HANDBOOK

OF

CHEMISTRY AND PHYSICS

A READY-REFERENCE BOOK OF CHEMICAL AND PHYSICAL DATA

THIRTY-SEVENTH EDITION

EDITOR IN CHIEF

CHARLES D. HODGMAN, M.S.

Professor Emeritus, Case Institute of Technology

ASSOCIATE EDITOR IN CHARGE OF CHEMISTRY

ROBERT C. WEAST, Ph.D.

Associate Professor of Chemistry at Case Institute of Technology

ASSOCIATE EDITOR IN CHARGE OF MATHEMATICS

SAMUEL M. SELBY, Ph.D.

Chairman, Mathematics Department at University of Akron

IN COLLABORATION WITH A LARGE NUMBER OF PROFESSIONAL CHEMISTS AND PHYSICISTS WHOSE ASSISTANCE IS ACKNOWLEDGED IN THE LIST OF GENERAL COLLABORATORS AND IN CONNECTION WITH THE PARTICULAR TABLES OR SECTIONS INVOLVED.

1955—1956

PREFACE

THE Handbook of Chemistry and Physics, continuing the policy of the past, is being revised at frequent intervals.

The general features and scheme of arrangement, which have received extensive endorsement in former editions have been retained. The aim throughout has been to present in condensed form as large an amount of accurate, reliable and up-to-date information in the fields of chemistry and physics as was consistent with convenience in form and the possibility of wide utility and distribution. A very large proportion of the tables have been compiled especially for the Handbook from various authoritative collections of data and from the current journals.

Since the beginning special consideration has been given to the requests and suggestions of those who have used former editions. In this way it has been hoped to develop the book along lines most acceptable to those interested in a volume of this type. Suggestions and contributions are received each year from many eminent chemists and physicists including members of the teaching profession and those engaged in industrial work. We believe this coöperation to have been of very great value in the growth and development of the work.

An attempt has been made to include material on all branches of chemistry and physics and the closely allied sciences, which would be likely to find any extended use. On the other hand, in order to retain the convenience of moderate dimensions and at the same time allow for natural growth due to the extension of knowledge in these sciences, and logical additions along lines already developed, it has seemed necessary to exclude types of material of use only in certain highly specialized lines of work.

Chemistry and physics, always closely related sciences, have been brought into much more intimate relations by the more recent developments of research. To an increasing extent the student of either science should have a knowledge of the other. It would seem that there should be a large field for a single volume containing the constants and formulæ of the two sciences together with mathematical and conversion tables adequate for

accurate computation. The generous response which the previous editions have met indicates that the volumes have been found useful and it is with the hope of even more completely meeting the needs of the chemists and physicists of the English speaking world that succeeding editions are offered.

CHARLES D. HODGMAN

PREFACE TO THE THIRTY-SEVENTH EDITION

It is the object of those associated with the Handbook of Chemistry and Physics to publish annually new technical and scientific information which will be of value to those who teach, study, or work with chemistry or physics. To this end certain new tables have been added in the present edition. Among these are:

Oxidation potentials
Formulas for Calculating Titration Data
Ionization Potentials
Viscosity Conversion Factors
Dielectric Constants of Water
Dipole Moments
Activity Coefficients
Crystal Ionic Radii of Elements
Allowable Carrying Capacities of Conductors.

Some new definitions have also been added to supplement the already extensive list included in past editions.

As man's knowledge increases he learns how to obtain better values and to make more nearly exact measurements. This results in revised data becoming available to aid the scientist in further work. For this reason the present edition of the Handbook of Chemistry and Physics contains a considerable quantity of information which must be considered as revised information. Some of this is as follows:

Gravimetric Factors
Dissociation Constants of Acids and Bases
Data for some Industrial Organic Compounds
Half-wave Potentials for Polarographic Analysis
Physical Constants for Ozone and Oxygen
Properties of Plastics
Photographic Formulas
Values for Velocity of Light
Properties of Dielectrics.

In collecting information to be placed in the present edition care was taken to use data which can be considered reliable. No attempt was made to prepare specialized subjects. Rather, a limited selection was made based on the viewpoint of need and interest expressed in suggestions and contributions from chemists and physicists.

CLEVELAND, OHIO,
September 1, 1955.

THE EDITORS.

COLLABORATORS AND CONTRIBUTORS

to the

HANDBOOK OF CHEMISTRY AND PHYSICS

Albright, J. G., Ph.D.,
Professor and Head of Department of Physics, Rhode Island State College

Allen, S. J. M., Ph.D.,
Professor Emeritus of Experimental Physics, University of Cincinnati

Arnold, Eric A.
Professor of Chemistry, Case Institute of Technology

***Ashley, R. H., Ph.D.**

Baxter, Robert A., M.S.,
Professor of Chemistry, Colorado School of Mines

***Benford, Frank, B.E.E.**

Cork, James M., Ph.D.,
Professor of Physics, University of Michigan

Currie, Lauchlin, M., Ph.D.,
Carbide and Carbon Chemicals Corporation, New York City

Deming, H. G., Ph.D.,
Greensboro, North Carolina

De Vries, Thomas, Ph.D.,
Professor of Physical Chemistry, Purdue University

Dunn, Max S., Ph.D.,
Professor of Biochemistry, University of California at Los Angeles

Gaskill, H. V., Ph.D.,
Dean of Division of Science, Iowa State College

Hale, Harrison, Ph.D.,
Professor Emeritus, University of Arkansas

***Harkins, William D., Ph.D.**

Hartman, W. W., Ph.D.
Department of Synthetic Chemistry, Eastman Kodak Company, Rochester, New York

Haynes, F. B., Ph.D.,
Atomic Energy Commission, Washington, D. C.

Hoyt, Creig S., Ph.D.,
Professor of Physical Chemistry, Grove City College

Jordan, Charles Neal, Ph.D.,
Professor of Chemistry, St. Louis University School of Medicine

***Lewis, Howard Bishop, Ph.D.**

Lyons, Edward, Ph.D.,
Gainesville, Florida

Martin, John R., M.S.,
Associate Professor of Electrical Communication, Case Institute of Technology

Marvel, C. S., Ph.D.,
Professor of Organic Chemistry, University of Illinois

***Mason, Thomas W., M.S.**

Parker, Charles B.,
Arlington, Va.

Patterson, Austin M., Ph.D.,
Professor Emeritus of Chemistry, Antioch College

Peters, F. N., Ph.D.,
Director of Research, Quaker Oats Company, Chicago, Illinois

Post, Howard W., Ph.D.,
Professor of Chemistry, The University of Buffalo

Prebluda, H. J., Ph.D.,
Manager Special Products Sales, U. S. Industrial Chemicals, Inc., New York City

Prettyman, Irven B., M.S.,
The Firestone Tire and Rubber Company, Akron, Ohio

Prutton, Carl F., Ph.D.,
Food Machinery Corporation, New York City

***Randall, Merle, Ph.D.**

Rennerfelt, Ivar.,
Electro-Metallurgist, Stockholm Sweden

Roberts, Robert C., Ph.D.,
Professor of Chemistry, Colgate University

Roush, G. A., M.S.,
Former Editor of Mineral Industry, Arlington, Va.

* Deceased.

Sheely, M. L.,
Technical Director Auxiliaries Group, Armour and Company Chicago, Illinois

***Sheppard, Oden E., Ph.D.**

Shipman, Charles H.,
The Dodd Company, Cleveland, Ohio

Sweeney, Orland Russel, Ph.D.,
Professor and Head of the Department of Chemical Engineering, Iowa State College

Turrill, Park L.,
Department of Chemistry, Glendale Junior College

Weniger, W., Ph.D.,
Professor and Head of Department of Physics, Oregon State Agricultural College

Yoe, John H., Ph.D.,
Professor of Chemistry, and Director Pratt Trace Analysis Laboratory, University of Virginia

Young, Thomas F., Ph.D.,
Professor of Chemistry, University of Chicago

In addition to those whose connection with the Handbook began with the earlier editions the following have contributed material in special or general fields to the successive later editions.

†Adams, Howard W., M.S.

Aldred, Jacob W. H., Ph.D.,
Sheffield Alabama

Allen Gabriel
N. A. C. A., Cleveland, Ohio

Apfelbaum, Percy M., Ph.D.,
College of the City of New York

Aungier, V. C., A.B.,
E. I. du Pont de Nemours and Company

Austin, Paul R., Ph.D.,
E. I. du Pont de Nemours and Company

Bacon, Charles S., Jr., Ph.D.,
Case Institute of Technology

Ballar, John C., Ph.D.,
University of Illinois

Barker, Augustus L., Ph.D.,
Alabama Polytechnic Institute

Bassett, Lewis G., Ph.D.,
Rensselaer Polytechnic Institute

Bennett, Albert A., Ph.D.,
Brown University

Bennett, George W., Ph.D.,
Grove City College

Billman, John H., Ph.D.,
Indiana University

Bonner, Walter D., Ph.D.,
Professor Emeritus, University of Utah

***Boomer, E. H., Ph.D.**

Bradford, John R., Ph.D.,
U. S. Radium Corporation, New York, N. Y.

Bradley, James A., A.M.,
Newark College of Engineering

***Brewer, Ralph E., Ph.D.**

†Brewster, Carl M., M.A.,
State College of Washington

Brown, B. H., Ph.D.,
Dartmouth College

***Burchard, Charles W., M.A.**

Burg, Anton B., Ph.D.,
University of Southern California

Buxton, Mrs. Jane E.,
Institutim Divi Thomae

Capps, Julius D., Ph.D.,
Alabama Polytechnic Institute

Carleton, Ralph K., Ph.D.,
Boston College

Carrick, Leo L., Ph.D.,
University of Michigan

Chittum, John W., Ph.D.,
College of Wooster

Coleman, George H., Ph.D.,
Wayne University

Cook, Graham, Ph.D.,
Carbide and Carbon Chemicals Corporation

Cook, Walter A., Ph.D.,
University of Akron

Cooke, Giles B., Ph.D.,
Research Laboratories, Crown Cork and Seal Company

Copenhaver, James E., Ph.D.,
Hartsville, S. Car.

Cottle, Delmer L., Ph.D.,
Standard Oil Development Company, Linden, N. J.

Cragoe, Edward J., A.M.,
Baker University

† Emeritus.
* Deceased.

Cramer, Howard I., Ph.D., Sharples Chemicals, Inc.

Culbertson, Julius L., Sc.D., State College of Washington

Degering, Edward F., Ph.D., Q.M.R. and D. Center, Natick, Massachusetts

***de Milt, Clara, Ph.D.**

Dermer, Otis C., Ph.D., Oklahoma A. and M. College

De Witt, Clyde C., Ph.D., Michigan State College

Di Cyan, Erwin, Ph.D., Consulting Chemist, New York, N. Y.

Dunlap, Howard L., Ph. D., Ohio University

Fernelius, Willis C., Ph.D., Pennsylvaria State College

Finger, Glenn C., Ph.D., Illinois State Geological Survey

Foster, Laurence S., Ph.D., Watertown Arsenal

Foster, Luther M., Ph.D., Aluminum Company of America

Furtsch, Edward F., Ph.D., Virginia Polytechnic Institute

Gamma Chapter, Alpha Chi Sigma, Case Institute of Technology

Gettens, Rutherford J., M.A., Freer Gallery of Art, Smithsonian Institute

***Gilkey, Wallace A., Ph.D.**

Gilman, Henry, Ph.D., Iowa State College

Goodwin, Robert C., Ph.D., Texas Technical College

Grady, Roy I., Ph.D., College of Wooster

Gregg, Earle C., Jr., Ph.D., Case Institute of Technology

Harwood, H. J., Ph.D., Armour and Company

Hass, Henry B., Ph.D., Sugar Research Foundation, Inc., New York City

†**Hendricks, B. Clifford, Ph.D.,** Longview, Washington

Hennion, George F., Ph.D., University of Notre Dame

Hill, D.A., Ohio Public Service Company

Holton, William B., Ph.D., American University

Howard, Joseph W., Ph.D., Montana State University

Hurd, Charles D., Ph.D., Northwestern University

Hussey, Robert E., Ph.D., Virginia Polytechnic Institute

***Jacobson, Carl A., Ph.D.**

Jones, Elmer M., M.S., Professor Emeritus, Adrian College

Jones, Hardin D., Ph.D., University of California

Kassner, James L., Ph.D., University of Alabama

Kauffmann, Ralph J., Ph.D., University of Tulsa

Kennard, T. G., Ph.D., Glendora, California

King, Henry J., Fresno State College

Kinney, Corliss R., Ph.D., Pennsylvania College

Kistler, Samuel S., Ph.D., University of Utah

Le Vesconte, Amy M., Ph.D.

MacMasters, M. M., Ph.D., U. S. Department of Agriculture, Peoria, Illinois

Magill, Mary A., Ph.D., Ohio State University

***C. A. Marlies, Ph.D.**

Mason, John P., Ph.D., Boston University

Mathers, Frank C., Ph.D., Bloomington, Indiana

Maynard, Julian L., Ph.D., University of Minnesota

Meites, Louis, Ph.D., Yale University

Mellon, Melvin G., Ph.D., Purdue University

Michaelson, Herbert B., Sylvania Electric Products, Inc.

Montgomery, Jack P., Ph.D., University of Alabama

Morgan, William M., Ph.D., Mount Union College

Morton, J. R., M.S., Professor Emeritus, Ohio University

Mullinex, Roger, Long Beach City College

McGuire, Waldemar S., A.M., Northeastern University

Newton, Roy F., Ph.D., R.D. 19 Pittsburgh, Penn.

Norton, Francis J., Ph.D., General Electric Company, Schenectady, N. Y.

Pardee, Arthur M., Ph.D., University of South Dakota

Parker, Haywood, Jr., Eastman Kodak Company, Rochester, N. Y.

* Deceased.

Parks, Lytle R., Ph.D.,
Pennsylvania State College

Parks, W. George, Ph. D.,
Rhode Island State College

Payne, Virgil F., Ph.D.,
Signal Corps Engineering Laboratories, Fort Monmouth, N. J.

Peed, Allie C., Jr.,
The Eastman Kodak Company
Rochester, N. Y.

Pierce, Willis C., Ph.D.,
University of California

Pollard, C. B., Ph.D.,
University of Florida

Potts, William M., Ph.D.,
A. and M. College of Texas

Powell, Parker P., M.S.,
Alabama Polytechnic Institute

Powell, Sargent G., Ph.D.,
University of Washington

***Ralston, A. W., Ph.D.**

Ray, Francis E., Ph.D.,
University of Cincinnati

***Reedy, John H., Ph.D.**

Reinders, Victor A., Ph.D.,
University of Wisconsin

Robertson, George R., Ph.D.,
University of California

***Robinson, Charles J., Ph.D.**

Rosen, Raymond J.,
Los Angeles, California

Rosendahl, Edward,
Glyco Products Company

Ross, W. Bruce, Ph.D.,
McGill University

Schierz, Ernest R., Ph.D.,
University of Wyoming

Schuyler, William H., M.S.,
Bucknell University

Schwartz, Frederick W., Ph.D.,
Rensselaer Polytechnic Institute

Scott, Janet D., M.S.,
Assistant Editor, Encyclopedia of Chemical Technology

Shelton, J. Reid, Ph.D.,
Case Institute of Technology

***Shipley, J. W., Ph.D.**

Shriner, Ralph L., Ph.D.,
State University of Iowa

Smith, J. M.,
General Electric Company, Cleveland, O.

Smith, Lawrence,
Glendale, California

Smull, J. G.,
Lehigh University

Sneed, M. Cannon, Ph.D.,
University of Minnesota

Spencer, Clayton C., Ph.D.,
Syracuse University

Spielman, Marvin A., Ph.D.,
Abbott Laboratories

Swann, Sherlock, Jr., Ph.D.,
University of Illinois

Technical Division,
Carbide and Carbon Chemical Corp., New York City

van der Meulen, P. A., Ph.D.,
Rutgers University

Vernon, Arthur A., Ph.D.,
Northeastern University

Vickery, Hubert B., Ph.D.,
Connecticut Agricultural Exp. Station

Walker, O. J., Ph.D.,
University of Alberta

Walker, Walter O., Ph.D.,
University of Miami

Ward, Nell, Ph.D.,
Municipal University of Omaha

Watson, John W., Ph.D.,
Virginia Polytechnic Institute

***Weatherby, L. S., Ph.D.**

Whitney, Robert B., Ph.D.,
Amherst College

Williams, Leon F., Ph.D.

Wilson, John H., Ph.D.,
Lafayette College

Winkler, C. W.,
KFBA, Lincoln, Nebraska

Wise, Louis E., Ph.D.,
Institute of Paper Chemistry

Wohlleben, William J., Ph.D.,
University of Dayton

Wood, Sylvan R., Ph.D.,
Oklahoma A. and M. College

Wooster, Charles B., Ph.D.,
Ciba Products Corporation

Yohe, Gail R., Ph.D.,
Illinois State Geological Survey

Zuffanti, Saverio, A.M.,
Northeastern University

* Deceased.

The Publishers and Editor will be grateful to readers of this Handbook who will call their attention to errors which may be discovered. Suggestions for improvement are also welcome.
CHEMICAL RUBBER PUBLISHING COMPANY

ANTIDOTES OF POISONS

Acetic Acid.—Emetics, magnesia, chalk, soap, oil.

Acetylene.—Same as for carbon monoxide.

Arsenic, Rat Poison, Paris Green.—Milk, raw egg, sweet oil, lime water, flour and water.

Carbolic Acid.—Any soluble non-toxic sulphate, after provoking vomiting with zinc sulphate; uncooked white of egg in abundance, milk of lime, saccharate of calcium, olive or castor oil with magnesia in suspension, ice, washing the stomach with equal parts water and vinegar; give alcohol or whiskey or about four fluid ounces camphorated oil at one dose.

Carbon Monoxide.—Remove to fresh air immediately and call for pulmotor; apply artificial respiration for at least one hour or until the pulmotor arrives. Administration of oxygen containing 5% of carbon dioxide is beneficial; inhalation of ammonia or amyl nitrite is often of value.

Chloroform, Chloral, Ether.—Dash cold water on head and chest, artificial respiration.

Ethylene.—Same as for carbon monoxide.

Gas (illuminating).—Same as for carbon monoxide.

Hydrochloric Acid.—Magnesia, alkali carbonates, albumen, ice.

Hydrocyanic or Prussic Acid.—Hydrogen peroxide internally, and artificial respiration, breathing ammonia or chlorine from chlorinated lime, ferrous sulphate followed by potassium carbonate, emetics, warmth.

Iodine.—Emetics, stomach siphon, starchy foods in abundance, sodium thiosulphate.

Lead Acetate.—Emetics, stomach siphon, sodium, potassium or magnesium sulphates, milk, albumen.

Mercuric Chloride or Corrosive Sublimate.—Zinc sulphate, emetics, stomach siphon, white of egg, milk, chalk, castor oil, table salt, reduced iron.

Nitrate of Silver.—Salt and water.

Nitric Acid.—Same as for hydrochloric acid.

Opium, Morphine, Laudanum, Paregoric, etc.—Strong coffee. hot bath. Keep awake and moving at any cost.

Phosphoric Acid.—Same as for hydrochloric.

Sodium Hydroxide or Potassium Hydroxide.—Vinegar, lemon juice, orange juice, oil, milk.

Sulfuric Acid.—Same as for hydrochloric acid with the addition of soap or oil.

Sulfurous Acid or Sulfur Dioxide.—Mustard plaster on chest; narcotics, expectorants.

Wood Alcohol (Methyl Alcohol or Methanol).—Emetic or wash out stomach (stomach tube) with a solution of 10 grains sodium citrate per ounce of water. Give milk, white of egg or flour in water; purgative of magnesium sulfate (15 grams); stimulate and combat collapse. In case of cardiac or pulmonary failure use artificial respiration. Physicians may administer atropine, digitalin or strychnine as stimulants; to cause perspiration and elimination of the poison use 0.1 grain of pilocarpine hydrochloride.

BURNS AND SCALDS

Exclude air by thin paste of starch, flour, or baking soda. Ordinary oils such as Vaseline petroleum jelly, olive or castor oil, lard or cream may also be used except for phosphorus burns. Lime water mixed with an equal part of raw linseed oil makes an excellent dressing. An especially valuable material for all burns is picric acid gauze which may be applied in the form of a compress.

After treatment with any of the above materials, cover with a cloth or with cotton and hold in place with a light bandage.

Apply a freshly prepared 5% tannic acid solution. Place several layers of sterile gauze over the burned area, saturate with the tannic acid solution and bandage loosely.

CHEMICAL BURNS

With either, wash off as quickly as possible with a large quantity of water. Water from a tap may be allowed to flow over burns.

Acids

While the injury is being washed, have procured lime water or lime water and raw linseed oil mixed together in equal proportions or a mixture of baking soda and water or soap suds and apply freely. For acid in the eye wash as quickly as possible with water and then with lime water.

Alkalis

Wash with a large quantity of water as for acid burns. Neutralize with weak vinegar, hard cider or lemon juice. For lime or other strong alkali burns in the eye wash with weak solution of vinegar or with olive oil or a saturated solution of boric acid.

Bromine.—Sponge immediately with a strong solution of sodium thiosulfate until all the bromine color is gone, then wash off the mildly poisonous sodium thiosulfate with plenty of water.

Acetone.—Dilute with a spray of water to avoid spread of burning liquid. Use suitable gas mask.

Alcohol.—See under acetone.

Ammonia.—Use water and dilute acid. Use suitable gas mask.

Benzol or Benzene.—Use water to cool containers which are endangered; extinguish flame with sand, earth, fire-foam or carbon tetrachloride fire extinguishers. Use suitable gas mask.

Calcium Carbide.—Do not use water as this generates acetylene, an inflammable and explosive gas; cut off electric current to avoid ignition of gas. Remove containers to a dry place. Use gas mask.

Carbon Disulfide.—Use water to cool containers which are endangered; extinguish blaze with sand, earth, fire-foam or carbon tetrachloride fire extinguishers. Use suitable gas mask.

Carbon Tetrachloride.—When a carbon tetrachloride type extinguisher is used on a fire in a confined space, the fire should be attacked from outside the enclosure, if possible, or the area should be vacated immediately after the fire is out. No one should return to the enclosure until the air is cleared of smoke and fumes. These precautions should be observed regardless of the means by which the fire is extinguished, however, since fire in a confined space rapidly produces a toxic atmosphere.

Do not put carbon tetrachloride on a sodium fire, violent explosions may be caused.

Celluloid.—Use large volumes of water and sand. The smoke contains oxides of nitrogen which are injurious. Use suitable gas mask.

Chlorine.—Spray with water. The pungent nature of the gas makes the use of a gas mask imperative.

Collodion.—See under carbon disulfide.

Ether.—See under carbon disulfide.

Gasoline.—See under carbon disulfide.

Hydrochloric Acid.—Use large volumes of water also chalk or soda. Use gas mask.

Hydrocyanic or Prussic Acid.—Suitable gas mask is essen tial because of the extremely poisonous nature of the vapors. Provide ventilation.

Lacquer Solvents.—See under carbon disulfide.

Magnesium.—Do not use water. Use sand or earth to extinguish flames. Remove containers to a dry place.

Nitric Acid and Oxides of Nitrogen.—Use large volumes of water. Do not use sand or earth. Use gas mask.

Potassium.—Do not use water. Remove containers to a dry place. Extinguish flames with sand or earth. For storage, potassium is kept immersed in petroleum.

Potassium Hydroxide.—Use large volumes of water or dilute acids.

Phosphorus.—Use water and wet sand. Use gas mask. For storage, white phosphorus must be kept immersed in water. Red phosphorus is less dangerous.

Sodium.—See under potassium.

Sodium Hydroxide.—See under potassium hydroxide.

Sulfur.—Extinguish with water or sand. Use gas mask.

Sulfuric Acid.—See under hydrochloric acid.

Turpentine.—See under acetone.

CONTENTS

PROPERTIES AND PHYSICAL CONSTANTS

GENERAL CHEMICAL TABLES

SPECIFIC GRAVITY AND PROPERTIES OF MATTER

HEAT