



**NBSIR 74-535**

# **A Selected and Annotated Bibliography of Compilations of Data Relevant to Biochemical Thermodynamics**

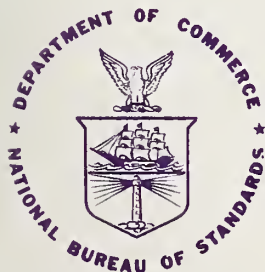
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G. T. Armstrong, G. R. Janes, and R. N. Goldberg

Thermochemistry Section  
Physical Chemistry Division  
Institute for Materials Research  
National Bureau of Standards  
Washington, D. C. 20234

July 1974

Final



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DEPARTMENT OF COMMERCE  
NATIONAL BUREAU OF STANDARDS

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**U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary**  
**NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director**



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## Introduction

There is an increasing demand by workers in the biological and biochemical sciences for thermochemical data. However, even the location in the literature of an existing piece of data may present a problem due to the sheer bulk of the existing scientific literature. This is aggravated somewhat by the fact that much of the pertinent data is relevant not only to biochemistry, but also to other disciplines such as classical solution chemistry, electrochemistry, and thermochemistry. As part of the program of the Thermochemistry Section at the National Bureau of Standards, it was felt that it would be useful to survey the existing sources of compiled thermochemical data and to prepare a bibliography selected from this literature on the basis of its relevance to biochemistry. This bibliography should serve to assist in the location of desired information where it is available pending the appearance of comprehensive reviews and compilations of data specific to biochemistry.

The bibliography is listed in alphabetical order by leading author. A brief description of the contents of each item is given to permit the reader to select those references which will most directly apply to his own needs. Some of the compilations were prepared specifically for use in biological sciences; other were prepared for a more general thermodynamic audience, but also contain substantial amounts of data valuable in the biological sciences; still others are of very general interest and contain some, but comparatively limited amounts of data specific to biological processes. These three degrees of relevance are indicated by the Roman numerals I, II, and III, respectively.

This report was put together partly to place in the hands of interested scientists some information which we think will be useful--derived from our efforts in a slightly different direction. The real goal of this work is to provide a survey upon which to base judgments as to the adequacy of existing compilations, recommendations for compilation and evaluation of information not included, and suggestions for areas requiring new experimental work.

In accord with the above goal the report is intended to be fairly complete with respect to category I and category II, but makes no attempt at completeness in category III.

The alphabetical subject index that follows the main section of this bibliography gives an indication of thermodynamic properties, physical or chemical processes, classes of substances, and in a few cases individual substances for which information is to be found in the bibliography. It is not practical to give an exhaustive index to the contents of the individual references; hence the absence of a piece of information in the index does not necessarily mean its absence in the references. This is particularly true with respect to particular substances, which the reader should assume are not listed except by chance of title or abstract. However, the index is provided to steer the reader to some appropriate bibliographical entries. The index together with the annotations in the bibliography should allow the reader to select some appropriate sources of information.

This bibliography was instigated by J. T. Edsall, I. Wadsö, W. P. Jencks, and P. Privalov of the joint IUPAC, IUB, IUPAB joint Subcommittee on Thermodynamics for the Biological Sciences, to whom acknowledgement is given for suggestions and encouragement.



Armstrong, G. T., Domalski, E. S., Furukawa, G. T., Reilly, M. L., Wilhoit, R. C. and others.

I

A Survey of Thermodynamic Properties of the Compounds of the Elements  
CHNOPS - A Series of Eighteen Reports

(National Bureau of Standards Reports No. 8521, 8595, 8641, 8906, 8992, 9043, 9089, 9374, 9449, 9501, 9553, 9607, 9883, 9968, 10070, and 10291, published during the years 1964 to 1970, U.S. Department of Commerce, Washington, DC 20234).

This series of reports is a survey of the thermodynamic properties of selected compounds of biological importance containing the elements carbon, hydrogen, nitrogen, oxygen, phosphorous, and sulfur. Included in these reports are heat capacity data; heats and free energies of formation; vapor pressure data; tables of thermodynamic functions; Gibbs energies, entropies and enthalpies of solution and dilution; and thermodynamic properties of mixed solvent systems. References to sources of data in the literature are included.

Standard Gibbs Free Energy, Enthalpy, and Entropy Changes as a Function of pH, and pMg for Several Reactions Involving Adenosine Phosphates (Journal of Biological Chemistry, 244, 3290 (1969))

The standard Gibbs energy, enthalpy, and entropy changes for the hydrolysis of adenosine-5'-triphosphate to adenosine-3'-diphosphate are computed as a function of pH and magnesium ion concentration. A critical evaluation of the relevant literature data is included.

Thermochemistry of Transition Metal Complexes  
(Academic Press, London, New York, 1970)

This book surveys the literature to 1968 on energy changes for processes involving transition metal complexes including both organic and inorganic ligands. A critical review of the thermochemical data for over 1500 systems of complexes is given. Comparable data from various sources are shown in juxtaposition. Values of  $\Delta H$ ,  $\Delta G$ , and  $\Delta S$  for various stages of complex formation are usually listed for processes in aqueous solution.  $\Delta H_f^\circ$ ,  $\Delta G_f^\circ$ ,  $\Delta S_f^\circ$  for crystalline complex substances are given where available. In many instances correlations of the data for various metals with a single ligand, and for various related complexes of a given metal, are given graphically or by means of bond-energy estimates based in the data.

Thermochemical Kinetics

Methods for the Estimation of Thermochemical Data and Rate Parameters  
(John Wiley and Sons, Inc., New York, London, Sydney, 1968)

This monograph gives tables of necessary data and descriptions of methods of their use for calculating  $\Delta H_f$ ,  $C_p$ , and  $S$ , at 25°C for gas phase molecules and radicals and for extrapolating them to higher temperatures.

The procedures can be applied to hydrocarbons, oxygen-containing compounds, nitrogen-containing compounds, haloalkanes, organo-sulfur compounds, and organo-metallic compounds; and deal principally with organic compounds.

Benson, S. W., Cruickshank, F. R., Golden, D. M., Haugen, G. R.,  
O'Neal, H. E., Rogers, A. S., Shaw, R., and Walsh, R.

III

Additivity rules for the estimation of thermochemical properties.  
(Chem. Rev. 69, 279-324 (1969))

This lengthy technical article gives procedures for calculating the properties  $\Delta H_f^\circ$ ,  $S^\circ$ ,  $C_p^\circ$ , for organic compounds in the gas phase. Parameters for calculating  $C_p$  are given for temperatures from 300 to 1500 K at intervals. The availability of  $C_p$  at T allows calculation of  $\Delta H_f^\circ$  and  $S^\circ$  at the same temperatures. The necessary constants for making the calculations are given for individual chemical groupings in some 38 tables. Many classes of functional groups and molecular conformations are included. Examples are given comparing calculated and observed values. Agreements of 1 kcal mol<sup>-1</sup> or less in  $\Delta H_f^\circ$  and 1 cal mol<sup>-1</sup> K<sup>-1</sup> or less in  $C_p^\circ$  and  $S^\circ$  are generally found.

Physical Properties of Molecular Crystals, Liquids, and Glasses  
(John Wiley and Sons, Inc., New York, London, Sydney, 1968)

This monograph is designed for the use of chemical engineers to estimate physical properties needed in design calculations, as well as of physical chemists and synthetic chemists who need to understand the relationship between structure and physical properties. Correlations of several kinds are described in the text. These are then restated as methods for estimation of the properties.

Substances considered include non-polar and polar gases, non-polar and polar liquids, associated liquids, crystalline solids, glasses, polymers, and polymer melts, as well as others. Procedures given include many variants, depending upon the properties given as initial information. Among the properties for which procedures are given are: density, heat capacity, enthalpy, entropy, enthalpy and entropy of fusion, enthalpy of sublimation and vapor pressure, cubical thermal expansion coefficient, bulk modulus, Young's modulus, compressibility, thermal conductivity, rotational diffusion constant, relaxation times, mass diffusion, viscosity, and others.

Biochemical Microcalorimetry  
(Academic Press, New York, London, 1969)

This book contains seventeen articles on subjects concerning heat measurements and their relationship to biology and biochemistry. Several of the articles contain tabulations of data:

Title of Article

Author(s)

Thermodynamic Properties of Biochemical  
Substances

R. C. Wilhoit

This review includes several tables: (1) Selected values of thermodynamic properties ( $\Delta H_f^\circ$ ,  $\Delta G_f^\circ$ ,  $S^\circ$ , and  $C_p^\circ$ ) for  $\sim 120$  important biochemical species or compounds; (2) Enthalpies and Gibbs energies of formation of adenosine phosphoric acid species relative to  $H_2ADP^{-1}$  at  $25^\circ C$ ; (3)  $\Delta H^\circ$  and  $\Delta G^\circ$  for six important biochemical processes; and (4) Partial molal properties ( $\bar{L}_2$ ,  $\bar{L}_1$ ,  $\bar{C}_2$ , and  $\bar{C}_1$ ) of glucose, glycerol, glycine, and urea at  $25^\circ C$ .

Chemical Structure and Reactions of Carbohydrates

S. Ono and K. Takahashi

This article has a table of enthalpies of isomerization of eleven carbohydrates and a table giving enthalpies of hydrolysis of  $\alpha$ -1,4 and  $\alpha$ -1,6 glucosidic linkages in several glucosides at  $25^\circ C$ .

Physical States of Biomolecules: Calorimetric  
Study of Helix-Random Coil Transitions in Solution

T. Ackermann

There is a tabulation of calorimetrically determined enthalpy values accompanying conformational changes of macromolecules in solution (26 articles).

Calorimetry of Enzyme-Catalyzed Reactions

H. D. Brown

Tabulated are calorimetric enthalpy values for enzyme catalyzed systems (21 articles).

A Compilation of Selected Thermodynamic and Transport Properties  
of Binary Electrolytes in Aqueous Solution  
(Lawrence Radiation Laboratory, UCRL-17767, Berkeley, California, 1968)

Data from the literature on the properties of sixty-one common binary inorganic electrolytes at various temperatures are tabulated with appropriate references. The properties include the density, viscosity, transference number, diffusion coefficient, and the activity coefficient.



Christensen, J. J. and Izatt, R. M.

II

Handbook of Metal Ligand Heats and Related Thermodynamic Quantities  
(Marcel Dekker, Inc., New York, 1970)

This handbook gives tabulated values of thermodynamic functions in aqueous solution. Enthalpies are given for equilibria involving metal ions and ligands, together with the related thermodynamic quantities,  $\log K$ ,  $\Delta S$ , and  $\Delta C_p$ , where available. The body of the book consists of a table (192 pp) in which are summarized the published literature values up to 1969, classified according to ligand. In addition, the appropriate reaction, the temperature, the method, and conditions of measurement of  $\Delta H$  are given. Both inorganic and organic ligands, and complexes of about seventy metallic elements are given. A seven page guide to the use of the table and indexes is given.

The table is indexed by author, by ligand formula, and by metal. An index of synonyms and a chronological list of references are also given.

Oxidation-Reduction Potentials of Organic Systems  
(The Williams and Wilkins Company, Baltimore, 1960)

This 584 page monograph contains a comprehensive discussion on the determination of the electrochemical potentials of organic systems with emphasis both on theory and experimental practice. Included are approximately 100 tables of critically evaluated oxidation and reduction potentials for organic and biochemical systems thru circa 1960. Included are the quinones, phenols, anilines, porphyrins, NAD, and NADP systems, and several others. The author has, in most cases, specified the conditions to which the data refer.

Electrochemical Data  
(Elsevier Publishing Company, New York, 1952)

This monograph is a comprehensive (359 pp) collection of data on various aspects of pure and applied electrochemistry, relating to organic and inorganic substances, both solid and in solution. All data are presented in tabular form, organized into ten chapters, each introduced briefly by the author, with references to all data sources and short explanations of approach. A chapter on physical properties includes tables of densities and vapor pressures of various aqueous solutions, dielectric constants and dipole moments and other properties. Relative partial molal enthalpies and activity and osmotic coefficients are tabulated in Chapter III, on molecular and ionic interaction in the liquid phase, followed by a section on transport in solutions of strong electrolytes, which includes lists of conductance values, ionic mobilities, transference numbers and diffusion coefficients. A chapter on dissociation constants, solubilities, and buffer solutions also includes instructions for the preparation of 12 buffer solutions. The chapter on properties of electric double layers contains tables of electrokinetic potentials and properties of various interfaces including ones of such biological interest as the mammalian red blood cell. The biologist would also find relevant the section on transport and general properties of colloids and macromolecular electrolytes, including extensive tables of mobilities for such compounds as hemoglobins, serum albumins, and red blood cells, among others. With the exception of the chapter on the electrochemistry of melts,

which deals primarily with electrochemical parameters of molten and fused salts and various oxides, the final third of the book concerns electrode chemistry. Chapter IX is a compilation of data on reversible electrode processes, including listings of liquid junction potentials, half-cell potentials, and electrochemical equivalents for certain elements. Chapter X is titled, "Parameters of electrode kinetics" and represents a critical selection of the available determination of the parameters of a number of electrode reactions.

Cox, J. D. and Pilcher, G.

II

Thermochemistry of Organic and Organometallic Compounds  
(Academic Press, London, New York, 1970)

This monograph is a critical compilation of thermochemical data published since 1930. The enthalpies of formation of some 3000 substances are listed, with estimates of error. Where enthalpies of vaporization are known or can be reliably estimated these are listed and in these cases the enthalpies of formation of both gaseous and condensed phases are given. Extensive introductory material presents experimental procedures and procedures for reduction of experimental data of the type found in the book. Applications of thermochemical data are given, and there is a section on methods of estimating enthalpies of formation of organic compounds.

Selected Values of Heats of Combustion and Heats of Formation of Organic Compounds Containing the Elements C, H, N, O, P, and S. (Journal of Physical and Chemical Reference Data 1, 221-277 (1972))

Selected values of the enthalpies of combustion and enthalpies of formation of 719 organic compounds are reported. The selected values are augmented by commentary and original source references. The Wiswesser Line Notation is also given for each compound. The methods used in updating older work are described.

Florkin, M. and Mason, H.

I

Comparative Biochemistry, Volume II  
Free Energy and Biological Function  
(Academic Press, New York, London, 1960)

This book contains several chapters dealing with the use of Gibbs energy data in biochemistry. The following chapters contain references to and/or tabulations of thermochemical data:

M. R. Atkinson and R. K. Morton, "Free Energy and Biosynthesis of Phosphates". This chapter contains a tabulation of Gibbs energies and equilibrium constants for various metabolic processes involving phosphates. The temperature, pH, magnesium ion concentration, and appropriate literature references are given.

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L. F. Leloir, C. E. Gardini, and E. Cabib, "Utilization of Free Energy for the Biosynthesis of Saccharides". Included in the discussion are some references to equilibrium data relevant to the biosynthesis of saccharides.

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P. P. Cohen and G. W. Brown, Jr., "Ammonia Metabolism and Urea Biosynthesis". In their discussion of ammonia metabolism, the authors have used other compilations of thermodynamic data to compute Gibbs energy changes for these processes.

Fox, D., Labes, M. M., and Weissberger, A. (editors)

II

Physics and Chemistry of the Organic Solid State  
(Interscience Publishers (Wiley), 1963)

Chapter 1. Thermodynamics of Crystals  
E. F. Westrum and J. P. McCullough

In addition to discussion of thermodynamic properties of organic substances and their measurement, this chapter (178 pp) gives tables of entropy of fusion, and vapor pressures and a table of thermodynamic data sources for about 800 organic compounds (798 references).



Hamer, W. J. and Wu, Y. C.

III

Osmotic Coefficients and Mean Activity Coefficients of Uni-univalent Electrolytes in Water at 25°C  
(Journal of Chemical Reference Data, 1, 1047 (1972))

This evaluation gives values for the osmotic coefficients and mean activity coefficients of 79 uni-univalent electrolytes in aqueous solution at 25°C, with values expressed on the molality scale. The data from the literature were fitted, by statistical procedures, to equations which express the quantities as functions of electrolyte concentration. Literature references are given to 51 additional uni-univalent electrolytes.

Harned, H. S. and Owen, B. B.

III

The Physical Chemistry of Electrolytic Solutions  
(Reinhold, Publishing Corporation, New York, 1958)

This book (~800 pp) is a treatise on the physical chemistry of electrolytic solutions with coverage of both equilibrium and non-equilibrium properties. The book includes tables of values of the equivalent conductance, dissociation constants, transference numbers, diffusion coefficients, relative apparent molal heat contents, activity coefficients, pH values, densities, and activity coefficients for many of the more common inorganic and organic electrolyte solutions.

Izatt, R. M., Christensen, J. J., and Rytting, J. H.

I

Sites and Thermodynamic Quantities Associated with Proton and Metal Ion Interaction with Ribonucleic Acid, Deoxyribonucleic Acid, and Their Constituent Bases, Nucleosides, and Nucleotides  
(Chemical Reviews, 71, 439 (1971))

This review contains twenty-three journal pages of tables of thermodynamic data ( $\log K$ ,  $\Delta H$ ,  $\Delta S$ , and  $\Delta C_p$ ) pertinent to the interaction of protons and metal ions with the nucleic acids and their molecular components together with the methods and experimental conditions (pH, temperature, ionic strength) used in their determination. There are 229 references to articles in the literature.

Thermodynamic Properties of Organic Compounds  
Estimation methods, principles, and practice (revised edition)  
(Academic Press, Inc., New York, London, 1967)

This well established monograph discusses computation of thermodynamic properties such as heat capacities, entropies, enthalpies and Gibbs energies by statistical mechanical methods, by methods of structural similarity, by methods of group contributions, by methods of group equations, and by methods of generalized vibrational assignments.

The chemical properties: enthalpy of formation, and enthalpy of combustion are treated in terms of bond energies and group increments.

Some 78 tables are given of increments, group contributions, and bond contributions as specifically needed for estimation of particular properties.

Jordan, T. Earl

III

Vapor Pressure of Organic Compounds  
(Interscience Publishers, Inc., New York, 1954)

A comprehensive compilation (266 pages) of vapor pressure data for organic compounds. Included are tables on the hydrocarbons, alcohols, aldehydes, esters, ketones, acids, phenols, and metal organic compounds. Data for each compound are shown in graphical form, i.e. vapor pressure as a function of temperature. References to the data sources in the literature are given.

Vinyl Polymerization, Volume 1, Part I, edited by G. E. Ham  
(Marcel Dekker, Inc., New York, 1967)

Chapter 8: Heats of Polymerization and their Structural and  
Mechanistic Implications

The authors discuss experimental methods used to measure and derive heats of polymerization. A listing of experimental data on heats of polymerization is provided for 81 organic polymerization reactions. Other tables give heats of formation, heats of vaporization, entropies, Gibbs energies, equilibrium constants, rate constants and activation energies at 25°C for a variety of polymerization processes. A discussion of the structural influence upon the heat of polymerization is also given. At the end of the chapter, 164 references are cited.

Dissociation Constants of Organic Acids in Aqueous Solution  
(Butterworths, London, 1961)

This book is a compilation of 1056 dissociation constants of organic acids in aqueous solution, presented in tabular form. Introductory and explanatory remarks are in both German and English. Remarks in the Table are in German. Part I is a critical discussion of techniques for measurement of dissociation constants by conductance, electrometric, catalytic and optical methods. Each method is classified and coded in Part II, on use of the table, where methods of calculation and corrections for solvent and for hydrolysis of salts in conductivity measurements are also coded, for reference in the table. The Table itself is arranged by acid class including: aliphatic and alicyclic carboxylic acids, aromatic carboxylic acids, phenolic acids, and other acids and special classes. The Table gives the name, chemical formula, and thermodynamic dissociation constant  $K$  of each acid, the temperature ( $^{\circ}\text{C}$ ) of measurement, the range of concentration over which the measurements were made, code for the method of measurement, calculation procedure, and any corrections made, a critical evaluation of the quality of the measurement, and the source reference. All data were drawn from the literature, covering the period between 1927 and 1956, and are referenced in a classified reference list. A compound index is provided.

Energy Transformations in Living Matter  
(Springer-Verlag, Berlin, 1957)

The main part of this monograph surveys the various biochemical pathways by which living systems utilize energy. In the Appendix are (1) Tables of Gibbs energies of formation of ninety-eight compounds of biological importance, (2) Gibbs energies and electrochemical potentials of important biological oxidation-reduction reactions, and (3) Gibbs energy changes accompanying the processes of glycolysis and alcoholic fermentation, the tricarboxylic acid cycle, and of hydrolysis. The source of data is given for each entry.



Lange, E.

III

Heats of Dilution of Dilute Solutions of Strong and Weak Electrolytes in "The Structure of Electrolytic Solutions" (W. J. Hamer, editor) (John Wiley and Sons, Inc., New York, 1959)

A discussion of the theoretical interpretation and calculation of heats of dilution of electrolytes of various charge types with some information on non-electrolytes and weak electrolytes. Data from the literature are presented in graphical form. Included are data for eighteen inorganic electrolytes and seven inorganic non-electrolytes. Data refer to 25°C.

Heats and Entropies of Ionization  
in Solute-Solvent Interactions, J. F. Coetzee and C. D. Ritchie (editors)  
(Marcel-Dekker, New York and London, 1969)

This chapter is a detailed review and evaluation of the enthalpies, Gibbs energies, entropies, and heat capacity changes accompanying ionization of aqueous acids. Included are eleven tables of data on various types of acids, including the carboxylic acids, phenols, anilinium ions, ammonium ions, the amino acids, barbituric acids, and several inorganic acids. The authors also discuss the interpretation of the data in terms of molecular considerations. The tabulated data refer to 25°C and standard state conditions. There are 224 references.

The Oxidation States of the Elements and their Potentials in Aqueous Solution  
Second edition  
(Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1959)

Although originally published in 1938 the second edition copyrighted in 1952, still stands as a comprehensive (392 pp) and useful text for the worker interested in a summary of existing data on energy levels of the elements in their various oxidation states. Written in narrative form, organized into 23 chapters with 4 appendices and an author and subject index, the text is augmented by numerous graphs, charts, formulae, and solved mathematical problems. For each element the enthalpies of formation, Gibbs energies of formation and entropies have been tabulated for important compounds. A preliminary chapter discusses general methods by which the Gibbs energy data have been obtained, and gives references to more detailed treatments. A second chapter is devoted to values for the ionization potentials and the electron affinities of the elements, and their relationship to the oxidation-reduction potentials of the elements and their compounds in their standard states. The remainder of the text is devoted to a systematic review of each element. For each element is given a brief introductory passage, noting number of valence electrons and electronic states, followed by more detailed discussions of oxidation states,  $E^\circ$  values for relevant couples, and useful potential diagrams of potentials in acid and base solution. For quick reference, approximately 400 oxidation-reduction couples are listed in Appendix I, with the couples arranged in order to decreasing  $E^\circ$  values, and divided into those in acid solutions, and those in basic. Appendix II includes a list of activity coefficients for 77 strong electrolytes, and Appendix

III is a discussion of methods by which estimates of entropy values were made, where necessary. A group of study problems in Appendix IV is meant to be particularly useful to the student and/or instructor, who might wish to use the book in conjunction with a course.

Linke, W. F.

II

Solubilities: Inorganic and Metal-Organic Compounds--A Compilation of Solubility Data from the Periodical Literature. Volume I: A-Ir, Volume II: K-Z  
(Volume I: D. Van Nostrand Co., Princeton, New Jersey, 1958;  
Volume II: American Chemical Society, Washington, DC, 1965).

These two volumes (total of 3401 pages) are comprehensive compilations of unevaluated solubility data for inorganic and metal-inorganic compounds. Both aqueous and non-aqueous solvent systems are included.

References are given to the data sources.



Handbook of Analytical Chemistry  
(McGraw-Hill Book Co., New York, 1963)

This treatise on analytical chemistry contains several useful tabulations of thermochemical data. Several of these tabulations are taken directly from other sources cited in this bibliography and are not included below:

<u>Title of Section</u>	<u>Author(s)</u>
Equilibrium Constants of Proton-transfer Reactions in Water	V. E. Bowers and R. G. Bates

Tabulated are pK values at 15, 25, and 35°C for ~200 organic and inorganic acids; no literature references are given.

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Formal Equilibrium Constants of Proton-transfer Reactions at Finite Ionic Strength	L. Meites
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This section contains a tabulation of pK values at 25°C for a selected series of ~150 acids, and bases. This data was taken from Bjerrum, Schwarzenbach, and Sillen, "Stability Constants of Metal Complexes", part I, Chemical Society, London, 1957. Also given are tables of acid dissociation data pertinent to ethanol-water and methanol-water mixtures.

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Formation Constants of Metal Complexes	D. A. Aikens and C. N. Reilley
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Tabulated are log K values for the binding of the more common inorganic metal ions to 55 ligands.  $\Delta H$  and  $\Delta S$  values are also given for four ligands. Literature references are given.

(a) Energy Value of Foods; Basis and Derivation  
Agriculture Handbook No. 74, 1955.

(b) (Watt, B. K. and Merrill, A. L.)  
Composition of Foods; Raw, Processed, Prepared  
Agriculture Handbook No. 8, revised, 1963

(U.S. Government Printing Office, Washington, DC 20402)

This pair of monographs provides numerous composition and energy values for food and foodstuff ingredients. It should be noted, of course, that the Calorie used in food energy values is 1 kcal as used in thermochemistry. In Agriculture Handbook No. 74, Part I gives a discussion of the sources of food energy in terms of organic compound class, and of the experimental determination of heats of combustion. Parts II, III, and IV apply the data to physiological processes. An appendix gives composition and heat of combustion of foods. Tables 1-5 and table 24 give heats of combustion of specific food items or component substances. Care should be used in taking values from the numerous tables, as correction factors have sometimes been applied to adjust for physiological processes. These adjustments are indicated by footnotes. In Agriculture Handbook No. 8, Appendix A is of particular interest as it gives notes on energy values and nutrients, including (adjusted) heats of combustion of many foods and food ingredients.



Miller, D. G.

III

Application of Irreversible Thermodynamics to Electrolyte Solutions. I. Determination of Ionic Transport Coefficients  $\lambda_{ij}$  for Isothermal Vector Transport Processes in Binary Electrolyte Systems. II. Ionic Coefficients  $\lambda_{ij}$  for Isothermal Vector Transport Processes in Ternary Systems. (Journal of Physical Chemistry, 70, 2639 (1966); 71, 616 (1967)).

These papers derive equations relating fundamental isothermal transport coefficients ( $\lambda_{ij}$ 's) to experimentally measurable quantities for electrolytes in a neutral solvent.  $\lambda_{ij}$ 's for the most common aqueous ionic solutions are calculated from critically reviewed data.

The Partial Molal Volumes of Electrolytes in Aqueous Solutions. Compilation of the Partial Molal Volumes of Electrolytes at Infinite Dilution,  $\bar{V}^\circ$ , and the Apparent Molal Volume Concentration Dependence Constants,  $S_v^*$  and  $b_v$ , at Various Temperatures.

Water and Aqueous Solutions, R. A. Horne (editor)  
(Wiley-Interscience, New York, 1972)

Two chapters in this book are concerned with the measurement and interpretation of partial molal volumes and their concentration and temperature dependences. Included are tables of the partial molal volumes of the common inorganic and organic electrolytes ( $\sim 200$  systems) as well as values of the partial molal volumes of the more common inorganic and organic ions ( $\sim 100$  species). The data refer to temperatures from 0 to 200°C.

Mishchenko, K. P. and Poltoratzkii, G. M.

II

Aspects of the Thermodynamics and Structure of Aqueous and Non-aqueous Electrolyte Solutions  
(Izd. "Khimia", Leningrad, 1968) (In Russian)

This 350 p. monograph contains extensive discussions and correlations (theoretical and empirical) of existing experimental data on enthalpies, Gibbs energies, and entropies, of solution and ionization of inorganic acids, bases, and salts in water and selected organic solvents. Heat capacities, enthalpies, Gibbs energies, and entropies of the substances and their ions in solution are also discussed. Extensive use is made of diagrams relating observed properties to periodic groupings of the elements. The monograph contains numerous small tables of properties of limited groups of substances. A summary compilation of selected values of thermodynamic properties occupies 43 pages, giving  $\Delta H_f$ ,  $\Delta G_f$ ,  $S$  and  $C_p$  of pure and dissolved inorganic substances in their standard states at 25°C, selected enthalpies of solution at 25°C, enthalpies of dilution of common acids, bases, and salts at 25°C, and heat contents and partial molar heat capacities for selected salts vs. concentration and temperature in water, methanol, ethanol, and a few other organic solvents.

Thermal Properties of Aqueous Uni-univalent Electrolytes  
(NSRDS NBS 2, U.S. Government Printing Office, 1965)

This short (41 pp) monograph is a review of the heat-capacity, enthalpy of solution, and enthalpy-of-dilution data on simple 1-1 electrolytes, organic and inorganic, in dilute, aqueous solutions. From the critical analysis of this data, tables of selected "best" values of apparent heat capacities, and enthalpies of dilution are given, as well as selected values of the enthalpies of solution to the infinitely dilute solution. Also included is a review of data on the enthalpies of neutralization of monobasic acids which has led to a selected "best" value for the enthalpies of ionization of water. Data on each parameter are introduced with a discussion of methods employed in reducing the data to a standard form and are listed by compound, in the order: acids, ammonium and amine salts, silver salts, and salts of the alkali metals. For each compound are listed the various investigations, with the temperature and range of concentrations measured. Graphs of molal heat capacity and molal enthalpy as functions of concentration are also included, for aqueous solutions of many of the compounds discussed. In addition, there is an abbreviated listing, by compound, of review and compilation papers on the thermal properties of the aqueous uni-univalent electrolytes. These and other references are also listed alphabetically in a separate reference section with 652 entries. The chosen "best" values for each parameter and compound are arranged in a series of 21 tables, for  $T = 25^{\circ}\text{C}$ .

Pauling, L.

III

The Nature of the Chemical Bond, 3rd edition  
(Cornell University Press, Ithaca, New York, 1960)

This well established monograph provides general information about the nature of chemical bonding in (principally) inorganic compounds which is fundamentally very important for the estimation of enthalpies of formation, but not always easily applied.

Dissociation Constants of Inorganic Acids and Bases in Aqueous Solution (Butterworths, London, 1969).

This short (163 pp) monograph is a compilation of dissociation constants of 217 inorganic acids and bases. The classes of compounds include not only conventional acids and bases, but also hydrated metal ions and free radicals, such as hydroxyl, the only criterion being gain or loss of a proton or hydroxyl ion. The data are organized into a single table listing 217 compounds, preceded by a brief introduction to the use of the table, and a section on methods of measurement and calculation. The methods are classified as conductometric, electrometric, optical, or other. Elements and compounds are listed in decreasing extent of protonation.  $pK$  values are, wherever possible, obtained by extrapolation to ionic strength  $I = 0$ . The table also gives the temperature of each measurement, remarks as to ionic strength, concentration, and any other factors relating to  $pK$ , coded references to method of measurement, the procedure used in evaluating the constants and any corrections taken into consideration, and the literature references. There are approximately 1100 references listed alphabetically by author.

Perrin, D. D.

II

Dissociation Constants of Organic Bases in Aqueous Solution  
(Butterworths, London, 1965)

Published in the same series as the book by Kortum, Vogel, and Andrussov, this book tabulates values of dissociation constants for organic bases in aqueous solution. The bases are arranged under the headings aliphatic, alicyclic, aromatic, heterocyclic, natural products, dyes and indicators, substances lacking a basic nitrogen atom, and miscellaneous. Accompanying the data entry for each base is the temperature, method of measurement, formula, assessment of the measurement, and the appropriate reference. There are 3790 data entries in this book.

Phillips, R. C., George, P., and Rutman, R. J.

I

Thermodynamic Data for the Hydrolysis of Adenosine Triphosphate as a Function of pH,  $Mg^{2+}$  Ion Concentration, and Ionic Strength (Journal of Biological Chemistry, 244, 3330 (1969))

This article deals with the computation of the Gibbs energy change for the hydrolysis of adenosine-5'-triphosphate to adenosine-5'-diphosphate as a function of magnesium ion concentration, pH, and ionic strength.

A critical evaluation of the existing data pertinent to this computation is included. References to 24 papers are given.



Reid, Robert C., and Sherwood, T. K.

III

The Properties of Gases and Liquids, their Estimation and Correlation,  
2nd edition  
(McGraw Hill Book Co., New York, etc., 1966)

This lengthy monograph follows the procedure of discussing various methods available for calculating or estimating particular properties of particular materials, and then provides recommendations for action with respect to each kind of property. Included in the book are procedures for making estimates of critical constants, normal boiling temperatures, Lennard-Jones-potential parameters, compressibility factors and equations of state, liquid molal volumes and densities, and vapor pressures. Estimates of enthalpies of vaporization, and of ideal-gas heat capacities, enthalpies and Gibbs energies of formation are treated. For real fluids variations of enthalpy, entropy, internal energy, and heat capacity with pressure are treated. Some methods are given for estimating the properties of fluid mixtures. Surface tension and the transport properties--viscosity, diffusion coefficient and thermal conductivity--are discussed. Numerous tables present comparisons of observed and calculated properties.

Electrolyte Solutions, The Measurement and Interpretation of Conductance, Chemical Potential and Diffusion in Solution of Simple Electrolytes, second edition (revised)  
(Butterworths, London, 1965)

In this, the revised second edition of a monograph first published in 1955, the authors have approached their subject in terms of those fundamentals which distinguish or characterize aqueous organic and inorganic electrolyte solutions. Included in the text is a discussion of properties of ionizing solvents (ie. water), and electrolytic conductivities and transport numbers. The measurement and theoretical interpretation of chemical potentials are treated in some depth, as is the theory of diffusion, emphasizing conductance and diffusion in relation to viscosity in concentrated solutions, and methods of measurement of diffusion coefficients. The final third of the text deals primarily with characteristics of specific electrolyte solutions, including weak and mixed electrolytes, and strong acids, and includes an extensive (98 pp) appendix of approximately 75 tables of osmotic and activity coefficients, standard cell potentials ( $E^\circ$ ) in various organic solvents, ionic radii, and ionization constants of organic acids in aqueous solution, among others. The narrative is heavily supplemented with graphs, tables, equations, and an occasional derivation, all referenced at the end of each of the 15 chapters.

Rossini, F. D., Pitzer, K. S., Arnett, R. L., Brown, R. M., and  
Pimentel, G. C.

II

Selected Values of Physical and Thermodynamic Properties of Hydrocarbons  
and Related Compounds  
(Carnegie Press, Pittsburgh, Pennsylvania, 1953)

This monograph resulted from the work of American Petroleum Institute  
(API) Research Project 44. Values are given for 40-odd physical and  
thermodynamic properties of several hundred hydrocarbons in metric  
and U.S. Customary units. The data in most instances represent  
selected values from careful studies, many of which were done in  
connection with the same API Research Project. Experimental data are  
supplemented by theoretical calculations or empirical correlations.  
References to the source data and a bibliography are given. The  
data in many instances are identical to those in NBS Circular C461,  
listed below.

Rossini, F. D., Pitzer, K. S., Taylor, W. J., Ebert, J. P.,  
Kilpatrick, J. E., Beckett, C. W., Williams, M. D., and Werner, H. C.

II

Selected Values of Properties of Hydrocarbons  
National Bureau of Standards Circular C461 (1947)  
(U.S. Government Printing Office, Washington, DC)

This monograph was prepared as part of the work of the American Petroleum Institute (API) Research Project 44. Values are given for some 36 physical and thermodynamic properties of several hundred hydrocarbons in metric and in U.S. Customary units. The data in most instances represent values found from careful studies, many of which were done in connection with the same API Research Project. Experimental data are supplemented by theoretical calculations or empirical correlations. References to the source data and a bibliography are given. The data in many instances are identical to those in the Carnegie Press publication by Rossini et al listed above.

Rossini, F. D., Wagman, D. D., Evans, W. H., Levine, S., and Jaffe I. II

Selected Values of Chemical Thermodynamic Properties  
National Bureau of Standards Circular 500 (1952)  
(U.S. Government Printing Office, Washington, DC 20402)

This was for many years the most comprehensive authoritative compilation of thermochemical data at 298.15 K for inorganic substances. All inorganic substances and organic substances containing two carbon atoms or fewer per molecule are included if thermodynamic data exist for calculating one of the properties tabulated. Properties tabulated in Part I are  $\Delta H_{f0}^{\circ}$ ,  $\Delta H_{f298}^{\circ}$ ,  $\Delta G_{f298}^{\circ}$ ,  $\log K_f$ ,  $S_{298}^{\circ}$ , and  $C_{p298}^{\circ}$ . Properties tabulated in Part II are temperature, pressure, enthalpy change, entropy change and heat capacity change for the phase changes: transition, fusion, and vaporization. The data from original sources were critically evaluated by competent thermochemists and best values selected for the functions tabulated, maintaining internal consistency by the relationship:

$\Delta G_{f298}^{\circ} = \Delta H_{f298}^{\circ} - T\Delta S_{298}^{\circ}$ . The sources of data for each data item are listed and a bibliography is included. Some information in this book can still not be found readily elsewhere as the revision is not yet complete. Also, see Wagman et al in this bibliography.

Landolt-Börnstein  
Zahlenwerte und Funktionen aus Physik, Chemie, Astronomie,  
Geophysik, und Technik, Sechste Auflage  
Eigenschaften der Materie in Ihren Aggregatzuständen  
4 Teil, Kalorische Zustandsgrossen  
(Spring-Verlag, Berlin, Göttingen, Neudelberg, 1961)

This most recent issue of thermodynamic information of the Landolt-Bornstein series gives thermal properties: molar heat capacity, entropy, enthalpy, enthalpy of formation, Gibbs energy of formation, in the standard state, and enthalpies of phase changes for many organic and inorganic substances in SI units. The dependence of thermal functions and heat capacity upon temperature is given for many substances. Some other thermodynamic quantities are given. Extensive tables are given of group contributions to enthalpy of formation and the Gibbs energy of formation of organic substances (gases) in  $\text{kcal mol}^{-1}$  and  $\text{kJ mol}^{-1}$ . Many of the heat capacity data are presented in diagrams.

Stability Constants of Metal Ion Complexes, Section I: Inorganic Ligands, Section II: Organic Ligands, second edition (Special Publication No. 17, The Chemical Society, London, England, 1964 and Supplement No. 1, Special Publication No. 25, 1971)

With the publication of this second edition of Stability Constants, the Chemical Society combined two previously separate volumes into one, two-part volume (754 pages), the first covering constants of inorganic ligands, the second, organic ligands. Both sections include all data published up to the end of 1960 and some from 1961-63; the scope of the inorganic section has been extended to cover redox equilibria and the extraction of inorganic ligands into non-aqueous solvents. The data are organized into two separate tables, each table summarizing the data for the association of one particular ligand with all the metallic ions which have been studied in conjunction with it. Method of measurement, composition, and temperature of the media to which the data refer, are given for each ligand-metal pair. Acid dissociation constants of the ligands are recorded by including the hydrogen ion as one of the cations with which the ligands associate. Redox equilibria are represented by including the electron as a ligand, and hydrolysis of metallic ions is described by regarding the hydroxyl ion as one of the ligands.

The arrangement of material is now more uniform than in the two parts of the first edition, but there remain minor differences of presentation between the inorganic and the organic section. In the inorganic table, 80 ligands are ordered according to group in the periodic system; metal ions are arranged within each inorganic ligand table, in the same order. In the organic section, the ligands (1028) are in order of their

empirical formulae, and the metallic ions in the alphabetical order of their international symbols. Methods of measurement are highly variable, with 42 separate methods alphabetized and coded in the introduction; medium is usually aqueous. Equilibrium constants are given in both tables. The organic section includes consecutive or stepwise constants,  $K$ , whenever possible, and cumulative or gross constants,  $B_n$ , if they are the only quantities determined, or if the sequence of stepwise constants is incomplete. The inorganic table includes equilibrium constants for consecutive and cumulative reactions, solubility constants, acid constants and base constants. Certain special constants are also given; e.g.  $K_p$  - equilibria involving a gas. Both tables give enthalpy and entropy changes, and symbols relating to the references which are listed at the end of each table. Each of the metals, inorganic ligands and organic ligands are indexed alphabetically, with appropriate table number, at the end of the book.

This supplement to the second edition of "Stability Constants of Metal-Ion Complexes" is a review of pertinent literature published between the completion of the 1964 Tables and the end of 1968, including also some data published before the completion of the 1964 Tables, but omitted from them. In the organic part, a change of policy has been initiated; rather than being omitted, results seeming incomplete or of dubious validity are now included in the tables, with critical comments. The section "How to use the tables" has been brought up to date; a few methods have been added. Limits of error are now sometimes given. A new feature of the organic section is a Functional Group Index, covering also the 1964 Tables, and a table of 34 macromolecular organic ligands, including albumin, DNA, RNA, and insulin.



Handbook of Biochemistry - Selected Data for Molecular Biology  
(The Chemical Rubber Co., Cleveland, 1968) (See also 2nd edition, 1970)

This compendium contains the following twenty-three tables of thermo-chemical data. The same tables, some containing additional information are in the second edition (indicated in parentheses).

<u>Table</u>	<u>Author or Source</u>
Coefficients of Solubility Equations of Certain Amino Acids in Water	From "The Chemistry of the Amino Acids and Proteins", C.L.A. Schmidt (editor), Charles C. Thomas Co., Springfield, IL.
Solubility data for 34 amino acids are fit to equations giving the solubility as a function of temperature.	
Heat Capacities, Absolute Entropies, and Entropies of Formation of Amino Acids and Related Compounds	J. O. Hutchens
Cp°, S°, and $\Delta S^\circ$ at 25°C are tabulated for 28 amino acids, 3 peptides, 4 proteins, and 3 related substances.	
Heats of Combustion, Enthalpy and Free Energy of Formation of Amino Acids and Related Compounds	J. O. Hutchens
Enthalpies of combustion and formation and Gibbs energies of formation at 25°C are tabulated for 45 amino acids and related compounds.	
Solubilities of Amino Acids in Water at Various Temperatures	J. O. Hutchens and E. P. Kirby Hade, Jr.
The solubilities of 18 amino acids are tabulated at four different temperatures from 1 to 40°C.	
Heats of Solution of Amino Acids in Aqueous Solution at 25°C	J. O. Hutchens
The heats of solution for 37 amino acids at 25°C are tabulated.	
Free Energies of Solution and Standard Free Energies of Formation of Amino Acids in Aqueous Solution at 25°C.	J. O. Hutchens
Gibbs energies of solution and formation at 25°C are given for 18 amino acids.	

Activities of Amino Acids and  
Peptides at 25°C

J. O. Hutchens

Molal activity coefficients at 25°C are tabulated as a function of molality for 14 amino acids.

---

Solubility of Fatty Acids in Water

from K. S. Markley, "Fatty Acids-Part I", 2nd edition, Interscience, New York (1960)

The solubilities of 13 fatty acids in water at five temperatures from 0 to 60°C are tabulated.

---

Approximate Solubilities of Water in Saturated Fatty Acids at Various Temperatures

from K. S. Markley, "Fatty Acids-Part I", 2nd edition, Interscience, New York (1960)

The approximate solubilities of water in thirteen saturated fatty acids at various temperatures is given.

---

Solubilities of Simple Saturated Triglycerides

from K. S. Markley, "Fatty Acids-Part I", 2nd edition, Interscience, New York (1960)

Tabulated are solubilities of five saturated triglycerides in various non-aqueous solvents and at a variety of temperatures.

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Solubilities of Mixed Triacid Triglycerides at 25°C

from K. S. Markley, "Fatty Acids-Part I", 2nd edition, Interscience, New York (1960)

---

Oxidation-Reduction Potentials, Absorbance Bands and Molar Absorbance of Compounds Used in Biochemical Studies

P. A. Loach

Oxidation-reduction potentials at ambient temperatures for an assortment of 253 couples frequently encountered in biochemical studies are tabulated with appropriate references.

---

Oxidation-Reduction Potentials of Hemoproteins and Metalloporphyrins

R. W. Henderson and T. C. Morton

Tabulated are oxidation-reduction potentials for 241 (282) hemoproteins and metalloporphyrins at assorted temperatures.

Heats of Proton Ionization and  
Related Thermodynamic Quantities

R. M. Izatt and J. J. Christensen

This section is an extensive tabulation of enthalpy and entropy changes and pK values for organic and biochemical systems with 323 (418) references to the literature.

---

Calorimetric  $\Delta H$  Values Accompanying  
Conformational Changes of Macromolecules  
in Solution

G. C. Krescheck

Tabulated are  $\Delta H$  values accompanying the conformation changes of 25 macromolecular systems.

---

Free Energies of Hydrolysis and  
Decarboxylation

W. P. Jencks

A discussion is given of standard states appropriate to biochemical thermodynamics. Tabulated are Gibbs energies of hydrolysis of esters of acetic acids and related compounds, of thiol esters, amides, phosphates, and of glycolysis (and of decarboxylation).

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Ionization Constants of Acids and Bases

W. P. Jencks and J. Regenstein

Given is an extensive tabulation of pK values for ionization of several hundred acids and bases with 116 (117) references to the literature.

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Measurement of pH

R. G. Bates

Buffer Solutions

R. G. Bates

pH values have been assigned to several important buffer systems.

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Properties of Some New Buffers for  
Biological Research

Good, Winget, Winter, Connolly,  
Izawa, and Singh, *Biochemistry*,  
5, 472 (1966)

Tabulated are pK values with temperature coefficients and metal-buffer binding constants for several buffers useful for biological research.

---

Stephen, H. and Stephen, T.

II

Solubilities of Inorganic and Organic Compounds (in five volumes)  
(Pergammon Press, Oxford, 1963)

This series of five volumes (circa 5500 pages) is a selection from the literature of data on the solubilities of elements, inorganic compounds, and organic compounds in binary, ternary, and multi-component systems. References are given to sources of data in the literature.

The data are unevaluated.

Stull, D. R., Westrum, E. F., and Sinke, G. C.

II

The Chemical Thermodynamics of Organic Compounds  
(John Wiley and Sons, Inc., New York, London, Sydney, Toronto, 1969)

This monograph is divided into three parts. The first part gives theoretical basis and principles of thermodynamics and thermochemistry, some experimental and computational methods used, and some applications to industrial problems. The second part gives thermal and thermochemical properties in the ideal gas state from 298 to 1000 K. In this section, the sources of data are listed and discussed and standardized tables are presented for 918 organic compounds. Values of  $C_p^\circ$ ,  $S^\circ$ ,  $-(G - H_{298}^\circ)/T$ ,  $H^\circ - H_{298}^\circ$ ,  $\Delta H_f^\circ$ ,  $\Delta G_f^\circ$ , and  $\log K_p$  are given at 100 K intervals. In the third section are listed selected values of enthalpy of formation, entropy, and consistent values of  $\Delta G_f^\circ$  and  $\log K_p$  of organic compounds at 298 K. In excess of 4000 compounds are listed. A very few inorganic compounds are also found in this book. A chapter very briefly discusses methods of estimating thermodynamic quantities.

Rules and Methods for Calculating the Physico-chemical Properties  
of Paraffinic Hydrocarbons

(Translated from the Russian by M. F. Mullins and edited by B. P. Mullins)  
(Pergamon Press, New York, Oxford, London, Paris, 1961)

This monograph is a summary and a consolidation of the results of some years of work by Tatevskii and others, extending and elaborating some procedures introduced by Rossini and others. It suffers from ambiguity of statement which is somewhat distracting, but the methods presented in it have been attracting increasing attention recently. Properties calculated include: molar volume, molar refraction, vapor pressure, enthalpy of formation from atoms or elements, Gibbs energy of formation, and enthalpy of combustion. Three different methods are used. Tables of constants and illustrations of the accuracy of the methods are given.

Wagman, D. D., Evans, W. H., Parker, V. B., and (in various individual parts) Halow, I., Bailey, S. M., Schumm, R. H., Churney, K. L. II

Selected Values of Chemical Thermodynamic Properties  
National Bureau of Standards Technical Note 270, October 1965 (and continuing)  
(U.S. Government Printing Office, Washington, DC 20402)

This technical note is a revision of NBS Circular 500 Part I (see above) and is issued in parts as segments of the work relating to selected sequences of elements are completed. The following parts had been issued as of 1974.

270-1 Tables for the first twenty-three elements in the standard order of arrangement

270-2 Tables for elements 24-32--elements in the standard order of arrangement

270-3 Tables for the first thirty-four elements in the standard order of arrangement. This table includes thermochemical data for compounds containing one or two carbon atoms.

270-4 Tables for elements 35-53 in the standard order of arrangement.

270-5 Tables for elements 54-61 in the standard order of arrangement.

270-6 Tables for the alkaline earth elements, elements 92-97 in the standard order of arrangement.

270-7 Tables for the Lanthanide (Rare Earth) elements, elements 62 through 76 in the standard order of arrangement.

The remaining elements will be covered in two or three additional parts to appear over a period of about two years. Documentation and references have not yet been issued.

This is the most comprehensive recent compilation in English of critically evaluated thermochemical data at 298.15 K for inorganic substances. All

inorganic substances and organic substances containing two carbon atoms or fewer per molecule are included if thermodynamic data exist for calculating any of the properties tabulated. The coverage when complete will be approximately 12,000 substances. Properties tabulated are  $\Delta H_{f0}^{\circ}$ ,  $\Delta H_{f298}^{\circ}$ ,  $\Delta G_{f298}^{\circ}$ ,  $H_{298.15}^{\circ} - H_0^{\circ}$ ,  $S_{298}^{\circ}$ ,  $Cp_{298.15}^{\circ}$ . The data from original sources have been critically evaluated by competent thermochemists and best values selected for the functions tabulated, maintaining internal consistency by the relationships  $\Delta G_{f298}^{\circ} = \Delta H_{f298}^{\circ} - T\Delta S_{f298}^{\circ}$ , and  $\Delta H_{f298}^{\circ} - \Delta H_{f0}^{\circ} = \Sigma(H_{298}^{\circ} - H_0^{\circ})$ .



Bulletin of Thermodynamics and Thermochemistry  
(University of Michigan, Ann Arbor, Michigan)

The 16th annual issue appeared in 1973. The Bulletin is a current awareness bibliography of articles that pertain to thermodynamics and thermochemistry. The Bulletin is presently divided into sections on inorganic systems, organic systems, organic systems (mixtures), and, since 1971, biological and macromolecular systems. Also included are sections on work in progress at various laboratories, substance-property indexes, and bibliographies on books of interest to thermodynamicists. No data values are given.

Wilhoit, R. C. and Zwolinski, B. J.

II

Handbook on Vapor Pressures and Heats of Vaporization of Hydrocarbons and Related Compounds (API 44 - TRC)  
(Thermodynamics Research Center, Texas A and M Research Foundation, College Station, Texas, 1971)

This handbook gives subject data on 680 hydrocarbons, 95 sulfur compounds, and water from 0 to 150°C. It is indexed by compound name, and by boiling point.

Electrochemical Data. Part XIV. Osmotic Coefficients and Mean Activity Coefficients of a Series of Uni-Bivalent and Bi-Univalent Electrolytes in Aqueous Solutions at 25°C. Part XVI. Osmotic Coefficients and Mean Activity Coefficients of a Number of Uni-Trivalent and Tri-Univalent Electrolytes in Aqueous Solution at 25°C.

(National Bureau of Standards Reports No. 10052 and 10088, U.S. Department of Commerce, 1969).

These reports give values for the osmotic and mean activity coefficients of uni-bivalent, bi-univalent, uni-trivalent, and tri-univalent electrolytes in aqueous solution at 25°C. In each case, the values tabulated are those calculated by fitting the literature data to the equation for the excess Gibbs energy, and represents the best fit to the experimental data. Literature references are included.

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