NATIONAL ACADEMY OF SCIENCES

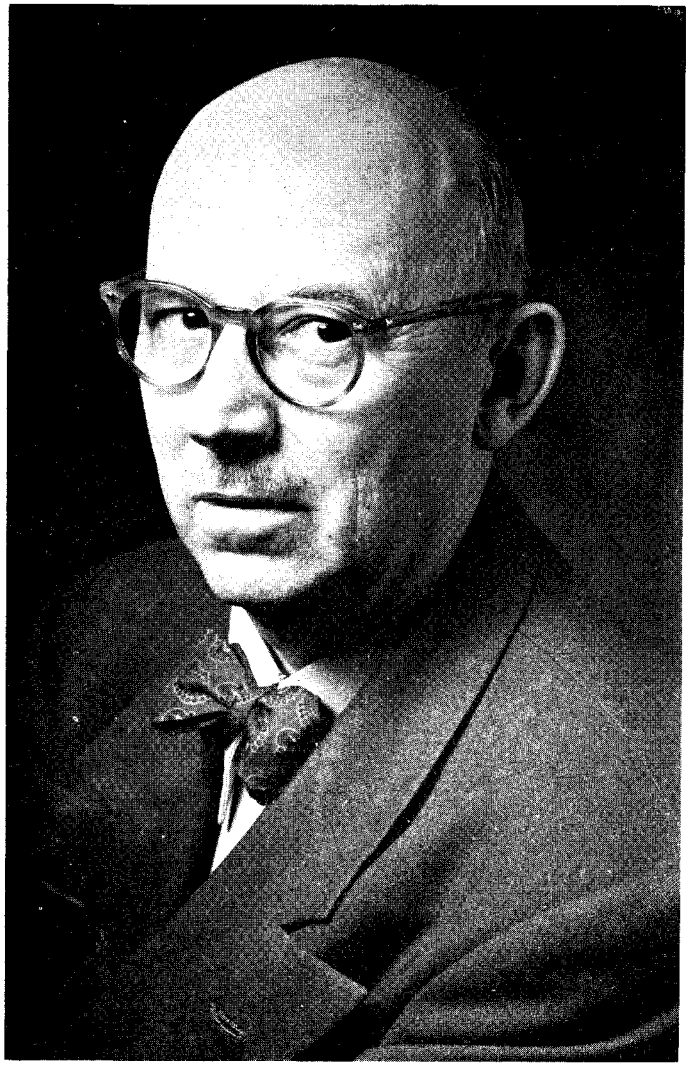
WENDELL MITCHELL LATIMER

1893—1955

A Biographical Memoir by

JOEL H. HILDEBRAND

Biographical Memoir



Howard M. Latimer

WENDELL MITCHELL LATIMER

April 22, 1893—July 6, 1955

BY JOEL H. HILDEBRAND

AMONG THE PAPERS in the files of Wendell Mitchell Latimer, there was found an autobiographical account of his earlier years that is so interesting and so revealing of the influences that shaped his career that it is here reproduced *in toto:*

"I am the tenth generation from Robert Latimer, a retired sea captain, who settled at New London, Connecticut, about 1660. I am a member of the Society of Mayflower Descendants from the Reverend Brewster, whose granddaughter married a Latimer. My great-great-grandfather, Colonel Jonathan Latimer, commanded the Third Connecticut Volunteers at the Battle of Saratoga. After the war he and his seven sons migrated to Tennessee. My great-grandfather, Alexander Latimer went with the Rutledges from Tennessee to Illinois at the time of the founding of New Salem, Illinois. Soon after he introduced Abraham Lincoln to Ann Rutledge. Lincoln wrote a letter to my grandfather at the time of her death. Unfortunately this letter, a family treasure, was destroyed in the Chicago fire.

"My maternal grandmother, Nancy Cook, migrated from Nashua, New Hampshire, with her sister in the eighteen fifties to Lawrence, Kansas to 'save Kansas for the free states.' My maternal grandfather, Milton Mitchell, had gone to California by way of Panama from Ohio during the Gold Rush, 1849–1850. He returned overland in 1860 and met my grandmother on the trip home. He served in the

Ohio Artillery for the four years of the Civil War and rose to the rank of Captain. After the war, he and my grandmother were married and homesteaded in eastern Kansas. My mother was born there in a log cabin in 1867.

"My father was born in Knox County, Illinois, and went to Garnett, Kansas, to take over the management of a bank in that city about the year 1886. There he met and married my mother. I was born in Garnett on April 22, 1893. When I was three years of age, we moved to Kansas City where my father was engaged in the banking and brokerage business. We lived in the Quindaro District, and I attended Hawthorne Elementary School.

"My early years were extremely happy. I had a pony and cart of my own, and the family had several teams of horses and carriages for excursions about the city. In the summers we took many long trips. I recall those to New England, Northern Michigan, Colorado, and to the Buffalo, New York Exposition.

"When I was eight my father contracted typhoid fever and died. My mother was left with rather meager funds. She and I spent one winter with an uncle near Abingdon, Illinois, and then we went to live with my grandfather on a farm near Greely, Kansas. From ten to fifteen years, I lived the life of a typical farm boy. I attended school in Greely, but at the end of my first year of high school my mother decided that I should attend the Garnett High School, which was distinctly better. Since Garnett was some ten miles away, this meant that I took a room in Garnett and came home week ends.

"The principal of the Garnett High School was Mr. C. H. Oman, a man of high standards and of excellent administrative ability. He had a fine staff of teachers, and the quality of the instruction was superior to that given in most small schools. I was a member of the debating team and competed in the interclass track meets, but without much success in the latter.

"In 1911 I entered the University of Kansas. I worked on a good many odd jobs to help pay expenses and finally got the job of looking after the University Weather Bureau. The hours were bad, and three

times a day I had to climb to the top of the highest building for wind velocity measurements. It was, nevertheless, one of the prized jobs of the university and included attending the university seismograph.

"I entered the university with a pre-legal course in mind, and during the first two years was active in the debating clubs. However, I became disgusted with the methods which one had to use to win debates; logic counted for little as against the technique of building straw men and tearing them down with irony and sarcasm. I had taken considerable mathematics and since I had done well in these courses, I decided to change to a major in mathematics. In the summer session following my sophomore year, I had my first course in chemistry, and in my last two years I completed majors in both mathematics and chemistry.

"The summer of 1912 I spent in the Pacus Valley of New Mexico. I worked for a time in the melon fields, and then I signed up with a crew driving a bunch of steers from Artesia, New Mexico, up over the Caprock to Plainview, Texas. This was one of the last remaining bits of open range country, and my experiences with the cowboys on that trip have provided many rich memories. On the return trip I rode one hundred miles in a twenty-four hour interval.

"I received the A. B. degree in 1915 and remained at the Unversity of Kansas for two years as an assistant instructor in chemistry. In view of the fact that I had started my scientific studies so late, these additional years enabled me to build up a background in both chemistry and physics. I carried out a research program on the dielectric constant of ammonia up to its critical temperature. This work was under Professor H. P. Cady, an inspiring teacher with a truly great mind.

"In the summer of 1916 I attended the University of Chicago and took two courses with Professor Harkins. At this time Harkins was thinking a lot about the nucleus, and I found his lectures most stimulating.

"Professor G. N. Lewis offered me a fellowship at the University of California in 1917. I received the Ph. D. degree there in 1919,

working under the direction of Professor G. E. Gibson. In 1918, when most of the staff were in France, I gave the freshman lectures. I probably should credit my debating experience for having been picked from the graduate student group to give these lectures.

"The years following the war were most exciting at Berkeley, and I was most happy to be asked to remain as a member of the staff. Dr. Gibson had translated Sackur's book on thermodynamics and probably had as clear a concept of entropy as anyone in the world. I owe much to him for my start in thermodynamics.

"I believe that I was the first to grasp the importance of the entropies of aqueous ions. These values have enabled us to use thermal data to calculate free energies and thus to give a thermodynamic treatment of most inorganic reactions. When I started this program, there was not a single ionic entropy known. With the assistance of an excellent group of graduate students over a period of thirty years, I have determined values for practically all of the stable inorganic aqueous ions. The theoretical interpretation of the ionic values has been significant in the general theory of strong electrolytes.

"One of the most useful applications of the large amount of data which I have accumulated on aqueous solutions was the preparation of extensive tables of oxidation-reduction potentials and of potential diagrams, relating the various oxidation states of every element. These potentials have had a profound influence upon the teaching of inorganic chemistry.

"In my early paper (1920) with W. H. Rodebush, I first clearly stated the principle of hydrogen bonding, which is now so generallly accepted. In this paper Rodebush wrote the first half on the general concept of polarization, and I wrote the last half which dealt with the structural interpretation. We naturally had to get G. N. Lewis' permission to publish the paper since we used his new theory of valence, and it was only with considerable argument that I was able to keep the hydrogen-bond theory in the paper.

"About 1934 I started W. F. Libby to work on some problems of soft Beta-emitters. As a graduate student, he developed many of the techniques which later were so important in his C^{14} work. After he received his degree, Libby and I started a seminar on nuclear problems which ran for many years. We attracted quite a group of young men, including Seaborg, Kennedy, Ruben, and Wahl. Thus in 1940, our department had one of the most active groups of nuclear chemists in the world, and this fact was of considerable significance in the A-bomb and general nuclear program."

This brief autobiography gives a glimpse of the influences and inherent characteristics that combined to produce the mature man and the scientist. Like the majority of successful scientists, he acknowledges his debt to a school whose principal was "a man of high standards," and whose "fine staff of teachers" provided superior instruction. Although his participation in debating in both school and college helped to make him the effective, clear lecturer and writer that he was, his intellectual integrity was such that he "became disgusted with the methods which one had to use to win debates." He became a biting critic of sophistry.

His contacts with many different sorts of people helped to make him an excellent judge of character. For many years he selected the teaching assistants and graduate students for the department of chemistry in Berkeley, and eventually, as chairman, he added to the regular staff many of the young men who are now maintaining its high standing in both teaching and research established originally by Gilbert N. Lewis.

He was unusually forthright. He left no one in doubt about his position. When he was a graduate student, presenting something or other in Colloquium, Gilbert Lewis constantly interrupted him, finally saying, "The trouble with you is that you don't take your audience into consideration." Wendell replied: "The trouble with me is that I can't keep my audience quiet long enough to say what I have to say." Lewis let him alone after that.

While in the Southwest Pacific during the war, addressing a group of chemical officers, at the same meeting to which a C. W. general had spoken, he said: "The General has just told you what is in the manuals. I will now tell you about recent developments that lead to very different conclusions." None but the thin-skinned could be offended by such remarks, because they would be accompanied by a disarming smile.

He was a shrewd card player. On one occasion, he and Roger Adams had been playing poker with two patent attorneys. After the game one of them said to Wendell: "I have to apologize to you. When we began I thought you were just another green pea."

He was an effective, stimulating teacher. He participated freely himself in the teaching of freshmen, both as lecturer and leader of quiz and laboratory sections. He worked first with Bray and eventually with Powell in the preparation and frequent revision of the laboratory manual, *A Course in General Chemistry*. The *Reference Book of Inorganic Chemistry,* by Latimer and Hildebrand was largely his work. Editions were published in 1929, 1940, and 1951.

Latimer served well both the Department of Chemistry and the University of California. He was an instructor from 1919 to 1921, an assistant professor from 1921 to 1924, and an associate professor from 1924 to 1931, when he became a professor. He was an assistant dean of the College of Letters and Science from 1923 to 1924, dean of the College of Chemistry from 1941 to 1949, and chairman of the department from 1945 to 1949. He participated freely in the affairs of the Academic Senate, serving at different times upon such important committees as Budget and Interdepartmental Relations, Educational Policy, and the elected Committee on Committees.

He started Willard F. Libby, who worked on his thesis under Latimer's direction, on the line of work that led ultimately to Libby's appointment to the United States Atomic Energy Commission. Together they organized a seminar on nuclear chemistry, whose participants included such future stars as Seaborg, Kennedy, and Wahl. His foresight in this matter laid one of the main founda-

tions for the separation of plutonium and the trans-uranium elements, and the vast atomic energy program. From 1942 to 1946 he was director of a Manhattan (code name) Engineering District Contract on the chemistry of plutonium. He played a leading role in the chemistry program of the University of California's Radiation Laboratory throughout the period from the Second World War until his death. He was appointed in 1954 as a Consultant to the Atomic Energy Commission.

Latimer was one of the first to realize the disastrous consequences to this country if a potential enemy should first develop a thermonuclear (hydrogen) bomb. He was responsible for convincing many government officials of this fact and assisted in many ways the program which was started in 1950. Subsequent events fully confirmed his wisdom and foresight.

His war services to the nation were varied and notable. He was a member of and a Special Investigator for the National Defense Research Committee from 1941 to 1945. In 1943 he was a member of a War Department Mission to England. He was a technical observer and scientific expert at G.H.Q., South Pacific Area, in 1944.

After the war he was a member of the Chemical Corps Research Council from 1947 to 1951, of the Office of Naval Research Panel on Chemical Research from 1949 to 1950, and of the AEC Special Weapons Panel, from 1947 to 1950.

Over one hundred papers bear witness to both the quantity and the high quality of his scientific activity. The first, with W. H. Rodebush, referred to in his autobiography, although viewed at first with scepticism by Lewis, proved to be very important indeed. The special properties of the hydrogen bond set substances so bound far apart from those containing ordinary dipoles. It has recently become evident that hydrogen bonds are mainly responsible for the structure of genetic material. Pauling has said, "I believe that as the methods of structural chemistry are further applied to physiological problems it will be found that the significance of the hydrogen bond for physiology is greater than that of any other structural feature."

Most of his early investigations, begun under the inspiration of G. E. Gibson, had to do with heat capacity and entropy down to low temperatures. Soon after earning his doctorate he built the first successful hydrogen liquefier in the United States. W. F. Giauque has paid a warm tribute to Latimer's influence upon him. Lewis, Gibson, and Latimer published in 1922 a revision of the entropies of the elements.

His interest in entropy soon extended to the entropy of aqueous ions, an entirely new field, and the first paper (with R. M. Buffington) was followed by a number upon that subject. In 1936 he published a paper in *Chemical Reviews,* "The Entropy of Aqueous Ions and the Nature of the Entropy of Hydration." These studies, with his vast knowledge of inorganic reactions as a guide, led to a comprehensive correlation of thermal data, entropies, and electrode potentials, published in 1938 in the book, *The Oxidation States of the Elements and Their Potentials in Aqueous Solution.* A second edition appeared in 1952.

The value of Latimer's critical evaluations of oxidation potentials can hardly be overstated. They can be combined to predict the potentials of oxidation-reduction reactions for all the vast number of their combinations. They have taken their place as an essential part of the equipment of every competent inorganic chemist. They furnished valuable guides in working out the chemistry of the new trans-uranium elements, and were applied by Latimer in a paper, "Astrochemical Problems in the Formation of the Earth."

Scientific honors include membership in the National Academy of Sciences, and chairmanship of its Section of Chemistry from 1947 to 1950; the Distinguished Service Award from his alma mater, the University of Kansas, in 1948; the Presidential Certificate of Merit, in 1948; Faculty Research Lecture in 1953, an honor that the Academic Senate of the University of California annually bestows upon one of its members; the William H. Nichols Medal from the New York Section of the American Chemical Society, 1955, with a

citation for his "Pioneer Studies on the Thermodynamics of Electrolytes, Especially the Entropies of Ions in Aqueous Solutions."

The Proceedings of the Seventh Meeting, in Lindau, in 1955, of the International Committee of Electrochemical Thermodynamics and Kinetics, published in 1957, carry a picture of Latimer as frontispiece and a full-page tribute to his memory, asserting that his "systematic work on oxidation states and potentials constitutes the very basis of this most important phase of C.I.T.C.E. activities." Concerning his death shortly before the meetings, it added: "This untimely death constitutes a severe loss for science and for the innumerable organizations and activities to which Professor Latimer contributed so much with such very great distinction."

Latimer spent the year 1930–1931 in Munich as a Guggenheim Fellow. From 1953 to 1955 he was a member of the Committee on Electrochemistry of the Internal Union of Pure and Applied Chemistry, and was appointed the same year to represent the National Academy of Sciences at the International Congress of Pure and Applied Chemistry in Zürich.

Latimer was editor of the Prentice-Hall chemistry series and served briefly as associate editor of the *Journal of Chemical Physics* and of *Chemical Reviews.*

Latimer lost his first wife, Bertha Eichenauer, whom he had married in 1917, also their son, Walter. In 1926 he married Glatha Hatfield. Their children are Eleanor Ann Colborn and Robert M., who is following in his father's footsteps. There are two grandchildren, Diane and Robert Edgar Colburn.

His health during later years was not good and he underwent several operations. He took it all stoically, hiding pain and discomfort under an ever-present sense of humor and interest in the welfare of students and colleagues. He died in his sleep July 6, 1955, at the age of sixty-two, at a time when he had been appointed to represent the National Academy of Sciences at the Fourteenth International Congress of Pure and Applied Chemistry in Zürich.

KEY TO ABBREVIATIONS

Chem. Eng. News = Chemical and Engineering News
Chem. Rev. = Chemical Reviews
J. Am. Chem. Soc. = Journal of the American Chemical Society
J. Chem. Ed. = Journal of Chemical Education
J. Chem. Phys. = Journal of Chemical Physics
J. Electrochem. Soc. = Journal of the Electrochemical Society
J. Phys. Chem. = Journal of Physical Chemistry
Phys. Rev. = Physical Review
Z. physik. Chem. = Zeitschrift für physikalische Chemie

BIBLIOGRAPHY

Dielectric Constant of Liquid Ammonia from −40° to 110°C. Master's Thesis, University of Kansas.

1920

With W. H. Rodebush. Polarity and Ionization from the Standpoint of the Lewis Theory of Valence. J. Am. Chem. Soc., 42:1419.

With G. E. Gibson and G. S. Parks. Entropy Changes at Low Temperatures. I. Formic Acid and Urea. A Test of the Third Law of Thermodynamics. J. Am. Chem. Soc., 42:1533.

With G. E. Gibson and G. S. Parks. Entropy Changes at Low Temperatures. II. Ethyl and Propyl Alcohols and Their Equal Molal Mixture. J. Am. Chem. Soc., 42:1542.

1921

The Mass Effect in the Entropy of Solids and Gases. J. Am. Chem. Soc., 43:818.

1922

The Distribution of Thermal Energy in the Tetrachlorides of Carbon, Silicon, Titanium and Tin. J. Am. Chem. Soc., 44:90.

With G. N. Lewis and G. E. Gibson. A Revision of the Entropies of the Elements. J. Am. Chem. Soc., 44:1008.

Thermo-electric Force, the Entropy of Electrons and the Specific Heat of Metals at High Temperatures. J. Am. Chem. Soc., 44:2136.

1923

The Ionization of Salt Vapors. J. Am. Chem. Soc., 45:2803.

With W. C. Bray. A Course in General Chemistry. New York, Macmillan.

1925

With R. M. Buffington and H. R. Hoenshel. A Hydrogen Liquefying Cycle and Cryostat for the Maintenance of Low Temperatures. J. Am. Chem. Soc., 47:1571.

1926

With H. R. Hoenshel. The Heat Capacity and Entropy of Lead Bromide and Bromine. J. Am. Chem. Soc., 48:19.

The Energy of Solution of Gaseous Ions in Relation to the Effect of a Charge upon the Dielectric. J. Am. Chem. Soc., 48:1234.

With R. M. Buffington. The Entropy of Aqueous Ions. J. Am. Chem. Soc., 48:2297.

With R. M. Buffington. The Measurement of Coefficients of Expansion at Low Temperatures. Some Thermodynamic Applications of Expansion Data. J. Am. Chem. Soc., 48:2305.

The Potential of the Fluorine Electrode from Thermal Data. J. Am. Chem. Soc., 48:2868.

1927

The Electrode Potentials of Beryllium, Magnesium, Calcium, Strontium and Barium from Thermal Data. J. Phys. Chem., 31:1267.

1928

With B. S. Greensfelder. The Heat Capacity and Entropy of Cesium Alum from 18 to 300° Absolute. The Entropy of Aluminum Ion. The Potential of the Aluminum Electrode from Thermal Data. J. Am. Chem. Soc., 50:2202.

With B. S. Greensfelder. The Heat Capacity and Entropy of Barium Bromate from 16 to 300° Absolute. The Entropy of Bromate Ion. J. Am. Chem. Soc., 50:3286.

1929

With C. Kasper. The Theoretical Evaluation of the Entropies of Aqueous Ions. J. Am. Chem. Soc., 51:2293.

The Repulsion of Atomic Kernels as a Factor in Organic Rearrangements. J. Am. Chem. Soc., 51:3185.

With J. H. Hildebrand. Reference Book of Inorganic Chemistry. New York, Macmillan.

1930

With C. W. Porter. The Polarities and the Orienting Influences of Substitutes in the Benzene Ring. J. Am. Chem. Soc., 52:206.

With J. E. Ahlberg. The Heat Capacity and Entropy of Potassium Perchlorate from 12° to 298° Absolute. The Heat of Solution of Potassium Perchlorate. The Entropy and Free Energy of Perchlorate Ion. J. Am. Chem. Soc., 52:549.

With J. E. Ahlberg. Die spezifische Wärme von Bariumnitrat von 15° bis 300° abs. Die Entropie des Nitrations. Z. physik. Chem. A, 148:464.

1931

A Theory of the Arrangement of Protons and Electrons in the Atomic Nucleus. J. Am. Chem. Soc., 53:981.

With B. S. Greensfelder. The Heat Capacity and Entropy of Silver Iodate from 16 to 300° Absolute. The Entropy of Iodate Ion. J. Am. Chem. Soc., 53:3818.

1932

The Existence of Neutrons in the Atomic Nucleus. J. Am. Chem. Soc., 54:2125.

With J. E. Ahlberg. The Heat Capacity and Entropy of Thallous Nitrate from 17 to 300° Absolute. The Entropy and Free Energy of Nitrate Ion. J. Am. Chem. Soc., 54:1900.

With W. C. Bray. *A Course in General Chemistry*. Rev. ed. New York, Macmillan.

1933

With W. F. Libby. The Radioactivity of Lanthanum, Neodymium and Samarium. J. Am. Chem. Soc., 55:433.

With W. F. Libby. Bond Energies and Mass Defects in Atomic Nuclei. J. Chem. Phys., 1:133.

With P. W. Schutz and J. F. G. Hicks, Jr. The Heat Capacity and Entropy of Calcium Oxalate from 19 to 300° Absolute. The Entropy and Free Energy of Oxalate Ion. J. Am. Chem. Soc., 55:971.

With P. W. Schutz and J. F. G. Hicks, Jr. The Heat Capacity and Entropy of Silver Sulfate from 14 to 300°K. The Entropy of Sulfate Ion. J. Chem. Phys., 1:424.

With H. A. Young. The Isotopes of Calcium by the Magneto-Optic Method. Phys. Rev., 44:60.

With J. F. G. Hicks, Jr. and P. W. Schutz. The Heat Capacities and Entropies of Calcium and Barium Sulfates from 15 to 300°K. The Entropy and Free Energy of Sulfate Ion. J. Chem. Phys., 1:620.

With H. A. Young. The Isotopes of Hydrogen by the Magneto-Optic Method. The Existence of H^3. Phys. Rev., 44:690.

1934

With P. W. Schutz and J. F. G. Hicks, Jr. A Summary of the Entropies of Aqueous Ions. J. Chem. Phys., 2:82.

With P. W. Schutz and J. F. G. Hicks, Jr. The Heat Capacity and Entropy of Potassium Chlorate from 13 to 300°K. The Entropy of Chlorate Ion. J. Am. Chem. Soc., 56:88.

With J. E. Ahlberg. The Heat Capacities and Entropies of Potassium Bromate and Iodate from 15 to 300° Absolute. The Entropies of Bromate and Iodate Ions. J. Am. Chem. Soc., 56:856.

1935

With D. E. Hull and W. F. Libby. The Beta-Particle from Actinium. J. Am. Chem. Soc., 57:593.

With W. F. Libby and E. A. Long. The Action of Neutrons on Heavy Water. Phys. Rev., 47:424.

With W. F. Libby. Absorption and Scattering of Neutrons. Phys. Rev., 47:193.

With D. E. Hull and W. F. Libby. Radio-cesium Activated by Neutrons. J. Am. Chem. Soc., 57:781.

With W. F. Libby and M. D. Peterson. Alpha Radioactivity of Argon Formed by Radiochlorine. Phys. Rev., 48:571.

1936

With D. E. Hull and W. F. Libby. The Beta-Ray of Actinium. J. Am. Chem. Soc., 57:1649.

Review of *Principles and Applications of Electrochemistry,* Vol. I, *Principles,* 3rd ed., by H. Jermain Creighton. J. Am. Chem. Soc., 58:538.

The Entropy of Aqueous Ions and the Nature of the Entropy of Hydration. Chem. Rev., 18:349.

The Constancy of Nuclear Bond Energies. J. Am. Chem. Soc., 58:1061.

With O. L. I. Brown and W. V. Smith. The Heat Capacity and Entropy of Barium Chloride Dihydrate from 15 to 300°K. The Heat of Solution of Barium Chloride Dihydrate. The Entropy of Barium Ion. J. Am. Chem. Soc., 58:1758.

With O. L. I. Brown and W. V. Smith. The Heat Capacity and Entropy of Potassium Permanganate from 15 to 300° Absolute. The Entropy and Free Energy of Permanganate Ion. J. Am. Chem. Soc., 58:2144.

With O. L. I. Brown. The Heat Capacity of Lithium Carbonate from 16 to 300°K. The Entropy and Heat of Solution of Lithium Carbonate at 298°K. The Entropy of Lithium Ion. J. Am. Chem. Soc., 58:2228.

1937

An Explanation of the Relative Stabilities of Isotopes of the Lighter Elements. Phys. Rev., 51:141.

With O. L. I. Brown and W. V. Smith. The Heat Capacity of Silver Nitrate from 15 to 300°K. The Heat of Solution at 298°K of Silver Nitrite, Barium Nitrate and Thallous Nitrate. The Entropy of Silver Nitrite, Thallous Ion, Nitrate Ion and Nitrite Ion. J. Am. Chem. Soc., 59:921.

With W. V. Smith and K. S. Pitzer. Silver Chlorite: Its Heat Capacity from 15 to 300°K, Free Energy and Heat of Solution and Entropy. The Entropy of Chlorite Ion. J. Am. Chem. Soc., 59:2640.

With W. V. Smith and K. S. Pitzer. Silver Chromate: Its Heat Capacity, Entropy and Free Energy of Formation. The Entropy and Free Energy of Formation of Chromate Ion. J. Am. Chem. Soc., 59:2642.

1938

With K. S. Pitzer and W. V. Smith. The Heat Capacity and Entropy of Barium Fluoride, Cesium Perchlorate and Lead Phosphate. J. Am. Chem. Soc., 60:1826.

With K. S. Pitzer and W. V. Smith. The Entropies of Aqueous Ions. J. Am. Chem. Soc., 60:1829.

The Oxidation States of the Elements and Their Potentials in Aqueous Solutions. New York, Prentice-Hall. 352 pp.

1939

With K. S. Pitzer and C. M. Slansky. The Free Energy of Hydration of Gaseous Ions and the Absolute Potential of the Normal Calomel Electrode. J. Chem. Phys., 7:108.

With H. W. Zimmerman. The Thermodynamics of Hyponitrous Acid. J. Am. Chem. Soc., 61:1550.

With H. W. Zimmerman. The Heat of the Reaction of Thiosulfate with Triiodite. J. Am. Chem. Soc., 61:1554.

With H. A. Young. The Nature of Visual Observations at Low Light Intensities. Phys. Rev., 56:963.

1940

With W. C. Bray. A Course in General Chemistry. 3rd ed. New York, Macmillan. 206 pp.

With J. H. Hildebrand. Reference Book of Inorganic Chemistry. 2nd ed. New York, Macmillan. 563 pp.

With C. Slansky. Ionic Entropies and Free Energies and Entropies of Solvation in Water-Methanol Solutions. J. Am. Chem. Soc., 62:2019.

With L. V. Coulter. The Heat of Solution of Gadolinium Sulfate. Octahydrate and the Entropy of Gadolinium Ion. J. Am. Chem. Soc., 62: 2557.

With L. V. Coulter and K. S. Pitzer. The Entropies of Large Ions. The Heat Capacity, Entropy and Heat of Solution of Potassium Chloroplatinate. Tetramethylammonium Iodide and Uranyl Nitrate Hexahydrate. J. Am. Chem. Soc., 62:2845.

1945

With F. J. Fornoff and K. S. Pitzer. The Heat Capacity and the Entropy of Hydrated Lanthanum Magnesium Nitrate. J. Am. Chem. Soc., 67: 1444.

Pancake Effect in Gas Clouds. OSRD Report No. 1176, Publication Board 15620.

The Hot Wire Analyser for Gas Concentrations. OSRR No. 3048.

1947

With B. J. Fontana. The Heat of Formation and Free Energy of Chlorous Acid. J. Am. Chem. Soc., 69:2598.

Tables of Free Energy Functions for Elements and Compounds in the Temperature Range 2000°–5000°K. MDDC No. 1462.

1948

With D. D. Cubicciotti. A Reaction between Carbon Tetrachloride and Ammonium Chloride. J. Am. Chem. Soc., 70:3509.

1949

The Dielectric Constants of Hydrogen-Bonded Substances. Chem. Rev., 44:59.

1950

General Micrometeorological Principles. In: Summary Technical Report of Division 10, National Defense Research Committee, *Handbook on Aerosols*. Washington, D. C., United States Atomic Energy Commission, p. 15.

Micrometeorological Instruments. In: *Handbook on Aerosols,* p. 40.

Astrochemical Problems in the Formation of the Earth. Science, 112:101.
Inorganic Chemistry at the University of California. J. Chem. Ed., 27:451.

1951

Structural Chemistry of Inorganic Compounds. Science, 113:253.
Methods of Estimating the Entropies of Solid Compounds. J. Am. Chem. Soc., 73:1480.
With Z. Z. Hugus. The Heat of Oxidation of Manganous Ion to Permanganate and the Manganese Potentials. J. Electrochem. Soc., 98:296.
With R. E. Powell. The Entropy of Aqueous Solutes. J. Chem. Phys., 19:1139.
Review of *Time's Arrow and Evolution,* by Harold F. Blum. Princeton, N. J., Princeton University Press. Science, 114:697.
With J. H. Hildebrand. Reference Book of Inorganic Chemistry. 3rd ed. New York, Macmillan Company.

1952

Oxidation Potentials. 2nd ed. New York, Prentice-Hall.
Oxidation and Reduction. In: Encyclopedia of Chemical Technology, 9:676.
Manganese, Chromium, Oxidation and Reduction. In: *Encyclopaedia Britannica.*
Biography of Gilbert N. Lewis. In: *Encyclopaedia Britannica.*
With W. L. Jolly. The Solubility of Hydrous Germanous Oxide and Potential of the Germanous Oxide-Germanic Oxide Couple. J. Am. Chem. Soc., 74:5751.
With W. L. Jolly. The Heat of Oxidation of Germanous Iodide to Germanic Acid. J. Am. Chem. Soc., 74:5752.
With W. L. Jolly. The Vapor Pressure of Germanic Iodide. The Disproportionation of Germanous Iodide. J. Am. Chem. Soc., 74:5754.
With W. L. Jolly. The Equilibruim $Ge_{(s)}+GeO_{2(s)}=2GeO_{(g)}$. The Heat of Formation of Germanic Oxide. J. Am. Chem. Soc., 74:5757.

1953

With W. L. Jolly. Heats and Entropies of Successive Steps in the Formation of AlF_6^{---}. J. Am. Soc., 75:1548.
With L. G. Hepler. The Heat and Entropy of Ionization of Hydrofluoric Acid. The Entropy of Bifluoride Ion. J. Am. Chem. Soc., 75:2809.

Review of *The Elements of Nuclear Reactor Theory,* by Samuel Glasstone and Milton C. Edlund. New York, Van Nostrand, 1952. J. Am. Chem. Soc., 75:3044.

Use of Potential Diagrams in the Interpretation of Inorganic Chemistry. National Bureau of Standards Circ. 524, Aug. 14, p. 165.

With H. Mel and W. L. Jolly. The Heat and Free Energy of Formation of Bromate Ion. J. Am. Chem. Soc., 75:3827.

With W. L. Jolly. Absolute Entropies in Liquid Ammonia. J. Am. Chem. Soc., 75:4147.

Prediction and Speculation in Chemistry. Chem. Eng. News, 31:3366.

With J. Kury and Z. Zielen. Heats of Formation and Entropies of HS^- and $S^=$. Potential of Sulfide-Sulfur Couple. J. Electrochem. Soc., 100:468.

With L. G. Hepler and Z. Z. Hugus. The Stability of the Lower Oxidation States of Indium in Aqueous Solution. J. Am. Chem. Soc., 75:5652.

The Entropy of Complex Ions. Symposium on Co-ordination Chemistry held in Copenhagen, Denmark, Aug. 9–13, 1953, Proceedings, pp. 31–35.

1954

Review of *Target: Earth,* by A. O. Kelly and Frank Dachille. Pensacola Engraving Co. Florida, Pensacola, 1953. Chem. Eng. News, 32:764.

The Sign of Oxidation-Reduction Potentials. J. Am. Chem. Soc., 76:1200.

Symposium on Hydration of Aqueous Ions. Introductory Remarks. J. Phys. Chem., 58:513.

1955

Single Ion Free Energies and Entropies of Aqueous Ions. J. Chem. Phys., 23:90.

1956

With H. Mel and Z. Z. Hugus. The Thermodynamics of Thiosulfate Ion. J. Am. Chem. Soc., 78:1822.

With R. E. Connick, L. G. Hepler, Z. Z. Hugus, J. Kury and M. Tsao. The Complexing of Iron (III) by Fluoride Ions in Aqueous Solution: Free Energies, Heats and Entropies. J. Am. Chem. Soc., 78:1827.