CRC

# HANDBOOK of CHEMISTRY and PHYSICS

DAVID R. LIDE
Editor-in-Chief

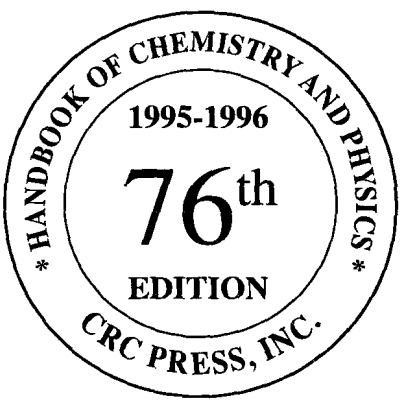
76TH EDITION
1995-1996

# CRC Handbook of Chemistry and Physics

76th Edition

# CRC Handbook of Chemistry and Physics

A Ready-Reference Book of Chemical and Physical Data




Editor-in-Chief

David R. Lide, Ph.D.

Former Director, Standard Reference Data
National Institute of Standards and Technology

Associate Editor

H. P. R. Frederikse, Ph.D.

(Retired)
Ceramics Division
National Institute of Standards and Technology


**CRC Press**

**Boca Raton New York London Tokyo**

International Standard Book Number 0-8493-0476-8
Library of Congress Card Number 13-11056
Printed in the United States of America 1 2 3 4 5 6 7 8 9 0
Printed on acid-free paper

# EDITORIAL ADVISORY BOARD

To Mary, David, and Grace Lide

# PREFACE
## 76th Edition

The highlight of the 76th Edition of the *Handbook of Chemistry and Physics* is a completely revised table of "Physical Constants of Inorganic Compounds". Judging from user inquiries, this table and its companion table for organic compounds are the most widely used parts of the *Handbook*. In addition to incorporating updated values of the physical constants, the table includes new information such as Chemical Abstracts Service Registry Numbers and pointers to other tables in the *Handbook* where additional properties are covered. The compounds in the table have been selected to include the most important inorganic substances encountered in research, industry, and environmental studies. An effort has been made to include inorganic compounds that are important in modern materials science. The table appears in a more readable format, and indexes by synonym and CAS Registry Number are given to facilitate location of compounds.

Several other parts of the *Handbook* have also been expanded or revised in this edition. The information on vapor pressure is enhanced by addition of a table covering values for less volatile substances at elevated temperatures. The table on solvents has been updated and expanded to include 200 common laboratory solvents. A new listing of carcinogenic chemicals, derived from the 1994 report of the National Toxicology Program, is given. On the physics side, the "Table of the Isotopes" and the "Summary Table of Particle Properties" have been completely updated, as have the tables on "Electron Affinities" and "Atomic and Molecular Polarizabilities". New tables appear on "Techniques for Materials Characterization", "Nonlinear Optical Properties", and "Organic Superconductors", and the tables on "High Temperature Superconductors" and "Physical and Optical Properties of Minerals" have been updated. Finally, several older tables have been converted to SI units and reset in a more readable format.

In order to make room for new material in the last few editions, some of the older tables have been dropped. The Editor will appreciate comments on the removal of these tables; if there is sufficient interest, an effort will be made to restore them in abbreviated form.

Suggestions and criticisms from users are very important to the success of this book. Suggestions on new topics of current interest (and on older tables whose usefulness is questionable) are particularly helpful. Address all comments to Editor, Handbook of Chemistry and Physics, CRC Press, Inc., 2000 Corporate Blvd. N.W., Boca Raton, FL 33431.

The *Handbook of Chemistry and Physics* is dependent on the efforts of many contributors throughout the world. The list of current contributors follows this Preface. Dr. H.P.R. Frederikse, Associate Editor, has made a major contribution during the last few years in expanding and improving the tables in solid state physics and materials science. I am indebted to Dr. S.L. Phillips and Dr. D.L. Perry for sending me information in advance from their forthcoming CRC Press publication *Handbook of Inorganic Compounds*, which was very helpful in planning the new inorganic table in this edition. I should finally like to express my gratitude to those at CRC Press who are responsible for the production of the *Handbook of Chemistry and Physics*, especially Paul Gottehrer, Barbara Caras, and James Brody. It is a great pleasure to work with them.

**David R. Lide**
**February 10, 1995**

**Note on the Ordering of Chemical Compounds:** The decision on the order in which to list chemical compounds in a table is always difficult. An alphabetical list by name has the disadvantage that several different synonyms are often in common use, with the result that a reader may conclude incorrectly that a compound is not present if he looks it up under the wrong name. Listing by line formula is satisfactory for simple inorganic compounds, but is cumbersome for organics. A listing by molecular formula is attractive because clear rules can be given for locating a compound, but the user may have to go to some effort to determine the molecular formula. In this book the choice is made on pragmatic grounds. The long tables, "Physical Constants of Organic Compounds" and "Physical Constants of Inorganic Compounds", are ordered by systematic name, but indexes to synonyms, formulas, and CAS Registry Numbers are provided. If the table is very short and includes only common substances, the listing is usually alphabetical by common name or formula. The remaining tables are ordered by molecular formula using a modification of the Hill convention. In this convention the molecular formula is written with C first, H second, and then all other elements in alphabetical order of their chemical symbols. For tables with organic compounds only, the sequence of entries then follows the alphabetical order of elements in the molecular formula and the number of atoms of each element, in ascending order, e.g., $C_3H_7Cl$, $C_3H_7N$, $C_3H_7NO$, $C_3H_7NO_2$, etc. In tables containing non-carbon compounds, those are listed first, followed by a separate listing of compounds that do contain carbon. This is in contrast to the strict Hill convention as followed by Chemical Abstracts Service, where the molecular formulas beginning with A and B precede the formulas

for carbon-containing compounds, while those beginning with D... Z follow. For tabular displays, as opposed to an index, it appears more convenient to the user if the non-carbon compounds are listed as a block, rather than being split by the longer list of carbon compounds.

For organic compounds, a quick way to determine the molecular formula is to use the "Physical Constants of Organic Compounds" table, which starts on Page **3**-1, and its synonym index on Page **3**-586.

# CURRENT CONTRIBUTORS


**Douglas Ambrose**
Department of Chemistry
University College London
London WC1H OAJ
England

**Donald L. Baulch**
School of Chemistry
University of Leeds
Leeds L52 9JT
England

**Lev I. Berger**
California Institute of Electronics and Materials Science
2115 Flame Tree Way
Hemet, California 92343

**Martin J. Berger**
5011 Elm St.
Bethesda, Maryland 20814

**George W. Burns**
National Institute of Standards and Technology
Gaithersburg, Maryland 20899

**A. K. Covington**
Department of Chemistry
University of Newcastle
Newcastle upon Tyne NE1 7RU
England

**Hans Dolezalek**
1812 Drury Lane
Alexandria, Virginia 22307

**Howard T. Evans**
U.S. Geological Survey
Reston, Virginia 22092

**Lev R. Fokin**
Institute for High Temperatures
Academy of Sciences
Izorskaye St. 13/19
Moscow 127412, Russia

**H. P. R. Frederikse**
9625 Dewmar Lane
Kensington, Maryland 20895

**Karl A. Gschneidner**
Ames Laboratory
Energy and Mineral Resources Research Institute
Iowa State University
Ames, Iowa 50011

**Lev V. Gurvich**
Institute for High Temperatures
Academy of Sciences
Izorskaye St. 13/19
Moscow 127412, Russia

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

**Robert F. Hampson**
Chemical Kinetics Division
National Institute of Standards and Technology
Gaithersburg, Maryland 20899

**Norman E. Holden**
National Nuclear Data Center
Brookhaven National Laboratory
Upton, New York 11973

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

**Henry V. Kehiaian**
ITODYS
1 rue Guy de la Brosse
75005 Paris
France

**J. A. Kerr**
Atmospheric Chemistry Group
EAWAG
CH-8600 Dubendorf-Zurich
Switzerland

**William F. Krupke**
Lawrence Livermore Laboratory
Livermore, California 94550

**Kozo Kuchitsu**
Department of Chemistry
Josai University
1-1 Keyakidai
Sakado 350-02
Japan

**John Latham**
Department of Physics
University of Manchester
Manchester M60 1QD
England

**Sharon G. Lias**
Chemical Kinetics and Thermodynamics Division
National Institute of Standards and Technology
Gaithersburg, Maryland 20899

**Reiner Luckenbach**
Beilstein Institute
Carl-Bosch-Haus
Varrentrapstrasse 40-42
D-6000 Frandfurt/Main 90
Germany

**Arthur Maki**
15012 24 Ave., S. E.
Mill Creek, Washington 98012

**B. W. Mangum**
Temperature and Pressure Division
National Insitute of Standards and Technology
Gaithersburg, Maryland 20899

**Thomas M. Miller**
Geophysics Laboratory
Hanscom AFB, Massachusetts 01731

**Dale L. Perry**
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, California 94720

**Sidney L. Phillips**
Camatx/Basic Chemistry
171 El Toyonal
Orinda, California 94563

## CURRENT CONTRIBUTORS (continued)

**C. N. R. Rao**
Solid State and Structural Chemistry Unit
Indian Institute of Science
Bangalore 560-012
India

**A. K. Raychaudhuri**
Solid State and Structural Chemistry Unit
Indian Institute of Science
Bangalore 560-012
India

**Hannes Tammet**
Air Electricity Laboratory
18 Ulikooli St.
Tartu 202400
Estonia

**B. N. Taylor**
National Institute of Standards and Technology
Gaithersburg, Maryland 20899

**D. Thorburn Burns**
Department of Chemistry
Queen's University of Belfast
Belfast BT9 5AG
Northern Ireland

**Thomas G. Trippe**
Particle Data Group
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, California 94720

**Martin A. Uman**
Department of Electrical Engineering
University of Florida
Gainesville, Florida 32611

**Petr Vanýsek**
Department of Chemistry
Northern Illinois University
DeKalb, Illinois 60115

**John H. Weaver**
Department of Chemical Engineering and Materials Science
University of Minnesota
Minneapolis, Minnesota 55425

**Anthony Wexler**
Department of Mechanical Engineering
University of Delaware
Newark, Delaware 19716

**Wolfgang L. Wiese**
Atomic Plasma and Radiation Division
National Institute of Standards and Technology
Gaithersburg, Maryland 20899

**Gwyn P. Williams**
National Synchrotron Light Source
Brookhaven National Laboratory
Upton, New York 11973

**Christian Wohlfarth**
Institut für Physikalische Chemie
Martin Luther University
D-06217 Merseburg
Germany

# TABLE OF CONTENTS

**SECTION 6: FLUID PROPERTIES**

**SECTION 7: BIOCHEMISTRY**



**SECTION 8: ANALYTICAL CHEMISTRY**

## SECTION 9: MOLECULAR STRUCTURE AND SPECTROSCOPY



## SECTION 10: ATOMIC, MOLECULAR, AND OPTICAL PHYSICS



## SECTION 11: NUCLEAR AND PARTICLE PHYSICS

## SECTION 12: PROPERTIES OF SOLIDS



## SECTION 13: POLYMER PROPERTIES



## SECTION 14: GEOPHYSICS, ASTRONOMY, AND ACOUSTICS