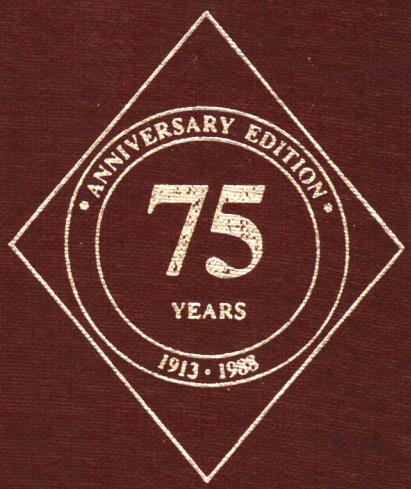
CRC Handbook of Chemistry and Physics

69TH Edition

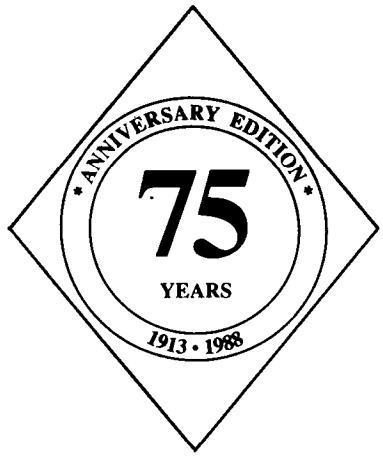
1988—1989



CRC Handbook of Chemistry and Physics

69TH Edition

1988—1989



Editor-in-Chief

Robert C. Weast, Ph.D.

Associate Editors

Melvin J. Astle, Ph.D.

William H. Beyer, Ph.D

A Ready-Reference Book of Chemical and Physical Data

CRC Press, Inc.
Boca Raton, Florida

Library of Congress Card No. 13-11056
PRINTED IN U.S.A.
ISBN-0-8493-0469-5

PREFACE

75th Anniversary Edition

Seventy-five years ago a young engineer, Mr. Arthur Friedman, who had been rather recently graduated from Case School of Applied Science followed through with his idea of there being need for a single-volume reference book containing data for chemistry, physics, and other closely allied sciences. At the time Mr. Friedman brought his idea to fruition he owned a company named the Chemical Rubber Company. This company sold rubber tubing, rubber aprons, rubber stoppers, and miscellaneous laboratory supplies and chemicals. These were sold primarily to high schools and colleges since there were very few industrial chemical laboratories prior to World War I. A reference book as the *Handbook of Chemistry and Physics* was a natural complement to those products being sold by the Chemical Rubber Company. The first edition was published and copyrighted in 1913.

In view of 1988 being the 75th Anniversary of the *Handbook of Chemistry and Physics* the current editor believes users of this book will appreciate inclusion in the present preface repetition of the 1913 Preface, which stated:

> In compliance with the requests of hundreds of our friends for a small but comprehensive book of reference on chemical and physical topics, we have designed and compiled this Pocket Manual of Chemistry and Physics.
>
> We shall feel amply rewarded for our effort and expense if this volume proves to be of use and convenience to the profession whose support has been a conspicuous factor in the growth of our establishment. The material here included has been carefully selected by W. R. Veazey, Ph.D., Chemistry Department, Case School of Applied Science. The compiler has been guided in his selection by suggestions of more than a thousand members of high standing in the Chemical and Physical profession. We desire to express our appreciation and thanks to the many persons who have co-operated with us in the preparation of this book.

Professor Veazey discontinued his editorship of the *Handbook of Chemistry and Physics* in 1914 and after several years became an officer and leader in the growth of the Dow Chemical Company. The second editor of the *Handbook* was Professor Charles D. Hodgman of the Department of Physics at Case School of Applied Science, an engineering college which was later to become Case Institute of Technology, and still later Case-Western Reserve University. Professor Hodgman continued to edit the *Handbook* until his retirement from Case in 1951. He was succeeded by the present editor who was a professor of chemistry at Case when he first became involved with the *Handbook*. Both Professor Hodgman and Professor Weast continued to develop a reference book along the general guidelines put forth by Mr. Friedman and in keeping with the statement prepared by Professor Veazey in the Preface of the 1st Edition of the *Handbook of Chemistry and Physics*.

The physical size of the *Handbook* has increased greatly since the first edition was published. The 1st Edition had 116 pages, each with an area of 187 square centimeters. The present edition has more than 2400 pages each with an area of 485 square centimeters. The index to the first edition was $3^1/_2$ pages in length with two columns of entries on each page. The current edition has 38 pages of index with three columns of entries per page. Even though the more recent editions of the *Handbook* contain extensive indices, suggestions continue to be received from users of the book that the index be enlarged still further on specified subjects. We strive to follow through with these suggestions.

When the first edition was published there were 81 known elements. Today nearly 30% more elements have been identified. In 1913 there was very little known of the fundamental constituents (elementary particles) of all matter. The electron had been discovered by J. J. Thomson only 15 years earlier. The proton would not be identified by Rutherford until the year following publication of the 1st Edition of the *Handbook of Chemistry and Physics*, and the neutron would not be discovered by Chadwick until 1932. By contrast, for the past several years the *Handbook* has contained more than 30 pages of up-to-date data on the properties of fundamental particles. This has been possible due to the cooperation of the Particle Data Group at the University of California (Berkeley). Undoubtedly there will continue to be still more information and data on fundamental particles and their properties after more powerful accelerators and colliders are constructed and put into operation.

This cooperation from the Particle Data Group is one example of the cooperation and help received from many scientists and groups of scientists from many countries. Without such help there would be no possibility

of annually revising the *Handbook* to provide data which are currently important. For example, superconductivity is an area of science now receiving a great amount of intense research. The rare earth elements and compounds are some of the constituents of these superconductors. For that reason this 69th Edition of the *Handbook of Chemistry and Physics* contains updated data on the rare earths. These were provided by Dr. Karl A. Gschneidner, Jr. of the Rare Earth Information Center at Iowa State University.

For the Rare Earths the following new or revised data are in this 69th Edition: (1) data for the trivalent ions, (2) data for the rare earth metals at 24°C or below, (3) transition temperatures and melting points, (4) heat capacities, standard entropies, heats of formation, and heats of fusion, (5) vapor pressures, boiling points, and heats of sublimation, (6) magnetic properties, (7) thermal expansions, thermal conductivities, electrical resistances, and Hall coefficients, (8) electronic specific heat constants, electron-electron (Coulomb) coupling constants, Debye temperatures at 0 K, and superconducting transition temperatures, (9) room temperature elastic modulii and mechanical properties, (10) liquid metal properties near the melting point, (11) ionization potentials, and (12) effective ionic radii.

Other new, revised and updated information and data in this 69th Edition include:

1. Heat of fusion data for polychlorinated biphenyls.
2. Dipole moments of alpha-amino acids, polypeptides and some proteins in water at 25°C.
3. The relative permitivity and conductivity for various biological tissues at 37°C at frequencies commonly used for therapeutic purposes.
4. General properties of semi-conductors (listed by crystal structure).
5. Letter designation for bands of wavelengths in the electromagnetic spectrum.
6. Classification of electromagnetic radiation (waves).
7. Viscosity conversion formulae.
8. Electrical resistivity of the elements and some alloys.
9. Conversion factors for units of electrical resistivity.
10. Summary of 1986 Recommended Values of the Fundamental Physical Constants.
11. Table of the 1986 Recommended Values of the Fundamental Physical Constants.
12. Energy conversion factors.
13. Expanded covariance and correlation coefficient matrix for 1986 Recommended Set of Fundamental Physical Constants.
14. Symbols, Units, and Nomenclature in Physics.
15. NBS Standard Reference Data System Publications, 1976 — 1986.

SI units are becoming nearly standard in books and articles on engineering and science throughout the world. Work was initiated this year to convert all pertinent data in the *Handbook of Chemistry and Physics* into SI units. Considerable progress was made toward achieving this. Although the conversion was not fully completed, the editor is confident the small portion of the book not yet converted to SI units will be converted in the next edition. Inputs which permitted most of this 69th Edition of the *Handbook* to be converted into SI units were made by Drs. Frank Stein and Peter Ratcliffe. Their assistance is sincerely acknowledged. Special thanks are due to Drs. E. Richard Cohen and B. N. Taylor who continue to make certain the most recent and authoritative data on the Fundamental Physical Constants appear in the *Handbook*, and to Dr. Lev Berger for his updating and extensive table on semiconductors. Again I wish to acknowledge the continuing outstanding help of Mr. Paul Gottehrer of CRC Press for his making certain the book is completed on schedule and in an orderly manner. The Editor is most appreciative to all persons who wrote to him pointing out typographical errors. Such errors are corrected immediately upon receiving notice so they will not be perpetuated from edition to edition.

Input and suggestions for improvement of the *Handbook* are earnestly solicited. Please direct all correspondence to CRC Press, Inc., 2000 Corporate Blvd., N.W., Boca Raton, FL 33431. Such help and guidance is truly welcome.

Robert C. Weast
March 20, 1988

COLLABORATORS AND CONTRIBUTORS

William E. Acree, Jr., Ph.D.
Department of Chemistry
Kent State University
Kent, Ohio 44242

L. Alberts, Ph.D.
Director-General
National Institute for Metallurgy
Randburg, South Africa

C. J. Allen
Illuminating Engineer
General Electric Company
Nela Park
Cleveland, Ohio 44112

W. A. Anderson, Ph.D.
Analytical Instrument Research
Varian Associates
611 Hansen Way
Palo Alto, California

W. J. Armento
Oak Ridge National Laboratory
P.O. Box X
Oak Ridge, Tennessee

J. Askill, Ph.D.
Chairman, Physics Department
Millikin University
Decatur, Illinois

C. Thomas Avedisian, Ph.D.
Sibley School of Mechanical and
Aerospace Engineering
Upson and Grumman Halls
Cornell University
Ithaca, New York 14853-7501

J. C. Bailar, Jr., Ph.D.
Professor of Inorganic Chemistry
University of Illinois
Urbana, Illinois

J. A. Bearden, Ph.D.
Department of Physics
Johns Hopkins University
Baltimore, Maryland

A. H. Benade, Ph.D.
Department of Physics
Case Western Reserve University
Cleveland, Ohio

F. F. Bentley
Air Force Materials Laboratory
Wright-Patterson Air Force Base, Ohio

Lev I. Berger, Ph.D.
Department of Physics
College of Sciences
San Diego State University
San Diego, California 92182

William H. Beyer, Ph.D.
Professor of Mathematics and Statistics
Head of the Department of Mathematics
and Statistics
University of Akron
Akron, Ohio

J. H. Billman, Ph.D.
Professor of Chemistry
Indiana University
Bloomington, Indiana

A. L. Bloom, Ph.D.
Spectra-Physics, Inc.
1255 Terra Bella Avenue
Mountain View, California

J. A. Bradley, Ph.D.
Dean, Newark College of Engineering
323 High Street
Newark, New Jersey

B. H. Brown, Ph.D.
Dartmouth College
Hanover, New Hampshire

J. E. Brown
Eastman Kodak Company
Rochester, New York

A. B. Burg, Ph.D.
Department of Chemistry
University of Southern California
Los Angeles, California

G. Preston Burns, Ph.D.
Staff Mathematician
Sperry Corporation
Fredericksburg, Virginia 22401

A. F. Burr, Ph.D.
Department of Physics
New Mexico State University
Las Cruces, New Mexico

L. P. Buseth
Grevinnev. 14H
N-3100 Tønsberg, Norway

J. P. Catchpole, Ph.D.
Admiralty Materials Laboratory
Holton Heath
Dorset, England

James C. Chang, Ph.D.
Department of Chemistry
University of Northern Iowa
Cedar Falls, Iowa

Roger Clay
Department of Physics
The University of Adelaide
Adelaide, South Australia 5001
Australia

E. Richard Cohen, Ph.D.
Associate Director
Science Center/Aerospace and Systems Group
North American Rockwell Corporation
Thousand Oaks, California 91360

Charles H. Corliss
Spectroscopy Section
Optical Physics Division
National Bureau of Standards
Washington, D.C. 20234

M. Davies, Ph.D.
Edward Davies Chemical Laboratories
University of Wales
Aberystwyth, Wales

J. DeMent, D.Sc.
Dement Laboratories
4847 S.E. Division Street
Portland, Oregon

H. G. Deming, Ph.D.
2316 Tuttle Terrace
Sarasota, Florida

E. DiCyan, Ph.D.
Consulting Chemist
420 Lexington Ave.
New York, New York

Hans Dolezalek
1812 Drury Lane
Alexandria, Virginia 22307

A. P. Dunlop, Ph.D.
Director of Chemical Research and Development
John Stuart Research Laboratories
The Quaker Oats Company
Barrington, Illinois

Robert W. Dykstra, Ph.D.
Research and Development Department
Union Carbide Corporation
South Charleston, West Virginia

L. M. Foster, Ph.D.
Thomas J. Watson Research Center
International Business Machines Corp.
Yorktown Heights, New York

J. L. Franklin, Ph.D.
Welch Professor of Chemistry
William Marsh Rice University
Houston, Texas

G. Fulford, Ph.D.
Assistant Professor of Chemical Engineering
University of Waterloo
Waterloo, Ontario,
Canada

Gladys H. Fuller
NBS Institute of Science and Technology
National Bureau of Standards
Washington, D.C.

E. F. Furtsch, Ph.D.
Department of Chemistry
Virginia Polytechnic Institute
Blacksburg, Virginia

COLLABORATORS AND CONTRIBUTORS (continued)

L. A. Gillette, Ph.D.
Manager, Product Development
Pennsalt Chemical Corporation
Philadelphia, Pennsylvania

H. Gilman, Ph.D.
Department of Chemistry
Iowa State University
Ames, Iowa

B. Girling, M.Sc., F.I.M.A.
Department of Mathematics
The City University
London E.C. 1, England

A. G. Gregory
Department of Physics
The University of Adelaide
Adelaide, South Australia 5001
Australia

Karl A. Gschneidner
Distinguished Professor in Sciences and Humanities
Senior Metallurgist
Director, RIC
Ames Laboratory
Energy and Mineral Resources Research Institute
Iowa State University
Ames, Iowa 50011

R. R. Gupta, M.Sc., Ph.D.
Department of Chemistry
University of Rajasthan
Jaipur-4, India

C. R. Hammond
17 Greystone
West Hartford, Connecticut 06107

W. E. Harris
Professor of Chemistry
University of Alberta
Edmonton, Alberta, Canada

H. J. Harwood, Ph.D.
Head, Durkee Famous Foods
Organic Chemistry Division
Glidden Company
Chicago, Illinois

William S. Harwood, Ph.D.
Department of Chemistry
Eastern Michigan University
Ypsilanti, Michigan 48197

R. L. Heath
Idaho National Engineering Lab
P.O. Box 1625
Idaho Falls, Idaho 83415

R. W. Hoffman, Ph.D.
Department of Physics
Case Western Reserve University
Cleveland, Ohio

Jesse F. Hunsberger
RD #1
East Cedarville Road
Pottstown, Pennsylvania

C. D. Hurd, Ph.D.
Chemical Laboratory
Northwestern University
Evanston, Illinois

H. D. B. Jenkins, Ph.D.
Department of Molecular Sciences
University of Warwick
Coventry CV4 7AL
England

J. L. Kassner, Ph.D.
Department of Physics
The University of Missouri-Rolla
Rolla, Missouri

Sidney O. Kastner, Ph.D.
National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland

Olga Kennard, Ph.D.
University Chemical Laboratory
Cambridge, England

T. G. Kennard, Ph.D.
20747 E. Palm Drive
Glendora, California

J. A. Kerr, Ph.D.
Chemistry Department
The University of Birmingham
Haworth Building
P.O. Box 363
Birmingham B15 2TT, England

A. L. King, Ph.D.
Department of Physics
Dartmouth College
Hanover, New Hampshire

C. R. Kinney, Ph.D.
1318 27th Street
Des Moines, Iowa

R. Kretz, Ph.D.
Department of Science and Engineering
University of Ottawa
Ottawa, Ontario, Canada K1N 6N5

G. Lang, Dipl. Ing.
A-4963
St. Peter am Hart
Austria

D. F. Lawden, Sc.D.
Department of Mathematics
University of Aston
Birmingham, England

K. Lee, Ph.D.
IBM Research Laboratory
San Jose, California

A. P. Levitt
75 Lovett Road
Newton Center, Massachusetts

M. M. MacMasters, Ph.D.
Department of Grain Science and Industry
Kansas State University
Manhattan, Kansas

George G. Maher, Ph.D.
Research Chemist
United States Department of Agriculture
Northern Regional Research Center
1815 North University Street
Peoria, Illinois 61604

W. Mahlig
Assistant Sales Manager
Laboratory Equipment Division
The W. S. Tyler Company
Cleveland, Ohio

C. J. Major, Ph.D.
Department of Chemical Engineering
University of Akron
Akron, Ohio

Georgia A. Martin, Ph.D.
Atomic and Plasma Radiation Division
National Bureau of Standards
Washington, D.C. 20234

J. C. McGowan, Ph.D., D.Sc.
"Quantock"
13 Moreton Avenue
Harpenden, Herts AL5 2EU, England

L. Meites, Ph.D.
Department of Chemistry
George Mason University
4400 University Drive
Fairfax, Virginia 22030

M. G. Mellon, Ph.D.
Professor Emeritus, Analytical Chemistry
Purdue University
West Lafayette, Indiana

H. B. Michaelson
IBM Journal of Research and
Development
Armonk, New York

Thomas M. Miller
Department of Physics and Astronomy
44 West Brooks, Room 131
University of Oklahoma
Norman, Oklahoma 73019

Karl Z. Morgan, Ph.D.
School of Nuclear Engineering
Georgia Institute of Technology
Atlanta, Georgia

R. R. Nimmo, Ph.D.
Professor of Physics
University of Otago
Dunedin, New Zealand

F. J. Norton, Ph.D.
General Electric Company
1133 Eastern Avenue
Schenectady, New York

David P. Onwood, Ph.D.
Indiana-Purdue University Fort Wayne
Fort Wayne, Indiana 46805

F. M. Page
Department of Chemistry
The University of Aston
Birmingham B4 7ET, England

B. R. Pamplin, Ph.D.
School of Physics
University of Bath
Claverton Down
Bath BA2 7AY, England

W. Parker, Ph.D.
Department of Physics
University of California
Irvine, California

M. J. Parsonage
Chemistry Department
The University of Birmingham
Birmingham 15, England

Saul Patai, Ph.D.
Department of Organic Chemistry
Hebrew University of Jerusalem
Jerusalem, Israel

I. A. Pearl, Ph.D.
The Institute of Paper Chemistry
Appleton, Wisconsin

F. R. Peart, Ph.D.
The Plessey Co. Ltd.
Allen Clark Research Centre
Northampton, England

A. C. Peed, Jr.
Eastman Kodak Company
243 State Street
Rochester, New York

R. Pepinsky, Ph.D.
Department of Physics and Astronomy
University of Florida
Gainesville, Florida

R. Pethig, Ph.D.
Director, Institute of Molecular
and Biomolecular Electronics
University College of North Wales
Dean Street
Bangor, Gwynedd LL57 1UT
Wales

Herbert A. Pohl, Ph.D.
Professor of Physics
Oklahoma State University
Stillwater, Oklahoma

Daniel D. Pollock
Department of Mechanical and Aerospace
Engineering
State University of New York at Buffalo
Buffalo, New York

Richard L. Pratt
Staff Analyst
Data Corporation
Dayton, Ohio

Harry J. Prebluda, Ph.D.
4101 Pine Tree Dr.
Suite 803
Miami Beach, Florida 33140

I. B. Prettyman, M.S.
The Firestone Tire and Rubber Co.
1200 Firestone Parkway
Akron, Ohio

Zvi Rappoport, Ph.D.
Department of Organic Chemistry
Hebrew University of Jerusalem
Jerusalem 91904 Israel

E. H. Ratcliffe
Institution of Electrical Engineers
Stenvenage
Herts SG1 1HQ
England

Peter Ratcliffe, M.Sc.
Rheinweg 12
D-5300 Bonn 1
West Germany

Joseph Reader, Ph.D.
Atomic and Plasma Radiation Division
National Bureau of Standards
Washington, D.C. 20234

M. C. Reed, Ph.D.
1368 Wood Valley Road
Mountainside, New Jersey

B. W. Roberts, Ph.D.
General Electric Research Laboratory
Schenectady, New York

R. C. Roberts, Ph.D.
Professor Emeritus of Chemistry
Colgate University
Hamilton, New York

R. A. Robinson
School of Chemistry
The University
Newcastle-upon-Tyne NE1 7RU, England

R. J. Rosen
Consulting Chemist
9301 Parkhill Drive
Los Angeles, California

A. H. Rosenfeld, Ph.D.
Lawrence Radiation Laboratory
University of California
Berkeley, California

Gordon D. Rowe
Specialist Lighting of GE Properties
General Electric Company
Cleveland, Ohio 44112

A. L. Rozek
Velsicol Chemical Corporation
Chicago, Illinois

S. I. Salem, Ph.D.
Professor, Department of Physics and Astronomy
California State University
Long Beach, California

Calvin E. Scheldknecht
R.D. 8
Box 398
Gettysburg, Pennsylvania

G. T. Seaborg, Ph.D.
Lawrence Berkeley Laboratory
University of California
Berkeley, California

R. Shaw
Chemical Physicist
Physical Organic Program
Stanford Research Institute
Menlo Park, California

J. R. Shelton, Ph.D.
Department of Chemistry
Case Western Reserve University
Cleveland, Ohio

G. W. Smith, Ph.D.
General Motors Corporation
Research Laboratories
Warren, Michigan

J. M. Smith, B.S.E.E.
Product Planning Large Lamp Department
General Electric Company
Cleveland, Ohio

L. D. Smithson
Air Force Materials Laboratory
Wright-Patterson Air Force Base
Dayton, Ohio

F. H. Spedding
Director, Ames Laboratory
Iowa State University
Ames, Iowa

R. H. Stokes, Ph.D.
Department of Chemistry
The University of New England
Armidale, N.S.W., Australia

Donald F. Swinehart, Ph.D.
Department of Chemistry
University of Oregon
Eugene, Oregon

A. Tarpinian
Army Materials and Mechanics Research Center
Arsenal Street
Watertown, Massachusetts

B. N. Taylor, Ph.D.
B-258 Metrology
National Bureau of Standards
Gaithersburg, Maryland 20899

D. H. Tomlin, Ph.D.
Department of Physics
University of Reading
Reading, Berkshire, England

A. F. Trotman-Dickenson, Ph.D.
Institute of Technology
Cardiff, England

Petr Vanýsek, Ph.D.
Department of Chemistry
Northern Illinois University
DeKalb, Illinois 60115

H. B. Vickery, Ph.D.
Connecticût Agricultural Experimental Station
112 Huntington Street
New Haven, Connecticut

John Weaver
Department of Chemical Engineering and Materials Science
University of Minnesota
Minneapolis, Minnesota

W. W. Wendlandt, Ph.D.
Professor of Chemistry
University of Houston
Houston, Texas

N. R. Whetten, Ph.D.
Research and Development Center
General Electric Company
P.O. Box 8
Schenectady, New York

Wolfgang L. Wiese, Ph.D.
Atomic Plasma and Radiation Division
National Bureau of Standards
Gaithersburg, Maryland 20899

J. H. Yoe, Ph.D.
Professor Emeritus of Chemistry
University of Virginia
Charlottesville, Virginia

G. R. Yohe, Ph.D.
Illinois State Geological Survey
University of Illinois Campus
Urbana, Illinois

T. F. Young, Ph.D.
Division of Chemical Engineering
Argonne National Laboratory
Argonne, Illinois

J. Zabicky, Ph.D.
Department of Biophysics
The Weizmann Institute of Science
Rehovoth, Israel

S. Zuffanti, A.M.
Professor of Chemistry
Northeastern University
Boston, Massachusetts

TABLE OF CONTENTS

SECTION A: MATHEMATICAL TABLES

Miscellaneous Mathematical Constants A-1
Exponential and Hyperbolic Functions and their Common Logarithms A-2
Natural Trigonomic Functions to Four Places A-7
Relation of Angular Functions in Terms of One Another A-11
Derivatives A-12
Integration A-15
Integrals A-20
Differential Equations A-65
Fourier Series A-75
The Fourier Transforms A-80
Series Expansion A-84
Vector Analysis A-87
Moment of Inertia for Various Bodies of Mass A-96
Bessel Functions A-96
The Gamma Function A-99
The Beta Function A-101
The Error Function A-101
Orthogonal Polynomials A-102
Normal Probability Function A-104
Percentage Points, Student's *t*-Distribution A-105
Percentage Points, Chi-Square Distribution A-105
Percentage Points, *F*-Distribution A-106

SECTION B: THE ELEMENTS AND INORGANIC COMPOUNDS

Atomic Weights of the Elements B-1
The Table of Standard Atomic Weights 1981 ..... B-2
Electronic Configuration of the Elements B-4
The Elements B-5
Nomenclature of Inorganic Chemistry B-44
Abbreviations Used in Table of Physical Constants of Inorganic Compounds B-67
Physical Constants of Inorganic Compounds B-68
Gravimetric Factors and their Logarithms B-147
Physical Constants of Minerals B-182
X-Ray Crystallographic Data, Molar Volumes, and Densities of Minerals and Related Substances B-188
Heat Capacity of Rock Forming Minerals B-205
Resistivities of Semiconducting Minerals (Zero Frequency) B-206
Minerals Arranged in Order of Increasing Vickers Hardness Numbers B-206
Solubility Product Constants B-207
Physical Properties of the Rare Earth Metals B-208
Density of Liquid Elements B-215
Heat of Fusion of Some Inorganic Compounds B-224
Table of Isotopes (1985 Update) B-227
Permissible Quarterly Intakes of Radionuclides B-448
Cryogenic Properties of Gases B-455
Conversion Factors for Table of Cryogenic Properties of Gases B-456
Viscosity and Thermal Conductivity of Nitrogen at Cryogenic Temperatures B-456
Solubility of Nitrogen and Air in Water B-457

SECTION C: ORGANIC COMPOUNDS

Definitive Rules for Nomenclature of Organic Chemistry C-1
Illustrative Prefixes C-27
Organic Ring Compounds C-29
Explanation of Table Physical Constants of Organic Compounds C-31
Symbols and Abbreviations C-38
Beilstein References C-39
Physical Constants of Organic Compounds C-42
Structural Formulas of Organic Compounds C-554
Melting Point Index of Organic Compounds C-603
Boiling Point Index of Organic Compounds C-619
Formula Index for Organic Compounds C-631
Sublimation Data for Organic Compounds C-664
Heats of Fusion of Some Organic Compounds C-666
Heat of Fusion Data for Polychlorobiphenyls C-671
Heats of Vaporization of Organic Compounds C-672
Solubility Parameters of Organic Compounds C-681
Microbility of Organic Solvent Pairs C-684
Steroid Hormones and Other Steroidal Synthetics C-687
Properties of the Amino Acids: Ionization Constants and pH Values at the Isoelectric Points of the Amino Acids in Water at 25°C C-704
Ionization Constants of the Amino Acids in Aueous Ethanol Solutions C-704
Ionization Constants of the Amino Acids in Aqueous Formaldehyde Solution C-705
Specific Rotations of the Amino Acids Using Sodium Light (5893 Å) C-705
Solubilities of the Amino Acids in Grams per 100 Grams of Water C-707
Solubilities of the Amino Acids in Grams per 100 Grams of Water-Ethanol Mixtures C-708
Solubilities of the Amino Acids in Grams per 100 Grams of Organic Solvent C-709
Densities of Crystalline Amino Acids C-709
Carbohydrates C-710
Waxes C-715
Trade Names of Dyestuff Intermediates C-716
Nomenclature of Some Monomers and Polymers C-718
Ion Exchange Resins C-720
Limits of Superheat of Pure Liquids C-721

SECTION D: GENERAL CHEMICAL

Azeotropes D-1
Heat of Formation of Inorganic Oxides D-33
Refractory Materials D-38
Thermodynamic Properties of Elements and Oxides D-43
Selected Values of Chemical Thermodynamic Properties D-50
Thermodynamic Functions of Copper, Silver, and Gold D-94
Values of Chemical Thermodynamic Properties of Hydrocarbons D-96
Key Values for Thermodynamics D-98
Lattice Energies D-100
Thermodynamic Properties of Alkane Hydrocarbons D-114
Heat of Dilution of Acids D-121
Heats of Solution D-122
Heat Capacity of Aqueous Solutions of Various Acids D-122
Thermodynamic Formulas D-123
Limits of Inflammability D-124

Limits for Human Exposure to Air Contaminants D-125
Flame and Bead Tests D-129
Preparation of Reagents D-130
Deci-Normal Solutions of Salts and Other Reagents D-135
Deci-Normal Solutions of Oxidation and Reduction Reagents D-136
Organic Analytical Reagents D-137
Calibration of Volumetric Glassware from the Weight of the Contained Water or Mercury when Weighed in Air with Brass Weights D-141
Solubility Chart D-142
Reductions of Weighings in Air to Vacuo D-143
Buffer Solutions D-144
Approximate pH Values D-146
Acid Base Indicators D-147
Fluorescent Indicators D-149
Formulas for Calculating Titration Data, pH vs. ml of Reagent D-150
Electrochemical Series D-151
Conversion Formulae for Solutions Having Concentrations Expressed in Various Ways D-151
Dissociation Constants of Organic Bases in Aqueous Solutions D-159
Dissociation Constants of Organic Acids in Aqueous Solutions D-161
Dissociation Constants of Acids in Water At Various Temperatures D-163
Dissociation Constants of Inorganic Acids in Aqueous Solutions D-163
Dissociation Constants (K_b) of Aqueous Ammonia from 0 to 50°C D-163
Ion Product of Water Substance D-164
Ionization Constant for Water (K_w) D-164
Ionization Constants for Deuterium Oxide from 10 to 50°C D-164
Standard Solutions for Calibrating Conductivity Cells D-164
Equivalent Conductances of Aqueous Solutions of Hydrohalogen Acids D-165
Equivalent Conductivities, λ, of Some Electrolytes in Aqueous Solution at 25°C D-167
Equivalent Ionic Conductivities Extrapolated to Infinite Dilution in Aqueous Solutions at 25°C D-167
Activity Coefficients of Acids, Bases, and Salts D-169
Specific Heat of Water D-171
Heat Capacity of Mercury D-172
Heat Capacity (C_p) of Organic Liquids and Vapors at 25°C D-173
Heat Capacity (C_p) of Organic Gases at 300 and 800 K D-176
Specific Heat of the Elements at 25°C D-178
Specific Heat and Enthalpy of Some Solids at Low Temperatures D-179
Constants of Debye-Sommerfeld Equation D-182
Boiling Point of Water (Hydrogen Scale) D-183
Melting Points of Mixtures of Metals D-183
Commercial Metals and Alloys D-184
Thermal Properties of Pure Metals D-185
Boiling Points and Triple Points of Some Low Boiling Elements D-185
Molecular Elevation of the Boiling Point D-186
Molecular Depression of the Freezing Point D-186
Correction of Boiling Points to Standard Pressure D-186
Van Der Waal's Constants for Gases D-188
Van Der Waal's Radii in Å D-188
Emergent Stem Correction for Liquid-in-Glass Thermometers D-189
Pressure of Aqueous Vapor D-189
Vapor Pressure of Water Below 100°C D-189

Vapor Pressure of Water Above 100°C D-190
Vapor Pressure D-192
Vapor Pressure of the Elements D-215
Vapor Pressure of Elements that are Gaseous at Standard Conditions D-216
Vapor Pressure of Nitric Acid D-217
Low Temperature Liquid Baths D-217
Fats and Oils D-218
Concentrative Properties of Aqueous Solutions: Conversion Tables D-219
Osmotic Prameters and Electrical Conductivities of Aqueous Solutions D-269
Density of Aqueous Invert Sugar Solutons D-271
Oxygen Solubility in Aqueous Electrolyte Solutions D-272
Heat of Combustion D-274
Heat of Formation D-280
Recommended Daily Dietary Allowances D-281

SECTION E: GENERAL PHYSICAL CONSTANTS

Lowering of Vapor Pressure by Salts in Aqueous Solutions E-1
Conversion Factors for Units of Thermal Conductivity E-2
Thermal Conductivity of Gases E-3
Thermal Conductivity of Gaseous Helium, Nitrogen and Water E-4
Thermal Conductivity of Dielectric Crystals E-5
Thermal Conductivity of Organic Compounds E-5
Thermal Conductivity of Inorganic Compounds E-6
Thermal Conductivity of Miscellaneous Substances E-6
Thermal Conductivity of Materials E-6
Thermal Conductivity Data on Ceramic Materials E-7
Thermal Conductivity of Glasses Between −150 and +100°C E-7
Thermal Conductivity of Certain Metals E-10
Thermal Conductivity of Certain Liquids E-11
Thermal Conductivity of the Elements E-12
Thermal Conductivity of Rocks E-15
Steam Tables E-16
Thermodynamic Properties E-24
Physical Properties of Fluorocarbon Refrigerants E-31
Underwriters' Laboratories' Classification of Comparative Lifehazard of Gases and Vapors E-33
Thermal Conductivity of Liquid Fluorocarbons E-33
Miscellaneous Properties of Common Refrigerants E-34
Hygrometric and Barometric Tables E-34
Temperature Correction for Barometric Readings E-36
Temperature Correction, Glass Scale E-37
Weight in Grams of a Cubic Meter of Saturated Aqueous Vapor E-37
Efficiency of Drying Agents E-37
Reduction of Barometer to Sea Level E-38
Latitude Factor E-38
Metric Units E-38
English Units E-39
Reduction of Barometer to Gravity at Sea Level E-40
Reduction of Barometer to Latitude 45° E-40
Relative Humidity — Dew Point E-41
Relative Humidity from Wet and Dry Bulb Thermometer (Cent. Scale) E-41
Reduction of Psychrometric Observation E-42
Constant Humidity E-42

Constant Humidity with Sulfuric Acid Solutions E-42
Velocity of Sound E-43
Sound Velocity in Water Above 212°F E-44
Musical Scales E-44
Absorption and Velocity of Sound in Still Air E-45
Velocity of Sound in Dry Air E-48
Spark-Gap Voltages E-49
Corrections for Temperature and Pressure E-49
Dielectric Constants E-49
Dielectric Constants of Gases at 760 mm Pressure E-54
Properties of Dielectrics E-55
Selected Values of Electric Dipole Moments for Molecules in the Gas Phase E-58
Dipole Moments E-61
Dipole Moments of α-Amino Acids, Glycine Polypeptides, and some Proteins in Water at 25°C E-62
The Relative Permitivity ϵ and Conductivity $\sigma(\Omega m)^{-1}$ for Various Biological Tissues at 37°C at Frequencies Commonly Used for Therapeutic Purposes E-62
Fine Structure Separations in Atomic Negative Ions E-64
Electron Affinities E-64
Atomic and Molecular Polarizabilities E-68
Ionization Potentials E-78
Nuclear Spins, Moments, and Magnetic Resonance Frequencies E-80
Ionization Potentials of Molecules E-85
Electron Work Functions of the Elements E-91
Properties of Metals as Conductors E-93
Superconductivity E-93
Selective Properties of Superconductive Elements E-94
Range of Critical Temperatures Observed for Superconductive Elements in Thin Films Condensed Usually at Low Temperatures E-95
Elements Exhibiting Superconductivity Under or After Application of High Pressure E-95
Selected Superconductive Compounds and Alloys E-96
Critical Field Data E-101
Key to Crystal Structure Types E-102
High Critical Magnetic-Field Superconductive Compounds and Alloys E-102
Tables of Properties of Semiconductors E-104
Standard Calibration Tables for Thermocouples E-114
Temperature-E.M.F. Values for Copper-Constatan E-119
Reference Table for Pt to Pt — 10 Percent Rh Thermocouple E-120
Reference Table for Pt to Pt — 13 Percent Rh Thermocouple E-121
Values for the Langevin Function £(u) E-122
Magnetic Properties and Composition of Some Permanent Magnetic Alloys E-122
High Permeability Magnetic Alloys E-123
Cast Permanent Magnetic Alloys E-124
Saturation Constants and Curie Points of Feromagnetic Elements E-125
Magnetic Properties of Transformer Steels E-126
High Silicon Transformer Steel E-126
Saturation Constants for Magnetic Substances E-126
Initial Permeability of High Purity Iron for Various Temperatures E-126
Magnetic Materials E-126
Magnetic Susceptibility of the Elements and Inorganic Compounds E-127
Diamagnetic Susceptibilies of Organic Compounds E-132