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WORTH HUFF RODEBUSH

1887—1959

A Biographical Memoir by
CARL S. MARVEL AND FREDERICK T. WALL

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W. H. Rodebush

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May 24, 1887–August 16, 1959

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BORN IN A SOD HOUSE on a farm near Selden, Kansas, on May 24, 1887, Worth Huff Rodebush became a significant participant in a branch of science which appeared in this same period. The child of a frontier, rural society which had little interest in pure science, he became part of the scholarly community which developed modern physical chemistry.

Western Kansas was a world far different from the one in which he spent his mature life. Sparsely settled and lacking the conveniences known in eastern urban centers, it was settled by homesteaders who had little contact with the outside world. It was a community which required the utmost in self-sufficiency, physical stamina, and adaptability. His father, Milton L. Rodebush, was a Civil War veteran who had studied briefly at the University of Iowa following his military service. His mother, Rosa Huff, was evidently well schooled in mathematics and literature, and their home contained many books and periodicals which were shared in family reading sessions. In later years, Worth Rodebush often mentioned that he first became interested in chemistry by reading and rereading a textbook which had somehow become part of the family library.

Beginning school at the age of four because he could already read and spell, he moved quickly through the public schools. No school busses served rural areas in those days; consequently, he worked for his keep with a family while going to high school. One result of this experience was that he never again milked a cow except when

stranded by a flood in New Mexico in 1924 and forced to choose between this onerous task and going hungry. He was ready to carry out his family's plan to have him attend the University of Kansas when a hailstorm destroyed the wheat crop. This meant a year's delay while he taught at a country school to earn enough cash for fees and books. Then he again started working for room and board, but he found the schedule too strenuous and at the end of a year he dropped out of college to teach in a Kansas high school for several years—an experience which gave him a lasting interest in secondary education. Returning then to the University of Kansas, he left the engineering course in which he originally enrolled and entered the chemistry curriculum.

The Chemistry Department at Kansas was very stimulating and inspiring. It was there that Worth Rodebush met Professor H. P. Cady, a great teacher who took a personal interest in all his students. Professor Cady's influence and guidance had much to do with launching Rodebush on a scientific career in chemistry. It was at the University of Kansas that the early work on liquid ammonia and its compounds was begun and carried on by E. C. Franklin with the cooperation of Professor Cady and Charles A. Kraus. This tradition of scholarly research was very strong and affected all who came in contact with the department. Rodebush was a teaching assistant for several years while continuing graduate work, and one of his students with whom he developed a lifelong friendship was Wendell Latimer.

Worth Rodebush received his baccalaureate degree from the University of Kansas in 1912, his master's from the same institution in 1914, and his doctorate from the University of California in 1917. After working about one year each for the Bureau of Mines and the U. S. Industrial Alcohol Company, he returned to the University of California as a National Research Fellow, having decided that he was more interested in academic work than in an industrial career. In 1921, Dr. Rodebush joined the staff of the University of Illinois as an Associate Professor in charge of the Division of Physical Chem-

istry, and in 1924 he was promoted to the rank of Professor. He remained as Professor and Head of the Division of Physical Chemistry for twenty-nine years; in 1953 he resigned from his departmental administrative work and became a research Professor until he retired from the University in 1955.

While at the University of California, Professor Rodebush worked closely with Professor Wendell Latimer, and together they recognized a most important concept in modern structural chemistry, namely: the existence of the hydrogen bond. Accounting as it does for the association of water, alcohols, and numerous other substances, and explaining in part the structure of proteins and other biological materials, recognition of the hydrogen bond constituted a major contribution to science. Some years later, while at the University of Illinois, Professor Rodebush carried out pioneering work in the used of infrared absorption methods for studying molecular structures, especially those involving hydrogen. Since this was before the day of neutron diffraction, and since hydrogen atoms contribute little to X-ray scattering, the infrared method proved for some time to be the only reliable means for obtaining physical chemical measurements on the hydrogen of innumerable chemical compounds.

During the war, Professor Rodebush was a civilian with the National Defense Research Committee, and after the war he actively continued his work in behalf of our national defense. Dr. Rodebush was a charter member of the Naval Ordnance Test Station Scientific Advisory Board established in 1948, a time when the research and development activities of that center were beginning to assume a form which later resulted in major contributions to the Navy weapons program. In particular, the objectives of the center's rocket work were directed toward a new investigation of solid propellants. Worth Rodebush was one of the Board's leading scientists in the areas of chemical research most significant in this work, and his contributions, both as a consultant to the senior personnel of the Naval Ordnance Test Station Chemistry Division and in the determination of Board recommendations for program focus, organization, and op-

erations, were of primary importance. The position attained through research concerned with double base propellants was to no small extent the result of his stimulating and able guidance.

After retirement at statutary age in 1955, he continued to take an active part in various researches. He served as consultant to the Cloud Physics project at the University of Chicago and to a National Institutes of Health research project for the study of water in biological material at the University of Florida. He also continued as advisor to the Ordnance Departments of the Army and Navy. These activities lead to posthumus publications. He continued active participation in the affairs of the National Academy of Sciences and other learned societies, and he was called on for the contribution of papers to various national and international scientific symposia. He was scientifically productive to the last.

Rodebush was an active member of several scientific societies, including the American Chemical Society, the American Physical Society, and the Faraday Society. He was elected to membership in the National Academy of Sciences in 1938.

In 1919 he married Esther Kittredge, with whom he became acquainted during his graduate student days. They had three daughters, Harriet Rodebush Newton, Susan Rodebush Beyer, and Annette Rodebush Frey, as well as eight grandchildren at the time of his death. It was while visiting one of his daughters in Chicago during the summer of 1959 that Worth Rodebush suffered a serious stroke. He died in Billings Hospital on August 16, 1959.

Worth Rodebush was a personable individual with interests extending far beyond science. A description of him as a man is provided by the following quotation from an editorial which appeared in the Champaign-Urbana *Courier:* "He was living proof of the aphorism that 'reading maketh a full man.' He was convivial yet unbendingly moral and ethical, he was skilled in the precisions of science but loved the overtones of the mind and the intangibles."

KEY TO ABBREVIATIONS

Chem. Rev. = Chemical Reviews
Ind. Eng. Chem. = Industrial and Engineering Chemistry
J. Am. Chem. Soc. = Journal of the American Chemical Society
J. Chem. Educ. = Journal of Chemical Education
J. Chem. Eng. Data = Journal of Chemical Engineering Data
J. Chem. Phys. = The Journal of Chemical Physics
J. Phys. Chem. = Journal of Physical Chemistry
Nat. Res. Council = National Research Council
Phys. Rev. = The Physical Review
Proc. Nat. Acad. Sci. = Proceedings of the National Academy of Sciences
Rev. Modern Phys. = Reviews of Modern Physics
School Sci. Math. = School Science and Mathematics
Trans. Far. Soc. = Transactions of the Faraday Society

BIBLIOGRAPHY

1918

With E. D. Eastman. The Specific Heats at Low Temperature of Sodium, Potassium, Magnesium and Calcium Metals, and of Lead Sulfide. J. Am. Chem. Soc., 40:489.

The Freezing Points of Concentrated Solutions and the Free Energy of Solution of Salts. J. Am. Chem. Soc., 40:1204.

With G. N. Lewis and E. D. Eastman. The Heat Capacity of Electropositive Metals at the Thermal Energy of the Electron. Proc. Nat. Acad. Sci., 4:25.

1920

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

1922

A Simple Graphical Method of Calculating the Number of Plates Required for a Distilling Column. Ind. Eng. Chem., 14:1036.

The Atom of the Chemist. School Sci. Math., 22:737.

1923

With T. O. Yntema. A Low Temperature Electrolyte. J. Am. Chem. Soc., 45:332.

A Statistical Theory of Monomolecular Reactions. J. Am. Chem. Soc., 45:606.

The Rate of Evaporation of Electrons from Hot Filaments. J. Am. Chem. Soc., 45:997.

The Atomic Heats of Cadmium and Tin at Low Temperatures. J. Am. Chem. Soc., 45:1413.

With M. F. Fogler. The Heats of Vaporization of Mercury and Cadmium. J. Am. Chem. Soc., 45:2080.

The Mass Law and Statistical Equilibrium. Science, n.s., 57:358.

1924

The Ionization of Strong Electrolytes. J. Phys. Chem., 28:113.

The Subject Matter of a Course in Physical Chemistry. Science, n.s., 59: 430.

The Third Law of Thermodynamics. In: *Treatise on Physical Chemistry,* ed. by H. S. Taylor (N. Y., Van Nostrand), pp. 1131–1204.

1925

With J. W. Andrews and J. B. Taylor. The Temperature-Entropy Diagrams for Nitrogen and Oxygen. J. Am. Chem. Soc., 47:313.

With A. L. Dixon. The Entropies of the Vapors of Zinc and Lead. J. Am. Chem. Soc., 47:1036.

A Compact Arrangement of the Periodic Table. J. Chem. Educ., 2:381.

With F. Hovorka. The Freezing Points of Very Dilute Solutions of Electrolytes. J. Am. Chem. Soc., 47:1614.

With E. F. Fiock. The Measurement of the Absolute Charge on the Earth's Surface. Proc. Nat. Acad. Sci. 11:402.

With J. C. Michalek. The Atomic Heat Capacities of Iron and Nickel at Low Temperatures. J. Am. Chem. Soc., 47:2117.

With T. DeVries. The Vapor Pressure of Sodium. J. Am. Chem. Soc., 47:2488.

With A. L. Dixon. The Vapor Pressures of Metals: A New Experimental Method. Phys. Rev., 26:851.

1926

The Activity of Several Types of Electrolytes Calculated from Freezing Point Data. J. Am. Chem. Soc., 48:709.

With J. Kunz and J. B. Taylor. The Magnetic Properties of Atoms. Science, n.s., 53:550.

With E. Fiock. The Vapor Pressures and Thermal Properties of Potassium and Some Alkali Halides. J. Am. Chem. Soc., 48:2522.

1927

The Deflection of a Beam of Atoms in an Inhomogenous Magnetic Field. Proc. Nat. Acad. Sci., 13:50.

Chemical Constants and Absolute Entropy. Proc. Nat. Acad. Sci., 13:185.

With C. C. Coons. A New Absolute Manometer for Low Pressures. J. Am. Chem. Soc., 49:1953.

With Alfred L. Dixon. The Heat Capacities of Liquid Metals. J. Am. Chem. Soc., 49:1162.

With Thomas DeVries. The Thermal Dissociation of Iodine and Bromine. J. Am. Chem. Soc., 49:656.

Thermal Equilibrium of Electrons in Metals: Contact Potentials and Thermoelectric Force. Chem. Rev., 4:255.

1928

The Electron Theory of Valence. Chem. Rev., 5:509.

Valence and the Rule of Eight. Nature, 122:56.

With J. Merriam Peterson. A Cryoscopic Study of Benzene Solutions. J. Phys. Chem., 32:709.

With J. C. Michalek. The Effect of Intensive Drying on the Vapor Pressure and Vapor Density of Ammonium Chloride. Proc. Nat. Acad. Sci., 14:131.

1929

The Entropy of Hydrogen. Proc. Nat. Acad. Sci., 15:678.

With J. M. Peterson. The Electrolysis of Metallo-organic Compounds. J. Am. Chem. Soc., 51:638.

With J. C. Michalek. The Vapor Pressure and Vapor Density of Intensively Dried Ammonium Chloride. J. Am. Chem. Soc., 51:748.

1930

Third Law of Thermodynamics. Phys. Rev., 35:210.

With W. F. Henry. The Vapor Pressure of Sodium. Low Pressure Measurements with the Absolute Manometer. J. Am. Chem. Soc., 52:3159.

With W. A. Nichols, Jr. Molecular Ray Experiments. The Chemical Activity of Molecular and Atomic Oxygen. J. Am. Chem. Soc., 52:3864.

With E. G. Walters. The Vapor Pressure and Vapor Density of Sodium. J. Am. Chem. Soc., 52:2654.

With W. A. Nichols. Atomic Oxygen as a Reducing Agent. Phys. Rev., 35:649.

With E. J. Shaw and T. E. Phipps. Magnetic Moment of the Sulfur Molecule. Phys. Rev., 35:1126.

With W. A. Nichols. An Attempt to Determine Nuclear Moments. J. Am. Chem. Soc., 52:3024.

With S. M. Troxel. Heat of Formation of Molecular Oxygen. J. Am. Chem. Soc., 52:3467.

1931

The Entropy of Hydrogen. Phys. Rev., 37:221.

The Superposition of Electron Charges in Molecules and α-Particles, J. Am. Chem. Soc., 53:1611.

The Calculation of Chemical Equilibrium from Spectroscopic Data. Chem. Rev., 9:319.

Molecular Rays. Rev. Modern Phys., 3:392.

With J. DeVries. The Dipole Moment of Semi-polar Bonds. J. Am. Chem. Soc., 53:2888.

1932

The Entropy of Nitrous Oxide and Carbon Dioxide. Phys. Rev., 40:113.

The Heat of Dissociation of the Sodium Molecule. J. Am. Chem. Soc., 54:2123.

With M. J. Copley. The Effect of Foreign Gases on Unimolecular Reactions. J. Am. Chem. Soc., 54:2560.

With R. H. Ewart. The Effect of the Solvent upon the Activity of Acids: The Vapor Pressure of Hydrogen Chloride in Glacial Acetic Acid Solutions. J. Am. Chem. Soc., 54:419.

With W. C. Klingelhoefer. The Reaction of Chlorine with Hydrogen. Proc. Nat. Acad. Sci., 18:531.

With W. F. Henry. Molecular Beams of Salt Vapors. Phys. Rev., 39:386.

With Esther Rodebush. An Introductory Course in Physical Chemistry. N. Y., Van Nostrand.

1933

With M. H. Wahl. A New Band in the Water Vapor Discharge. J. Am. Chem. Soc., 55:1742.

With D. Haas. Observations on the Rare Earths. XXXIX. The Transference Numbers of the Chlorides of Neodymium, Samarium and Gado-

linium. Part II. Measurement of the Transference Numbers. J. Am. Chem. Soc., 55:3238.

With W. C. Klingelhoefer. Atomic Chlorine and Its Reaction with Hydrogen. J. Am. Chem. Soc., 55:130.

With M. H. Wahl. The Reactions of the Hydroxyl Radical in the Electrodeless Discharge in Water Vapor. J. Chem. Phys., 1:696.

Thermodynamics and the Kinetics of Gaseous Reactions. J. Chem. Phys., 1:440.

1934

The Third Law of Thermodynamics. J. Chem. Phys., 2:668.

Dipole Moment and Ionic Binding. Trans. Far. Soc., 30:778.

Some Chemical Reactions Involving Active Nitrogen. J. Am. Chem. Soc., 56:97.

1935

Absolute Rate of a Chemical Reaction. J. Chem. Phys., 3:242.

With T. G. Cooke. Conductance of Salt Crystals. J. Chem. Phys., 3:834.

With M. L. Spealman. The Recombination of Hydrogen Atoms in the Presence of Hydrogen Chloride. J. Am. Chem. Soc., 57:1040.

With M. L. Spealman. The Reactions of Some Oxides of Nitrogen with Atomic Oxygen and Nitrogen. J. Am. Chem. Soc., 57:1474.

With M. L. Spealman. The Action of Hydrogen Bromide on the Nitrogen Afterglow. J. Am. Chem. Soc., 57:1881.

1936

The Hydrogen Bond and Coordination. Chem. Rev., 19:59.

The Dipole Moments of the Alkali Halides. J. Chem. Phys., 4:536.

The Absolute Rate of a Chemical Reaction: The Formal Thermodynamic Treatment. J. Chem. Phys., 4:744.

With L. A. Murray, Jr. and M. E. Bixler. The Dipole Moments of the Alkali Halides. J. Chem. Phys., 4:372.

With R. W. Campbell. The Formation of Hydrogen Peroxide in the Electrodeless Discharge in Water Vapor. J. Chem. Phys., 4:293.

1937

The Reactions of Oxygen and Hydrogen at Low Pressures. J. Phys. Chem., 41:283.

With C. W. J. Wende and R. W. Campbell. The Formation of Water and Hydrogen Peroxide at Low Pressures. J. Am. Chem. Soc., 59:1924.

1938

With A. M. Buswell. Hydrogen Bond and Infrared Absorption. J. Chem. Phys., 6:296.

With L. B. Borst and A. M. Buswell. Infrared Absorption Studies. IV. The Infrared Spectrum of Water in an Inert Solvent. J. Chem. Phys., 6:61.

With A. M. Buswell and M. F. Roy. Infrared Absorption Studies. V. Association in the Carboxylic Acids. J. Am. Chem. Soc., 60:2239.

With A. M. Buswell and M. F. Roy. Infrared Absorption Studies. VI. Association in the Acid Amides and Oximes. J. Am. Chem. Soc., 60:2444.

With A. M. Buswell and M. F. Roy. Infrared Absorption Studies. VII. Complex Formation Due to Hydrogen Bonding. J. Am. Chem. Soc., 60:2528.

With Esther Rodebush. An Introductory Course in Physical Chemistry, 2nd ed. N. Y., Van Nostrand.

1939

With A. M. Buswell. Association through Hydrogen. J. Phys. Chem., 43: 219.

With A. M. Buswell and R. L. Maycock. Infrared Absorption of Hydrogen Fluoride. J. Chem. Phys., 7:857.

With A. M. Buswell, G. W. McMillan, and F. T. Wall. Infrared Absorption Studies. VIII. Hydrazoic Acid., J. Am. Chem. Soc., 61:2809.

With A. M. Buswell and R. C. Gore. Effect of Ions of the Lytotropic Series on the Infrared Absorption Spectrum of Water. J. Phys. Chem., 43:1181.

With A. M. Buswell and J. R. Downing. Infrared Absorption Studies. IX. Bonding of Hydrogen in Nitrogen Compounds. J. Am. Chem. Soc., 61:3252.

1940

With A. M. Buswell and R. L. Maycock. Infrared Absorption Studies. X. The Infrared Absorption of Hydrogen Fluoride in the Vapor State and in Solution in an Inert Solvent. J. Chem. Phys., 8:362.

With C. R. Eddy. Dielectric Polarization in Solution. I. The Failure of the Clausius-Mosotto Equation. J. Chem. Phys., 8:424.

With A. M. Buswell and J. R. Downing. Infrared Absorption Studies. XI. NH–N and NH–O Bonds. J. Am. Chem. Soc., 62:2759.

With M. T. O'Shaughnessy. Ultraviolet Absorption Spectra of Organic

Molecules: The Dependence upon Restricted Rotation and Resonance. J. Am. Chem. Soc., 62:2906.

With C. R. Eddy and L. D. Eubank. Dielectric Polarization in Solution. II. The Polarization of Some Alcohols as a Function of Concentration and Temperature. J. Chem. Phys., 8:889.

1941

With W. C. Dunlop, Barbara Williamson, and A. M. Buswell. Ultraviolet Absorption of Diphenic Acids. J. Am. Chem. Soc., 63:1167.

With B. Williamson. Ultraviolet Absorption Spectra of Organic Molecules. II. The Effect of Substituent Groups upon the Absorption of Biphenyl. J. Am. Chem. Soc., 63:3018.

Entropy of Surface Formation. J. Chem. Phys., 9:284.

With C. Kretschmer. Association of Phenols. J. Chem. Phys., 9:284.

1946

With Isaac Feldman. Ultraviolet Absorption Spectra of Organic Molecules. III. Mechanical Interference of Substituent Groups with Resonance Configurations. J. Am. Chem. Soc., 68:896.

1947

With C. R. Keizer. F. S. McKee, and J. V. Quagliano. The Reactions of the Hydroxyl Radical. J. Am. Chem. Soc., 69: 538.

The Correlation of Resonance Structure with Ultraviolet Absorption in Nitro-substituted Organic Molecules. Chem. Rev., 41:317.

1949

Nuclei in Evaporation and Condensation. Chem. Rev., 44:269.

1950

The Dynamics of Gas Flow. J. Chem. Educ., 27:39.

Aerosols in the Atmosphere. Washington, D. C., Atomic Energy Commission.

Chapter 4, General Properties of Aerosols. Chapter 9, Filtration of Aerosols. Chapter 11, Travel and Persistence of Aerosol Clouds. In: *Handbook on Aerosols*. Washington, D. C., Atomic Energy Commission.

1952

Spontaneous Nucleation in Supersaturated Water Vapor. Ind. Eng. Chem., 44:1289.

1954

The Vapor Pressure of Small Drops. Proc. Nat. Acad. Sci., 40:789.

1957

Thermodynamics and Properties of Saline Water. In: *Symposium on Saline Water Conversion*. Nat. Acad. Sci., Nat. Res. Council, Pub. 568, p. 395.

1958

With John V. Clarke, Jr. Spontaneous Nucleation in Supersaturated Vapors. Proc. Nat. Acad. Sci., 44:536–40.

With A. M. Buswell. Properties of Water Substance. Proc. Internat. Symposium on Water and Its Conduction in Soils, Special Report 40, Highway Res. Board, Nat. Res. Council.

1961

With Thomas A. Wittstruch, Wallace S. Brey, and A. M. Buswell. Solid Hydrates of Some Halomethanes. J. Chem. Eng. Data, 6:343.

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1,402,317	Glycol	8–25–19	1–3–22