 8 Vols., 1931–40. (Photo-lithoprinted by Edwards Bros., Ann Arbor, Mich.)

Mark, H., Marvel, C. S., Melville, H. W., and Whitby, G. S. (eds.), *High Polymers*, Interscience, N.Y., 8+ Vols., 1940–.

Mellor, J. W., *Comprehensive Treatise on Inorganic and Theoretical Chemistry*, Longmans, Green, N.Y., Vols. I–XVI, 1922–37.

Merck Index, The, 6th ed., Merck & Co., Inc., Rahway, N.J., 1952.

Müller, E. (ed.), *Methoden der organischen Chemie (Houben-Weyl)*, 4th ed., Thieme, Stuttgart, approx. 12 Vols., 1952–.

National Formulary, The, 9th ed. (N.F. IX), Committee on National Formulary, American Pharmaceutical Association, Washington, D.C., 1950.

New and Nonofficial Remedies—1954 (N.N.R.) (1954); *Tests and Standards for New and Nonofficial Remedies* (1953); Council on Pharmacy and Chemistry of the American Medical Association, Lippincott, Philadelphia.

Organic Syntheses, Wiley, N.Y., Collective Vol. I (Vols. I–IX), 2nd ed., 1941; Collective Vol. II (Vols. X–XIX), 1943; Vols. XX–, 1940–.

Osol, A., and Farrer, G. E., Jr., *et al.*, *The Dispensatory of the United States of America* (U.S.D.), 24th ed., Lippincott, Philadelphia, 1947; Supplement, 1950.

Palache, C., Berman, H., and Frondel, C., *Dana's System of Mineralogy*, 7th ed., Wiley, N.Y., 3 Vols., 1944–.

Patterson, A. M., and Capell, L. T., *The Ring Index* (*R.I.*), Reinhold, N.Y., 1940.

Perry, J. H. (ed.), *Chemical Engineers' Handbook*, 3rd ed., McGraw-Hill, N.Y., 1950.

Pharmacopeia of the United States of America, The (*The United States Pharmacopeia*), 14th revision (U.S.P. XIV), United States Pharmacopœial Convention, Mack Pub. Co., Easton, Penna., 1950.

Radt, F. (ed.), *Elsevier's Encyclopædia of Organic Chemistry*, Elsevier, Houston, Texas, and Amsterdam, 20 Vols., 1946–.

Richter, V. von, *Chemistry of the Carbon Compounds*, 3rd ed. (trans. from 12th German ed.), Elsevier, Houston, Texas, and Amsterdam, Vols. I–IV, 1934–47.

Rodd, E. H. (ed.), *Chemistry of Carbon Compounds*, Elsevier, Houston, Texas, and Amsterdam, Vols. I–V, 1952–.

Rowe, F. M. (ed.), *Colour Index* (*C.I.*), 1st ed., Society of Dyers and Colourists, Bradford, Yorkshire, 1924; Supplement, 1928.

Schultz, G., and Lehmann, L., *Farbstofftabellen* (Sch.), 7th ed., Akadem. Verlag., Leipzig, 4 Vols., 1931–39. (Photo-lithoprinted by Edwards Bros., Ann Arbor, Mich.)

Scott, W. W., *Standard Methods of Chemical Analysis*, Furman, N. H. (ed.), 5th ed., Van Nostrand, N.Y., Vols. I–II, 1939.

Seidell, A., *Solubilities*. Vol. I: *Solubilities of Inorganic and Metal Organic Compounds*; Vol. II: *Solubilities of Organic Compounds*; Vol. III: *Supplement to Volumes I and II*; 3rd ed., Van Nostrand, N.Y., 1940–52.

Sidgwick, N. V., *The Chemical Elements and Their Compounds*, Oxford Univ. Press, London, Vols. I–II, 1950.

Thorpe's Dictionary of Applied Chemistry, 4th ed., Longmans, Green, N.Y., 12 Vols., 1937–.

Ullmann, F., *Enzyklopädie der technischen Chemie*, 2nd ed., Urban & Schwarzenberg, Vienna, 11 Vols., 1928–32 (photo-lithoprinted by Edwards Bros., Ann Arbor, Mich.); 3rd ed., 14 Vols., 1951–.

Walker, W. H., Lewis, W. K., McAdams, W. H., and Gilliland, E. R., *Principles of Chemical Engineering*, 3rd ed., McGraw-Hill, N.Y., 1937.

Weissberger, A. (ed.), *Technique of Organic Chemistry*, Interscience, N.Y., 8+ Vols., 1948–.

Weissberger, A. (cons. ed.), *The Chemistry of Heterocyclic Compounds*, Interscience, N.Y., 8+ Vols., 1950–.

PERIODICAL ABBREVIATIONS

The abbreviations used are, for the most part, those given in the "List of Periodicals Abstracted by Chemical Abstracts" (Vol. 45, No. 24, Pt. 2 (1951), also published separately). See also *Literature (survey)*, especially the sections on "Reviews, yearbooks, and monographs" and "Periodicals," Vol. 8, pp. 437–40.

Am. Soc. Testing Materials, Proc.	American Society for Testing Materials, Proceedings
Anal. Chem. (superseding *Ind. Eng. Chem., Anal. Ed.*)	Analytical Chemistry
Angew. Chem. (superseding *Die Chemie; Z. angew. Chem.*)	Angewandte Chemie
Ann. Chem., Justus Liebigs	Annalen der Chemie, Justus Liebigs
Arch. Biochem. and Biophys. (superseding *Arch. Biochem.*)	Archives of Biochemistry and Biophysics
Arch. Ind. Hyg. and Occupational Med. (superseding *J. Ind. Hyg. Toxicol.*)	Archives of Industrial Hygiene and Occupational Medicine
Biochem. J. (*London*)	Biochemical Journal, The
Biochem. Z.	Biochemische Zeitschrift
Biochim. et Biophys. Acta	Biochimica et Biophysica Acta
BIOS Repts.	British Intelligence Objectives Subcommittee Reports
Bull. Chem. Soc. Japan	Bulletin of the Chemical Society of Japan
Bull. soc. chim. or *Bull. soc. chim. France*	Bulletin de la société chimique de France
C.A.	Chemical Abstracts
Can. J. Research	Canadian Journal of Research
Chem. Ber. (superseding *Ber.*)	Chemische Berichte
Chem. Eng. (superseding *Chem. & Met. Eng.*)	Chemical Engineering with Chemical & Metallurgical Engineering
Chem. Eng. News (superseding *News Ed. (Am. Chem. Soc.); Ind. Eng. Chem., News Ed.*)	Chemical and Engineering News
Chem. Eng. Progress (superseding *Trans. Am. Inst. Chem. Engrs.*)	Chemical Engineering Progress with Transactions of American Institute of Chemical Engineers
Chem. Eng. Science	Chemical Engineering Science
Chemische Industrie	Chemische Industrie
Chemistry & Industry (formerly part of *J. Soc. Chem. Ind.*)	Chemistry & Industry
Chem. Revs.	Chemical Reviews
Chem. Tech. (Berlin) (superseding *Chem. Fabrik*)	Chemische Technik, Die (Berlin)
Chem. Week (superseding *Chem. Inds. Week*)	Chemical Week
Chem. Zentr.	Chemisches Zentralblatt
Chem.-Ztg.	Chemiker-Zeitung mit dem Sonderteil, Die Chemische Praxis und der Beilage, Chemisch-technische Übersicht
Chimica e industria (*Italy*) or *Chimica e industria* (*Milan*)	Chimica, La, e l'industria (Italy) or (Milan)
Chimie & industrie	Chimie & industrie
CIOS Repts.	Combined Intelligence Objectives Subcommittee Reports
Compt. rend.	Comptes rendus hebdomadaires des séances de l'académie des sciences
FIAT Repts.	Field Information Agency Technical Reports
Fortschr. chem. Forsch.	Fortschritte der chemischen Forschung
Gazz. chim. ital.	Gazzetta chimica italiana
Helv. Chim. Acta	Helvetica Chimica Acta

PERIODICAL ABBREVIATIONS

Ind. Chemist	Industrial Chemist and Chemical Manufacturer, The
Ind. Eng. Chem. (superseding *J. Ind. Eng. Chem.*)	Industrial and Engineering Chemistry
J. Agr. Food Chem.	Journal of Agricultural and Food Chemistry
J. Am. Chem. Soc.	Journal of the American Chemical Society, The
J. Am. Med. Assoc.	Journal of the American Medical Association, The
J. Am. Pharm. Assoc.	Journal of the American Pharmaceutical Association
J. Appl. Chem. (*U.S.S.R.*) (see also *Zhur. Priklad. Khim.*)	Journal of Applied Chemistry (U.S.S.R.)
J. Appl. Phys. (superseding *Physics*)	Journal of Applied Physics
J. Assoc. Offic. Agr. Chemists	Journal of the Association of Official Agricultural Chemists
J. Biol. Chem.	Journal of Biological Chemistry, The
J. Chem. Phys.	Journal of Chemical Physics, The
J. Chem. Soc.	Journal of the Chemical Society (London)
J. Colloid Sci.	Journal of Colloid Science
J. Electrochem. Soc. (superseding *Trans. Electrochem. Soc.*; *Trans. Am. Electrochem. Soc.*)	Journal of the Electrochemical Society
J. Gen. Chem. (*U.S.S.R.*) (see also *Zhur. Obshchet Khim.*)	Journal of General Chemistry (U.S.S.R.)
J. Indian Chem. Soc.	Journal of the Indian Chemical Society
J. Inst. Metals	Journal of the Institute of Metals and Metallurgical Abstracts
J. makromol. Chem. (superseding *J. prakt. Chem.*)	Journal für makromolekulare Chemie
J. Org. Chem.	Journal of Organic Chemistry, The
J. Phys. Chem. (superseding *J. Phys. & Colloid Chem.*)	Journal of Physical Chemistry, The
J. Polymer Sci. (superseding *J. Polymer Research*)	Journal of Polymer Science
J. Research Natl. Bur. Standards (superseding *Bur. Standards J. Research*)	Journal of Research of the National Bureau of Standards
J. Sci. Food Agr.	Journal of the Science of Food and Agriculture
J. Soc. Chem. Ind. or *J. Soc. Chem. Ind.* (*London*) (formerly containing *Chemistry & Industry*)	Journal of the Society of Chemical Industry (London)
J. Soc. Chem. Ind., Japan	Journal of the Society of Chemical Industry, Japan
Kolloid-Z.	Kolloid-Zeitschrift
Mfg. Chemist	Manufacturing Chemist and Pharmaceutical and Fine Chemical Trade Journal Incorporating Manufacturing Perfumer
Monatsh. Chem.	Monatshefte für Chemie und verwandte Teile anderer Wissenschaften
Nature	Nature
Nucleonics	Nucleonics
Office Tech. Services (*OTS*) *Repts.* (superseding *Office Publication Board Repts.*)	Office of Technical Services Reports
Oil, Paint Drug Reptr.	Oil, Paint and Drug Reporter
Phys. Rev.	Physical Review, The
Rec. trav. chim.	Recueil des travaux chimiques des Pays-Bas
Research (*London*)	Research, A Journal of Science and Its Applications
Revs. Mod. Phys.	Reviews of Modern Physics
Science	Science
Trans. Am. Inst. Mining Met. Engrs.	Transactions of the American Institute of Mining and Metallurgical Engineers
Trans. Am. Soc. Metals (superseding *Trans. Am. Soc. Steel Treating*)	Transactions of the American Society for Metals
Trans. Inst. Chem. Engrs. (*London*)	Transactions of the Institution of Chemical Engineers (London)
Z. anorg. u. allgem. Chem. (superseding *Z. anorg. Chem.*)	Zeitschrift für anorganische und allgemeine Chemie
Z. Elektrochem.	Zeitschrift für Elektrochemie und angewandte physikalische Chemie
Zhur. Obshchet Khim.	Zhurnal Obshchet Khimii (Journal of General Chemistry (U.S.S.R.))
Zhur. Priklad. Khim.	Zhurnal Prikladnoĭ Khimii (Journal of Applied Chemistry (U.S.S.R.))
Z. physik. Chem.	Zeitschrift für physikalische Chemie

S *continued*

STILBITE, $(Na_2, Ca)Al_2Si_6O_{16}.6H_2O$. See *Silica and silicates (mineral)*.

STILLINGIA OIL. See *Fats and fatty oils,* Vol. **6,** pp. 144, 147.

STIMULANTS AND DEPRESSANTS OF THE NERVOUS SYSTEM

See also *Alkaloids*; *Analgesics and antipyretics*; *Anesthetics*; *Antispasmodics*; *Barbituric acid and barbiturates*; *Cardiovascular agents*; *Choline*; *Emetics and expectorants*; *Epinephrine*; *Heterocyclic compounds*; *Histamine and antihistamine agents*; *Hypnotics and sedatives*; *Quaternary ammonium compounds.*

Physiological Considerations

The nervous system of man and all other vertebrates includes both central and peripheral neuron networks. It is usually subdivided into:

A. Central nervous system
B. Peripheral nervous system
   1. Somatic or voluntary nervous system
   2. Autonomic or involuntary nervous system
      a. Sympathetic division
      b. Parasympathetic division

The *central nervous system* includes the cerebral cortex, brain stem, cerebellum, and spinal cord. All divisions of the peripheral nervous system contain both sensory (*afferent*) and motor (*efferent*) components. The *peripheral somatic nervous system* is composed of efferent nerves to skeletal (voluntary) muscle and afferent connections from superficial and deep receptors. The *autonomic nervous system* consists of efferent nerves, ganglia, and plexuses, which innervate the thoracic and abdominal viscera and widely distributed glands and blood vessels, as well as afferent fibers from most of the same areas.

The autonomic nervous system is subdivided into sympathetic and parasympathetic divisions. The *sympathetic division*, including the adrenal medulla, is organized to elicit a diffuse response, whereas the *parasympathetic division* provides for more discrete and limited effects. Efferent pathways of both the sympathetic and the parasympathetic divisions have peripheral synapses and therefore pre- and postganglionic nerve fibers. All preganglionic nerve fibers and most postganglionic parasympathetic fibers are *cholinergic*; that is, they release an acetylcholine-like substance when stimulated. On the other hand, most sympathetic postganglionic fibers are *adrenergic*; that is, they release an epinephrine- or norepinephrine-like substance when stimulated.

In general, but not in all areas, the sympathetic and parasympathetic systems act as physiological antagonists (Table I). If one inhibits a certain function, the other stimulates it, and vice

TABLE I. Responses of Effector Organs to Chemical Mediators.

Organ	Adrenergic	Cholinergic
Heart		
Rate	Increase	Decrease
Output	Increase	Decrease
Blood vessels		
Coronary	Dilatation	Dilatation
Muscle	Dilatation or constriction	Dilatation
Cerebral	Constriction	Dilatation
Skin and visceral	Constriction	Dilatation
Eye		
Iris	Mydriasis	Miosis
Ciliary muscle	—	Stimulation
Skin		
Pilomotor muscles	Stimulation	—
Lung		
Bronchial muscle	Inhibition	Stimulation
Glands	No effect or slight stimulation	Stimulation
Gastrointestinal tract		
Motility and tone	Inhibition	Stimulation
Sphincters	Stimulation	Inhibition
Liver	Glycogenolysis	—
Urinary bladder		
Detrusor	Inhibition	Stimulation
Trigone and sphincter	Stimulation	Inhibition
Autonomic ganglia and adrenal medulla	Inhibition	Stimulation
Skeletal muscle	Facilitation	Stimulation

versa. Many organs are innervated by both systems, and their responses are the algebraic sum of the effects of both. Removing the effects of one system by extirpation or by drug blockade may produce the same response as augmenting the activity of the other. The effects of adrenergic (usually sympathetic) and cholinergic (usually parasympathetic) mediators are summarized in Table I. Responses to sympathetic and parasympathetic nerve stimulation are similar to those listed, but some organs, such as most blood vessels, are not innervated by parasympathetic fibers. (See also 3,4.)

From a functional point of view, the rigid anatomical division of the nervous system into central and peripheral components is artificial. Any voluntary movement involves neurons of the cerebral cortex which send axons down the brain stem and spinal cord to synapse with motor horn cells. The axons of these motor neurons then pass through peripheral somatic nerves to innervate skeletal muscles which execute the desired movement. Likewise most autonomic nervous system activity is dependent upon connections with many parts of the brain and spinal cord.

Drugs may act at many different sites within the nervous system. They may facilitate or inhibit transmission along nerve cells or across their junctions, and either stimulate or depress effector cells in such a way as to mimic increased or decreased nervous activity. An agent may be depressant

TABLE II. Examples of Drugs Affecting the Nervous System.

Primary site of action	Stimulants	Depressants[a]
Central nervous system	Picrotoxin	Ethers
	Pentylenetetrazol	Halogenated compounds
	Nikethamide	Hydrocarbons
	Sympathomimetics	Carbamates (urethan, etc.)
	Carbon dioxide (low concn.)	Alcohols
	Strychnine	Barbiturates
	Xanthines	Ions (bromide, magnesium, etc.)
	Camphor	Opiates and related drugs
	Semicarbazides	Hydantoins
	Ammonium ion	Oxazolidines
	Fluoroacetate	Phenacetylureas
	Anticholinesterases	Glycerol derivatives (mephenesin, etc.)
	Local anesthetics	Benzazoles
		Ergot alkaloids
		Carbon dioxide (high concn.)
		Antihistaminics (diphenhydramine, etc.)
		Atropine and some other muscarinic blocking agents
Peripheral nervous system		
Nerve fibers	Calcium ion deficiency	Local anesthetics
Sensory receptors	Acetylcholine	Local anesthetics
	Histamine	
Motor endplate	Choline derivatives (low dose)	Choline derivatives (high dose)
	Nicotine (low dose)	Nicotine (high dose)
	Anticholinesterases[b]	Tubocurarine and related alkaloids
	Potassium ion	Synthetic quaternary nitrogen compounds (decamethonium, etc.)
		Magnesium ion
Autonomic nervous system		
Sensory receptors	Veratrum alkaloids	Ganglionic blocking agents (hexamethonium, etc.)
	Choline derivatives	
	Nicotine	
	Lobeline	
	Cyanide ion	
Motor ganglia	Choline esters and ethers (low dose)	Choline esters (high dose)
	Anticholinesterases[b]	Sympathomimetics
	Nicotine (low dose)	Nicotine (high dose)
		Tetraethylammonium
		Hexamethonium, etc.
Effector cells innervated by postganglionic cholinergic nerves	Choline derivatives	Solanaceous alkaloids
	Anticholinesterases[b]	Synthetic antispasmodics (adiphene, methantheline, etc.)
	Alkaloids (muscarine, pilocarpine, arecoline)	
Effector cells innervated by postganglionic adrenergic nerves	Phenethylamines	β-Haloalkylamines
	Pyrocatechol derivatives	Some ergot alkaloids
	Aliphatic and alicyclic amines	Some imidazolines
	Some imidazolines	Benzodioxans
		Yohimbine and other alkaloids

[a] Includes blocking agents.
[b] Act indirectly by inhibiting cholinesterases.

at one level or locus and stimulant at another; for example, morphine depresses the cerebral cortex and respiratory center but augments certain spinal cord reflexes. Likewise autonomic agents such as epinephrine may excite certain effector cells and inhibit others. Excitatory and inhibitory systems interact complexly, both centrally and peripherally. Depression of a central inhibitory system may cause apparent stimulation due to the phenomenon of release; likewise stimulation of an inhibitory system may cause further inhibition. Peripherally, stimulation of carotid sinus pressoreceptors may reflexly depress medullary activity and cause a reduction in blood pressure and inhibition of respiration. It is apparent that any classification of drugs as stimulants or depressants of nervous function is subject to error. Such a classification cannot be accurate unless the locus and mechanism of the action of each drug is known, and this information is rarely available.

The ubiquity of substances which affect the nervous system or simulate alterations in nervous activity by direct actions on effector cells may be seen by inspection of the partial list presented in Table II.

Many of these substances have been described in part in other sections of this Encyclopedia, to which the reader will be referred in the text. As indicated in Table II, many drugs have more than one locus of action. Autonomic agents especially have diverse effects. For example, atropine not only blocks postganglionic parasympathetic responses but also acts on the brain stem. Similarly, epinephrine and its congeners act on effector cells innervated by postganglionic adrenergic nerve fibers and also on several areas of the central nervous system.

In the following sections, agents will be classified on the basis of their most obvious gross pharmacological effects. Most of the compounds discussed are employed as salts. However, the anions involved are of importance only in determining certain physical properties of the products. Consequently the pharmacology and the structure-activity relations of the various compounds will be presented without regard for the specific anions involved. The reader may assume that the discussion is applicable to all salts which are reasonably soluble in aqueous mediums.

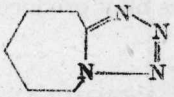
Central Nervous System Stimulants

Many drugs produce excitation of the central nervous system, but relatively few of these are of therapeutic importance. Increased nervous activity induced by drugs is always followed by a period of depression proportional to the previous excitation. Because of this, the more powerful stimulants are used for relatively short periods of time, usually to stimulate the depressed respiratory center in emergencies. These agents are frequently referred to as analeptics because they reduce narcosis. (See 3,35.)

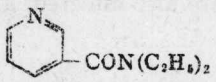
Picrotoxin, U.S.P. XIV, N.N.R., $C_{30}H_{34}O_{13}$, is obtained from the East Indian fishberry *Anamirta cocculus*. Its chemical structure has not been determined, but it seems to be an equimolecular compound of *picrotoxinin*, $C_{15}H_{16}O_6$, and *picrotin*, $C_{15}H_{18}O_7$; the former is pharmacologically the more active. Picrotoxin is a powerful stimulant of the central nervous system, but even when administered intravenously it acts only after a latency of 10–30 minutes. The metabolic fate of this agent is unknown, but it rapidly leaves the circulation. A portion can be recovered in the urine. The predominant action of therapeutic doses of picrotoxin is stimulation of the respiratory center of the medulla. Larger doses affect cerebral centers and produce clonic convulsions with subsequent depression. Death may result from respiratory failure.

Pentylenetetrazol, U.S.P. XIV (6,7,8,9-tetrahydro-5-azepotetrazole, Metrazol, 1), is another potent central nervous system stimulant. In contrast to picrotoxin, it has a rapid onset of action when administered intravenously. Pentylenetetrazol is rapidly detoxified by the liver, and consequently the duration of action is relatively short; it is only weakly active after oral administration. The drug acts chiefly on

the respiratory center of the medulla but also affects higher brain centers. Subconvulsant doses in certain laboratory animals may produce an electroencephalographic pattern of "spike and dome" waves similar to those seen in petit mal epilepsy. Large doses produce tonic-clonic convulsions.



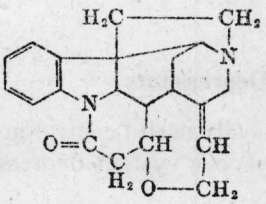
(1)



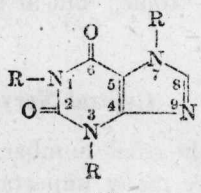
(2)

Nikethamide, U.S.P. XIV, N.N.R. (*N,N*-diethylnicotinamide, Coramine, **2**) (see Vol. **9,** p. 312) probably produces respiratory stimulation by a direct action on the medulla, although some action via peripheral chemoreceptors has been suggested. It is a less effective respiratory stimulant than are picrotoxin, pentylenetetrazol, or several sympathomimetics (see p. 20). When administered in large doses, it causes excitation of higher motor centers with subsequent convulsions. Postexcitatory depression is pronounced. Nikethamide does not have clinically significant cardiovascular effects, although trade names such as Coramine might imply otherwise. It can substitute for nicotinic acid or nicotinamide in nutritional deficiencies.

Strychnine, N.F. IX, $C_{21}H_{22}N_2O_2$, is the principal alkaloid obtained from seeds of the Indian tree *Strychnos nux vomica.* Its probable structure is as illustrated (**3**).



(3)



(4)

(R = CH_3 or H)

Strychnine stimulates all parts of the central nervous system but acts predominantly on the internuncial neurons of the spinal cord. It also depresses reciprocal reflex inhibition. In low doses strychnine increases reflex excitability, but after larger doses coordinated activity is lost and a simultaneous discharge of motor neurons to both flexor and extensor muscles occurs, giving rise to "spinal convulsions." Local application to any portion of the central nervous system causes increased excitability or spontaneous discharge of the part. This response has been used extensively in experiments designed to map out interconnections in the central nervous system.

The **methylated xanthines (4), caffeine,** U.S.P. XIV (1,3,7-trimethylxanthine), **theophylline,** U.S.P. XIV (1,3-dimethylxanthine), and **theobromine,** U.S.P. XIV, N. F. IX (3,7-dimethylxanthine), are widely distributed in plants whose aqueous extracts, such as coffee, tea, and cocoa, are used as beverages. (See also Vol. **1,** p. 475; *Caffeine*; *Cardiovascular agents,* Vol. **3,** p. 221; *Diuretics,* Vol. **5,** p. 191.) The popularity of these beverages can be attributed in part to their mild central stimulant actions. Methylated xanthines also have other important pharmacological effects, including cardiac and skeletal muscle stimulation and a diuretic action. The phar-