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LANGE'S
HANDBOOK
OF CHEMISTRY
Thirteenth Edition

LANGE'S HANDBOOK OF CHEMISTRY

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THIRTEENTH
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Tuma • Handbook of Physical Calculations

To those workers in science who through their labors determined the values recorded herein, this compilation is dedicated. Their devotion to the search for the constants of nature and the dissemination of this knowledge are the foundations upon which rest the achievements of applied science.

PREFACE TO THE THIRTEENTH EDITION

In this edition, the third under the aegis of the present editor, the large section devoted to the general description of 7600 organic compounds has been thoroughly revised. Nomenclature is now consistent with the 1979 rules of the Commission on Nomenclature, International Union of Pure and Applied Chemistry. A synopsis of the extensive nomenclature rules precedes the tabulation. All entries are listed alphabetically according to the senior prefix of the name rather than by indexing according to the Chemical Abstracts system. With the latter system there may be a bewildering array of subordinate entries listed under a key index name. The data for each organic compound include: name, structural formula, formula weight, Beilstein reference, density, refractive index, melting point, boiling point, flash point (introduced for the first time), and solubility in water and various organic solvents. Structural formulas are drawn for compounds either too complex or ambiguous to render by line formulas; these are grouped at the bottom of the same page on which the entry appears rather than being gathered together in a remote and separate listing. Many compounds will possess more than one approved name. These alternative names, as well as trivial names in long-standing usage, are listed in their respective alphabetical order at the bottom of each main page in the regular alphabetical sequence. Another aid to assist the user in locating a desired entry is the empirical formula index.

Expanded coverage is given to the areas of:

pK_a values of organic acids

Temperature dependence of selected values of pK_a and pK_{sp} in water

Properties of combustible mixtures; in particular, the autoignition temperature and the flammable limits in percent by volume, upper and lower limits

The section on thermodynamic properties has been revised to reflect the latest recommended values for heats of formation and Gibbs energies of formation, entropies, and heat capacities for the members of the alkali family and the compounds of uranium, protactinium, thorium, and actinium. These data, plus heats of melting, vaporization, and sublimation, are gathered into two sets of two tables each, one for 2400 inorganic compounds and the other for 1500 organic compounds. The editor feels that related properties are thus more readily available to the user than if they were scattered over several separate tabulations.

Offered for the first time are carbon-13 NMR data involving chemical shifts and spin-spin coupling constants. This addition recognizes the increased role played by carbon-13 NMR in the elucidation of chemical structures.

In response to user requests, gravimetric conversion factors, equations and equivalents for volumetric analyses, standard volumetric solutions, and volumetric factors have been restored and updated in this edition.

The mathematical section has been restructured to exclude the tables for logarithms and trigonometric functions, data now easily obtained with the ubiquitous hand calculator.

This Handbook still remains the only one-volume source for extensive entries involving solubility products, the estimation of vapor pressure at various temperatures for inorganic and organic compounds—Antoine equation data, formation constants of metal complexes both inorganic and organic, equivalent conductance, critical volumes among the other critical data of temperature and pressure, and Hammett and Taft substituent constants.

Grateful acknowledgment is extended to Mr. L. P. Buseth (Norway) who consented to revise the table of conversion factors in Section 2.

It is hoped that users of this edition will continue to offer friendly criticism and suggestions and call attention to errors. These communications should be directed to the editor at his home address.

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JOHN A. DEAN

PREFACE TO THE FIRST EDITION

This book is the result of a number of years' experience in the compiling and editing of data useful to chemists. In it an effort has been made to select material to meet the needs of chemists who cannot command the unlimited time available to the research specialist, or who lack the facilities of a large technical library which so often is not conveniently located at many manufacturing centers. If the information contained herein serves this purpose, the compiler will feel that he has accomplished a worthy task. Even the worker with the facilities of a comprehensive library may find this volume of value as a time-saver because of the many tables of numerical data which have been especially computed for this purpose.

Every effort has been made to select the most reliable information and to record it with accuracy. Many years of occupation with this type of work bring a realization of the opportunities for the occurrence of errors, and while every endeavor has been made to prevent them, yet it would be remarkable if the attempts towards this end had always been successful. In this connection it is desired to express appreciation to those who in the past have called attention to errors, and it will be appreciated if this be done again with the present compilation for the publishers have given their assurance that no expense will be spared in making the necessary changes in subsequent printings.

It has been aimed to produce a compilation complete within the limits set by the economy of available space. One difficulty always at hand to the compiler of such a book is that he must decide what data are to be excluded in order to keep the volume from becoming unwieldy because of its size. He can hardly be expected to have an expert's knowledge of all branches of the science nor the intuition necessary to decide in all cases which particular value to record, especially when many differing values are given in the literature for the same constant. If the expert in

a particular field will judge the usefulness of this book by the data which it supplies to him from fields other than his specialty and not by the lack of highly specialized information in which only he and his co-workers are interested (and with which he is familiar and for which he would never have occasion to consult this compilation), then an estimate of its value to him will be apparent. However, if such specialists will call attention to missing data with which they are familiar and which they believe others less specialized will also need, then works of this type can be improved in succeeding editions.

Many of the gaps in this volume are caused by the lack of such information in the literature. It is hoped that to one of the most important classes of workers in chemistry, namely the teachers, the book will be of value not only as an aid in answering the most varied questions with which they are confronted by interested students, but also as an inspiration through what it suggests by the gaps and inconsistencies, challenging as they do the incentive to engage in the creative and experimental work necessary to supply the missing information.

While the principal value of the book is for the professional chemist or student of chemistry, it should also be of value to many people not especially educated as chemists. Workers in the natural sciences—physicists, mineralogists, biologists, pharmacists, engineers, patent attorneys, and librarians—are often called upon to solve problems dealing with the properties of chemical products or materials of construction. For such needs this compilation supplies helpful information and will serve not only as an economical substitute for the costly accumulation of a large library of monographs on specialized subjects, but also as a means of conserving the time required to search for information so widely scattered throughout the literature. For this reason especial care has been taken in compiling a comprehensive index and in furnishing cross references with many of the tables.

It is hoped that this book will be of the same usefulness to the worker in science as is the dictionary to the worker in literature, and that its resting place will be on the desk rather than on the bookshelf.

Cleveland, Ohio
May 2, 1934

N. A. LANGE

PREFACE TO THE ELEVENTH EDITION

The new editor has assumed the task of data compilation from the late Dr. Lange, the man who initiated the *Handbook of Chemistry* almost four decades ago. It seems only fitting that his name should be embodied within the new title in recognition for his efforts on the ten preceding editions of this handbook.

Perhaps it would be simplest to begin by stating the ways in which this new edition has not been changed. It remains the one-volume source of factual information for chemists, both professionals and students—the first place in which to “look it up” on the spot. The aim is to provide sufficient data to satisfy all one’s general needs.

The changes, however, are both numerous and significant. First of all, there is a basic change in organization. The handbook is now divided into sections—mathematics, general information and conversion tables, atomic and molecular structure, inorganic chemistry, analytical chemistry, electrochemistry, organic chemistry, spectroscopy, thermodynamic properties, physical properties, miscellaneous—and within these sections related groups of factual data are presented. This arrangement, plus the new sectional tables of contents, which provide a complete listing of items within each section, backed up by a thorough and extensively cross-indexed subject index, makes it possible to find the information quickly.

The following subject matter is offered for the first time:

Emission and absorption lines for arc, spark, and flame and atomic absorption—with sensitivities and/or detection limits

Formation constants of metal complexes with organic and inorganic ligands

Mass absorption coefficients of X-ray emission lines commonly used in X-ray absorption work, with coefficients for all elements

Statistical tables

Atomic electron affinities

Electronegativities of the elements

Spatial orientation of common hybrid bonds

Hammett and Taft substituent constants

Selectivity coefficients for ion-exchange resins

Cross contamination and separation factors in separation methods

Also new are self-instructional sections developed for certain areas: measurement of pH, use of statistics, separation methods, and X-ray methods.

Expanded coverage is provided in such important areas as:

Solubility products

Proton transfer reactions (acid dissociation constants) with 1200 entries for organic compounds and 150 for inorganic compounds

Electrode potentials of elements and their compounds listed by element

Bond energies and radii of atoms and ions

Reference electrodes

Reference pH buffers for water, deuterium oxide, and aqueous-organic systems

Approved symbols and abbreviations

Updating has increased the usefulness of such valuable tabulations as:

Physical properties of 4000 inorganic compounds

Nomenclature of inorganic compounds

Heats and free energies of formation, entropies, and heat capacities—incorporating the latest recommended values of the National Bureau of Standards

X-ray emission spectra and X-ray K and L absorption edges, given both as wavelengths and as energies in keV

Critical properties

Limiting equivalent ionic conductances in aqueous solution

Table of nuclides, now 100 pages extending through element 105

Ionization potentials of the elements

Finally, the mathematical section has been expanded from its rather restricted size in recent editions so as to include mathematical information commonly needed by an upper-division or graduate student, or professional, without recourse to other reference sources.

It is hoped that users of this and previous editions will continue to offer friendly criticism and suggestions and call attention to errors.

Knoxville, Tennessee

JOHN A. DEAN

PREFACE TO THE TWELFTH EDITION

In this edition, the second under the aegis of the present editor, new and updated material has become available for incorporation from the numerous compilations of standard reference data that have appeared in the interim since the eleventh edition went to press. In particular, the section on thermodynamic properties has been thoroughly revised to reflect the latest recommended values for heats of formation and Gibbs energies of formation, entropies, heat capacities at five different temperatures, and latent heats of melting, vaporization, and sublimation for approximately 200 inorganic compounds and 1500 organic compounds.

The following subject matter is offered for the first time:

Structure-correlation tables for proton magnetic resonance and infrared spectroscopy

Ionization potentials of molecular and radical species

Potentials of reference electrodes for water-organic solvent mixtures

Wavenumber/wavelength conversion table

New explanatory sections have been added for thermodynamic relations, column chromatography, Hammett and Taft substituent constants, conductance relations, physical chemistry equations for gases, spectroscopic relationships, computation of pH values of solutions, and relationships involving refractive indices, dipole moments, dielectric constants, viscosity, and surface tension.

Expanded coverage is provided in the areas of:

Conversion factors—1800 entries, incorporating SI units

Atomic electron affinities

pH ranges of buffer solutions for control purposes

Temperature dependence of selected values of pK_a and pK_{sp} in water

Equivalent conductivities of 180 electrolytes in aqueous solutions at 11 concentrations

Concentrations of commonly used acids and bases

Physical properties of 450 organic solvents, a section useful for HPLC applications which lists refractive indices, dielectric constants, dipole moments, surface tensions, and viscosities

Physical properties of 225 inorganic substances listing dielectric constant, dipole moment, surface tension, and viscosity

Cryoscopic constants

Ebullioscopic constants

Drying agents

Solutions for maintaining constant humidity

Vapor pressures of approximately 370 inorganic and 770 organic compounds from data to be fitted into an Antoine or similar type equation

Solubilities of 400 inorganic compounds and metal salts of organic acids in water at 9 fixed temperatures

Updating has increased the usefulness of such valuable tabulations as:

Fundamental physical constants

Physical and chemical symbols and terminology

Hammett and Taft substituent constants

Bond energies

Nuclear properties of the elements

Ionization potentials of the elements

Fluorescent indicators

Oxidation-reduction indicators

Proton-transfer reactions of inorganic materials in water

Potentials of the elements and their compounds

International practical temperature scale, adopted in 1968—the IPTS-68, and the revised thermocouple reference data based on this scale

Finally, the mathematical section has been restructured to exclude data now easily obtained with the ubiquitous hand calculator. Reintroduced are commonly used differential equations and integrals.

It is hoped that users of this edition will continue to offer friendly criticism and suggestions and call attention to errors. These communications should be directed to the editor at his home address.

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Grateful acknowledgment is hereby made of an indebtedness to those who have contributed to former editions and whose compilations continue in use in this edition. In particular, acknowledgment is made of the contribution of Dr. Joseph R. Peterson, who prepared the expanded Table of Nuclides; also that of Mr. Theodore C. Rains who supplied many of the atomic absorption sensitivities. For this edition Mr. L. P. Buseth prepared the Conversion Tables of Section 2.