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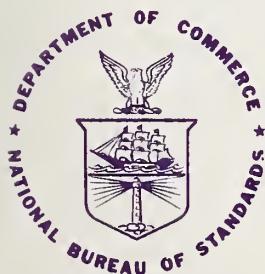
A Selected and Annotated Bibliography of Compilations of Data Relevant to Biochemical Thermodynamics

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

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Final



DEPARTMENT OF COMMERCE
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NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

Table of Contents

	page
Introduction.	1
Bibliography.	3
Author Index.	62
Subject Index	64

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 ΔH , ΔG , and ΔS for various stages of complex formation are usually listed for processes in aqueous solution. ΔH_f° , ΔG_f° , ΔS_f° 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 ΔH_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 ΔH_f° , S° , C_p° , 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
 ΔH_f° and S° 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 con-
formations are included. Examples are given comparing calculated and
observed values. Agreements of 1 kcal mol⁻¹ or less in ΔH_f° and 1 cal
mol⁻¹ K⁻¹ or less in C_p° and S° 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 (ΔH_f° , ΔG_f° , S° , and C_p°) for ~ 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) ΔH° and ΔG° 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 α -1,4 and α -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, $\log K$, ΔS , and ΔC_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 ΔH 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.

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.

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.

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 ($\log K$, ΔH , ΔS , and ΔC_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° 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° 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.

Long, Cyril (editor)

I

Biochemists Handbook

(D. Van Nostrand Co., Princeton, New Jersey, 1961)

This reference book contains several tables of thermochemical data:

"pH and Acid-Base Equilibria" S. P. Datta and A. K. Grzybowski

This chapter contains a discussion of pH scales and the electrometric measurement of pH, tables of assigned pH values for various buffered solutions, and tables (~600 entries) of thermodynamic acid dissociation constants of weak organic acids (some as a function of temperature).

"Free Energy Data and Oxidation-Reduction Potentials" K. Burton

This chapter contains some revisions and additions to Burton's earlier tables (see, in this bibliography, the book by Krebs and Kornberg).

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.

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.

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. ΔH and ΔS 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 λ_{ij} for Isothermal Vector Transport Processes in Binary Electrolyte Systems. II. Ionic Coefficients λ_{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 (λ_{ij} 's) to experimentally measurable quantities for electrolytes in a neutral solvent. λ_{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}° , 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 (~ 200 systems) as well as values of the partial molal volumes of the more common inorganic and organic ions (~ 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 ΔH_f , ΔG_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°) 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 ΔH_{f0}° , ΔH_{f298}° , ΔG_{f298}° , $\log K_f$, S_{298}° , and C_{p298}° . 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 kcal mol^{-1} and 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
--	----------------

C_p° , S° , and ΔS° 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
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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.

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 ΔH Values Accompanying
Conformational Changes of Macromolecules
in Solution

G. C. Krescheck

Tabulated are ΔH 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).

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.

Measurement of pH

R. G. Bates

Buffer Solutions

R. G. Bates

pH values have been assigned to several important buffer systems.

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° , S° , $-(G - H_{298}^\circ)/T$, $H^\circ - H_{298}^\circ$, ΔH_f° , ΔG_f° , 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 ΔG_f° 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 ΔH_{f0}° , ΔH_{f298}° , ΔG_{f298}° , $H_{298.15}^{\circ} - H_0^{\circ}$, S_{298}° , $Cp_{298.15}^{\circ}$. 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.

Author Index

	page		page
Ackermann, T.	9	Domalski, E. S.	3,16
Aikens, S.	33	Ebert, J. P.	46
Alberty, R. A.	4	Evans, W. H.	47,57
Andrussow, K.	25	Florkin, M.	17
Armstrong, G. T.	3	Fox, D.	18
Arnett, R. L.	45	Furukawa, G. T.	3
Ashcroft, S. J.	5	George, P.	42
Atkinson, M. R.	17	Golden, D. M.	7
Bailey, S. M.	57	Good, N. E.	53
Bates, R. G.	33,53	Grzybowski, A. K.	32
Beckett, C. W.	46	Hade, K.	51
Benderskii, V. A.	56	Halow, I.	57
Benson, S. W.	6,7	Hamer, W. J.	19,61
Bondi, A.	8	Harned, H. S.	20
Bowers, V. E.	33	Haugen, G. R.	7
Brown, H. D.	9	Henderson, R. W.	52
Brown, G. W.	17	Hepler, L. G.	28
Brown, R. M.	45	Hutchens, J. O.	51
Burton, K	26,32	Izatt, R. M.	11,21,53
Cabib, E.	17	Izawa, S.	53
Cardini, C. E.	17	Jaffe, I.	47
Chapman, T. W.	10	Janz, G. J.	22
Christensen, J. J.	11,21,53	Jencks, W. P.	53
Churney, K. L.	57	Jordan, T. E.	23
Clark, W. M.	12	Joshi, R. M.	24
Cohen, P. O.	17	Kilpatrick, J. E.	46
Connolly, T. N.	53	Kornberg, H. L.	26
Conway, B. E.	13	Kortum, G.	25
Cox, J. D.	15	Krebs, H. A.	26
Cruickshank, F. R.	7	Krescheck, G. C.	53
Datta, S. P.	32	Labes, M. M.	18

	page		page
Lange, E.	27	Reilly, M. L.	33
Larson, J. W.	28	Robinson, R. A.	44
Latimer, W. M.	29	Rogers, A. S.	7
Lax, E.	48	Rossini, F. D.	45,46,47
Leloir, L. F.	17	Rutman, R. J.	42
Levine, S.	47	Rytting, J. H.	21
Linke, W. F.	31	Schafer, D.	48
Loach, P. A.	52	Schmidt, C. L. A.	51
Long, C.	32	Schumm, R. H.	57
Markley, K. S.	52	Shaw, R.	7
Martell, A. E.	49	Sherwood, T. K.	43
Mason, H.	17	Sillen, L. G.	49
McCullough, J. P.	18	Singh, R. M. M.	53
Meites	33	Sinke, G. H.	55
Merrill, A. L.	34	Sober, H. A.	51
Miller, D. G.	35	Stephen, H.	54
Millero, F. J.	36	Stephen, T.	54
Mischenko, K. P.	37	Stokes, R. H.	44
Mortimer, C. T.	5	Stull, D. R.	55
Morton, T. C.	17,52	Takahashi, K.	9
Newman, J.	10	Tatevskii, V. M.	56
Ono, S.	9	Taylor, W. J.	46
O'Neal, H. E.	7	Vogel, W.	25
Owen, B. B.	20	Wagman, D. D.	47,57
Parker, V. B.	38,57	Walsh, R.	7
Pauling, L.	39	Watt, B. K.	34
Perrin, D. D.	40,41	Weissberger, A.	18
Phillips, R. G.	42	Werner, H. C.	46
Pilcher, G.	15	Westrum, E. F.	18,55,59
Pimentel, G. C.	45	Wilhoit, R. C.	3,9,60
Pitzer, K. S.	45,46	Williams, M. D.	46
Poltoratzkii, G. M.	37	Winget, G. D.	53
Regenstein, J.	53	Winter, W.	53
Reid, R. C.	43	Wu, Y. C.	19,61
Reilly, C. N.	33	Yarovoi, S. S.	56
		Zwolinski, B. J.	24,60

Subject Index

Subject	Page
acetic acid esters	
hydrolysis	53
acid constants	50
see also equilibrium constants	
acids, inorganic	
ionization	28, 33
thermodynamics in water and nonaqueous solvents	37
neutralization enthalpies	38
dissociation constants	40, 49, 53
acids, organic	
vapor pressures	23
dissociation constants	25, 32, 33, 49, 53
ionization	28
hydrolysis of esters	53
decarboxylation	53
acids, strong	44
activation energies	
polymerization	24
activity coefficients	
inorganic electrolytes	10, 13, 19, 20, 44
organic electrolytes	13, 19, 20, 44
strong electrolytes	29, 44
amino acids	52
peptides	52
uni-polyvalent electrolytes	61
adenosine-5'-diphosphate	4, 9, 42
adenosine-5'-triphosphate	4, 9, 12
albumin	13, 50
alcohols	
vapor pressures	23
Gibbs energy changes	26
aldehydes	
vapor pressures	23
alicyclic organic bases	
dissociation constants	41

Subject	Page
aliphatic organic bases dissociation constants	41
alkali metal salts thermodynamics of solutions	38
amides hydrolysis	53
amino acids	
ionization thermodynamics	28
solubilities	51
heat capacities, entropies	51
entropies and enthalpies of formation	51
enthalpies of combustion	51
enthalpies of solution	51
Gibbs energy of formation	51
Gibbs energy of solution	51
Gibbs energy of formation in solution	51
activities	51
ammonia metabolism	17
ammonium ions	
acid ionization thermodynamics	28
thermodynamics	38
anilines redox potentials	12
anilinum ions acid ionization thermodynamics	28
aqueous electrolytes	10, 37
aromatic organic bases dissociation constants	41
barbituric acids ionization thermodynamics	28
base constants	50
see also equilibrium constants	
bases	
see also acids	
inorganic	33, 37, 40, 53
organic	33, 41, 53
thermodynamics in aqueous and non-aqueous solvents	37
binary systems solubilities in	54

Subject	Page
binding constants (see also equilibrium constants) metal-buffer complexes	53
biochemical pathways	26
biosynthesis Gibbs energy changes	17
boiling point estimation organic compounds	43 60
bond energy	5, 6, 22, 39
buffer solutions	13, 32, 53
carbohydrates isomerization and hydrolysis	9
carboxylic acids (see acids, organic)	
chemical potential aqueous electrolytes	44
C,H,N,O,P,S compounds	3, 16
colloids transport properties	13
combustion energy	3, 15, 16, 34
complexes, metal-ligand organic ligands inorganic ligands	5, 11, 49 5, 11, 49
compressibility, estimation	8, 43
conductance aqueous electrolytes	13, 20, 44
conductivity, thermal estimation	8, 43
consecutive reactions equilibria in	49
correlations of thermodynamic data	4, 5, 6, 7, 8, 24, 43, 45, 46
creatine heat capacity, entropy, entropy of formation enthalpy of combustion and formation Gibbs energy of formation	51 51 51 51

Subject	Page
creatine	51
heat capacity, entropy	51
entropy of formation	51
enthalpy of combustion and formation	51
Gibbs energy of formation	51
critical constants, estimation	43
density	
estimation	8, 43
inorganic electrolytes	10, 13, 20
organic electrolytes	20
deoxyribonucleic acid	21, 50
dielectric constants	
aqueous electrolyte solutions	13
solvents	13
diffusion constants	
estimation	8, 43
inorganic electrolytes	10, 13, 20, 44
organic electrolytes	13, 20, 44
dilution, enthalpy of	26
dipole moments	13
dissociation constants	
aqueous electrolytes	13, 20
organic acids, aqueous	25, 32
inorganic acids and bases	40
organic bases	41
ligands	49
dyes and indicators bases	
dissociation constants	41
electrochemical data	13
oxidation-reduction potentials	12
electrochemical potentials	
biological oxidation-reduction reactions	26
vs pH	29
in organic solvents	44
electrode processes	14

Subject	Page
electrolytes	10, 13, 20, 44
aqueous and non-aqueous	37
uni-univalent	19, 38
uni-polyvalent	61
molar volumes	36
irreversible thermodynamics	35
equilibrium constants of	5, 11, 21, 25, 26, 28, 32, 33, 40, 41, 49, 51
Gibbs energies, enthalpies, heat capacities, and entropies	5, 11, 21, 26, 28, 47, 57
dilution of	27, 57
oxidation-reduction potentials	12, 26, 29, 49
solubilities	31, 51, 54
electron affinities	
of elements	29
elements	
solubilities	54
thermodynamic properties	57
energy transformations in living matter	26
energy values of foods	34
enthalpy	
estimation	8, 22
partial molal	13
apparent molal	20
enthalpies of salts, acids and bases vs. T and concentration in water, and organic solvents	37
hydrocarbons	45, 46
inorganic compounds	47, 48, 57
organic compounds	47, 48, 55, 57
enthalpy change	3, 4, 5, 9
of phase changes	47, 48
of fusion, estimation	8
of formation	3, 5, 6, 7, 9, 15, 16, 22, 24, 29, 37, 45, 46, 47, 48, 51, 55, 57
of dilution	3, 27, 38, 47, 57
of complex formation	11, 21
of sublimation	8
of vaporization	15, 24, 45, 46, 47, 60
of combustion	16, 22, 34, 45, 46, 51
of protonation of nucleic acids, nucleotides and nucleosides	21
of polymerization	24
of ionization	28, 37, 38, 53
of vaporization	15
of vaporization, estimation	43
of formation, estimation	43, 48, 56

Subject	Page
enthalpy change (continued)	
conformational change of macromolecules	53
of combustion (estimation)	56
entropy	3, 6, 7, 9
estimation	6, 7, 8, 22, 30
inorganic substances, various oxidation states	29
dissolved acids, salts, bases in water and non-aqueous solvents	37
hydrocarbons	45, 46
inorganic compounds	47, 48, 57
organic compounds	47, 48, 55, 57
amino acids and related compounds	51
entropy change	4, 5
of fusion	18
of fusion, estimates	8
of formation	5, 51
of dilution	3
of solution	3, 37
of complex formation	11, 21
of protonation of nucleic acids, nucleotides, and nucleosides	21
of polymerization	24
of ionization	28, 37, 53
enzyme catalyzed reactions	9, 26, 51
equation of state	
estimation of	43
equilibrium constants	
metal ion-ligand	11, 21, 33
protonation of nucleic acids, nucleotides, and nucleosides	21
of polymerization	24
acid-base	32
proton transfer reactions	33
of formation	47, 57, 55
esters	
vapor pressures	23
Gibbs energies of hydrolysis	53
estimates, bond energy	5, 6, 7
estimation, properties (various kinds)	8, 15, 22, 30, 43, 55, 56
ethanol as solvent	
thermodynamic properties of acids, bases salts in	37

Subject	Page
ethanol-water mixtures acid dissociation in	33
expansion coefficient, thermal estimation	8
fatty acids solubilities	52
fermentation Gibbs energy change	26
food and foodstuff ingredients composition and energy values	34
free energy - see Gibbs energy	
gases	
thermodynamic functions	55
polar properties, estimation	8, 43
non-polar, properties estimation	8, 43
Gibbs energy - see also chemical potential	
estimation	22
biological systems	32
hydrocarbons	45, 46
organic compounds	55
Gibbs energy change	3, 5, 9
of formation	3, 5, 9, 26, 29, 37, 45, 46, 47, 48, 51, 55, 57
of dilution	3, 37
of solution	3, 37, 51
phosphates hydrolysis	4, 17, 42
metabolic processes	17, 26, 32
biosynthesis of saccharides	17
urea biosynthesis	17
ammonia metabolism	17
of polymerization	24
biological oxidation-reduction reactions	26, 32
tricarboxylic acid cycle	26
fermentation	26
glycolysis	26
of ionization	28, 37
of formation (estimation)	43, 48, 56
of hydrolysis	53
of decarboxylation	53

Subject	Page
glasses - see solids	
glucose	
partial molal properties	9
glucosides	
hydrolysis	9
glycerol	
partial molal properties	9
glycine	
partial molal properties	9
glycolysis	26
glycosides	
hydrolysis	53
group contributions	6, 7, 22, 48
half-cell potentials	13
halogen compounds, organic	6
heat capacity	9
C,H,N,O,P,S compounds	3
estimation	6, 7, 8, 22, 43
dissolved acids, salts, bases in water	
and non-aqueous solvents	37
uni-univalent electrolytes	38
hydrocarbons	45, 46
inorganic compounds	47, 48, 57
organic compounds	47, 48, 55, 57
amino acids and related compounds	51
heat capacity change	
of complex formation	11, 21
of protonation of nucleic acids, nucleotides,	
and nucleosides	21
of ionization	28
heat content - see enthalpy	
heat of formation - see enthalpy changes of formation	
helix-random coil transition	9
hemoglobin	
mobility	13

Subject	Page
hemoproteins	
oxidation-reduction potentials	52
heterocyclic organic bases	
dissociation constants	41
hydrocarbons	6, 23, 45, 56, 60
hydrogen ion concentration	4, 17
hydrolysis	4, 9, 26
of ATP, ADP	42
metal ion hydrates	49
hydroxyl ion	
as a ligand	40, 49
index, substance-property	59
indicator bases	
dissociation constants	41
inorganic	
ligands - see ligands	
electrolytes	10, 13, 29, 36, 38, 44, 47, 57
inorganic compounds	13
oxidation states thermodynamics	29
solubilities	31, 54
thermodynamic properties	47, 48, 57
current awareness bibliography	59
chemical bonding	39
inorganic ligands - see ligands	
instability constants - see equilibrium constants	
insulin	50
interface potentials	13
intermolecular forces	
estimation	43
ionic strength, effects	21, 33, 42
ionic transport coefficients	35
ionization	
aqueous acids	28, 33

Subject	Page
ionization constants	
organic acids	44
acids and bases	53
ionization potentials	
elements	29
irreversible thermodynamics	35
isomerization	
carbohydrates	9
ketones	
vapor pressures	23
Kp - equilibria involving gases	50
Lennard-Jones potential - see intermolecular forces	
ligands	5, 11, 33, 49
liquids	
properties estimation	8, 43
liquid-junction potentials	13
macromolecules	
helix-random coil transitions	9
transport properties	13
as ligands	50
current awareness bibliography	59
magnesium ion (effects)	4, 17, 42
metabolic processes	26
metal complexes	5, 6, 11, 33, 49
hydrated ions	40
with nucleic acids, nucleotides, and nucleosides	21
with buffers	53
metalloporphyrins	
oxidation-reduction potentials	52
metal-organic compounds	
solubilities	31
thermodynamic properties	6, 15, 23

Subject	Page
methanol as solvent thermodynamic properties of salts, acids, and bases in	37
methanol-water mixtures acid dissociation in	33
mixed electrolytes	44
mixed solvent systems	3, 33
mixtures, fluid estimation of properties current awareness bibliography	43 59
mobilities ionic proteins	13 13
modulus bulk, estimation Young's, estimation	8 8
molar volume - see volume	
multi-component systems solubilities in	54
NAD redox potentials	12
NADP redox potentials	12
natural product bases dissociation constants	41
nitrogen compounds, organic	6
non-aqueous solvents solubilities in electrolytes in metal-ligand complexes in	31 37 49
non-polar gases - see gases	

Subject	Page
nucleic acids	50
nucleosides	21
nucleotides	21
nutrients - see foods	
organic bases	
dissociation constants	41
organic compounds	6, 7, 13, 15, 16, 18, 22, 24, 25, 36, 48, 55
C ₂ or C ₁	47, 57
solubilities	53
current awareness bibliography	59
organic electrolytes	
molar volumes	36
thermodynamic quantities	38
properties	44
organic ligands - see ligands	
organo-metallic compounds - see metal-organic compounds	
osmotic coefficients	
inorganic electrolytes	13, 19, 44
organic electrolytes	13, 19, 44
uni-polyvalent electrolytes	61
oxidation-reduction potentials	
organic systems	12
compounds of the elements	29
biological systems	26, 32
metal-ligand complexes	49
selected	52
hemoproteins and metalloporphyrins	52
oxygen compounds, organic	6
partial molar volumes - see volume	
peptides	
heat capacities, entropies	51
enthalpy of combustion and formation	51
Gibbs energy of formation	51
activities in aqueous solution	51

Subject	Page
pH	
effects on reactions	4, 17, 21
effect on oxidation-reduction potentials	29
acid-base equilibria	32
ATP hydrolysis	42
of buffers	53
phenols	
redox potentials	12
vapor pressures	23
acid dissociation constants, aqueous	25
ionization thermodynamics	28
phosphates	
Gibbs energy and biosynthesis	17
hydrolysis	53
physiological energy use	34
pK values	
acids and bases	33, 40, 53
buffers	53
polar gases - see gases	
polymers	
properties estimation	8
polymerization processes	24
porphyrins	
redox potentials	12
potential diagrams (emf)	
elements and compounds	29
pressure, effect of	
on enthalpy, entropy, internal energy, heat capacity, estimation	43
proteins	
heat capacities, entropies	51
proton transfer reactions	
equilibrium constants	33
quinones	12
redox potentials	12
rate constants	
polymerization	24

Subject	Page
red cells	
mobilities	13
redox potentials - see oxidation-reduction potentials	
refraction, molar	
estimation	56
relaxation time	
estimation	8
ribonucleic acid	21, 50
saccharides	
biosynthesis and Gibbs energy	17
salts	
thermodynamic properties in water, methanol, ethanol and other organic solvents	37
thermodynamic properties of uni-univalent in solution	38
serum albumin	
mobility	13
silver salts	
thermodynamic properties of solutions	38
solids	
crystalline, properties estimation	8
glasses, properties estimation	8
solubilities	13, 31
amino acids	51
fatty acids in water	52
water in fatty acids	52
triglycerides	52
elements, inorganic compounds, organic compounds	54
solubility constants - see also equilibrium constants	50
stability constants - see also equilibrium constants, binding constants	
metal-ion complexes	49
statistical mechanics	22
structure, relation to physical properties	8, 22

Subject	Page
sulfur compounds, organic	6, 60
surface tension estimation	43
ternary systems solubilities in	54
thermodynamic functions of temperature	7
C,H,N,O,P,S compounds	3
organic compounds	18, 48, 55
hydrocarbons	45, 46
inorganic substances	48
amino acids and related compounds	51
thiol esters hydrolysis	53
transference number	
inorganic electrolytes	10, 13, 20
organic electrolytes	13, 20
transition metal complexes - see metal complexes	
transition temperatures	
inorganic substances	47
organic compounds C ₁ and C ₂	47
transport coefficients, ionic	34, 35, 44
tricarboxylic acid cycle Gibbs energy changes	26
triglycerides solubilities	52
urea	51
partial molal properties	9
biosynthesis	17
enthalpy of formation and combustion	51
Gibbs energy of formation	51
vapor pressure	
C,H,N,O,P,S compounds	3
estimation	8, 43, 56
aqueous electrolyte solutions	13
organic compounds	3, 18, 23, 60
water	60

Subject	Page
vibrational assignments (estimation method)	22
viscosity	
estimation	8, 43
inorganic electrolytes	10
volumes, molar	
aqueous ions and electrolytes	36
liquids, estimation	43
hydrocarbons, estimation	56
water	
vapor pressure and enthalpy of vaporization	60
Wiswesser Line Notation	
organic compounds	16

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