NATIONAL ACADEMY OF SCIENCES

FARRINGTON DANIELS

1889—1972

A Biographical Memoir by

ROBERT A. ALBERTY

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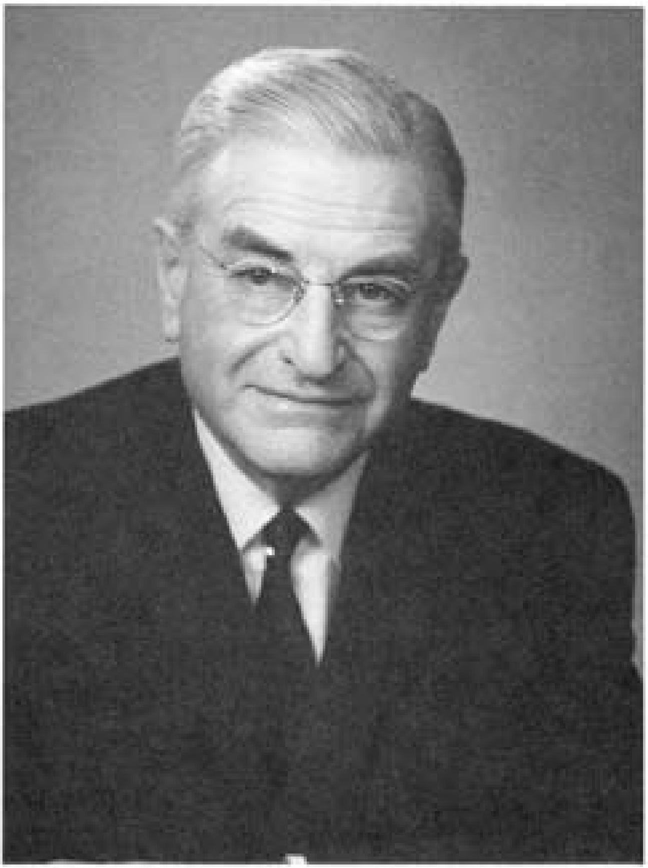

Farrington Daniels

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March 9, 1889–June 23, 1972

BY ROBERT A. ALBERTY

FARRINGTON DANIELS'S EARLY study of the kinetics of the decomposition of nitrogen pentoxide was a classic because for some time it was the only known first order gas reaction, and he used it to refute the then popular radiation hypothesis. He was a leader in the development of kinetics and photochemistry, and, at the same time, was involved in three textbooks that had a major impact on undergraduate instruction in physical chemistry. Farrington was director of the Metallurgical Laboratory at the time of the first testing and use of the atomic bomb, but after the war he turned his attention to solar energy and the promise it offered of pollution-free energy. Because of his good sense and enthusiasm, Farrington's statesmanship was much in demand at the University of Wisconsin, where he spent fifty-two years, in Washington, D.C., and in professional societies.

THE EARLY YEARS

Farrington Daniels was born on March 9, 1889, son of Franc Birchard Daniels and Florence L. Farrington Daniels, in Minneapolis, Minnesota, where his father had a position with American Express and later became district superintendent. He was the oldest of three boys. Farrington was interested in chemistry from a very early age and pursued these interests by making fireworks and batteries. His high school teacher urged him to choose the course in chemistry at the university and to plan for a chemical future. He entered the University of Minnesota in 1906 and earned a Bachelor of Science degree in June 1910. His Bachelor's thesis was on the determination of vapor pressure by the air-bubbling method. In the summer of 1910, he worked in the Analytical Laboratory of the Oliver Mining Company at Hibbing, Minnesota, determining the amount of manganese in iron ore and living in a tent. He earned a Master of Science degree from the University of Minnesota in June 1911. In February of 1911, Farrington met Prof. Theodore W. Richards at Harvard in connection with an Alpha Delta Phi convention in New York and liked him very much. He applied to Harvard for a scholarship for remission of tuition for the coming year and got it.

As a graduate student at Harvard from 1911 to 1914, Farrington worked on the electrochemistry and thermodynamics of thallium-mercury amalgams. He had a great time working for Richards and living in Cambridge. Richards was near the high point in his career; he received the Nobel Prize in Chemistry in 1914, the first American to do so. In the same year he was elected president of the American Chemical Society. Farrington submitted his doctoral thesis in May 1914, but it was not until five years later that Richards sent it to the *Journal of the American Chemical Society* for publication. The delay was caused by World War I. While a graduate student, Farrington applied for and received a fellowship to study abroad, and he had been accepted in Fritz Haber's laboratory in Berlin, but the war intervened, and Farrington secured a teaching position at Worcester Polytechnic Institute. He started a research program on adiabatic calorimetry there. In 1918, Farrington volunteered in the Chemical Warfare Service and was assigned to work with Prof. C. A. Kraus at Clark University on gas masks.

Olive Miriam Bell and Farrington had been acquainted since childhood, but they had moved in different circles until Farrington met Olive on the street car in Minneapolis while on a trip home from Worcester Poly. They were married September 15, 1917, in Minneapolis, and as Olive said in her biography of Farrington, "The marriage was to give mutual appreciation and devotion for nearly fifty-five years. They lived truly happily ever after."[1] They had four children: Farrington, Jr., Florence Mary (Mrs. J. D. Drury), Miriam Olive (Mrs. M. D. Ludwig), and Dorin Slater.

RESEARCH ON NITROGEN FIXATION

While Farrington was a graduate student at Harvard he had learned about the Haber process for making ammonia from Prof. W. K. Lewis of the MIT Department of Chemical Engineering and developed some ideas of his own about how to fix nitrogen using a cold or low energy electric discharge, which he discussed with Prof. A. A. Noyes in the MIT Department of Chemistry. As a result of these ideas, Farrington was invited by Wallace Carruthers to accept a position in the Bureau of Soils where they were working on nitrogen fixation. In the summer of 1919 a reorganization of the Bureau of Soils took place with all of the nitrogen work, including Farrington's, being transferred to the U.S. Fixed Nitrogen Research Laboratory under the administration of the recently established American University in Washington. The director was Arthur B. Lamb from Harvard, and the assistant director was Richard C. Tolman from the California Institute of Technology. Farrington's research there led to the measurement of the vapor pressure of nitrogen pentoxide and the discovery that its thermal decomposition is first order. Farrington's 1921 paper with Elmer H.

Johnston, a technician at the laboratory, was a classic. For some time the decomposition of nitrogen pentoxide was the best example of a unimolecular reaction, and it provided a test of the recently announced radiation hypothesis of Jean Perrin in France. In 1922 Perrin still argued that in a unimolecular reaction the energy necessary for decomposition did not depend on molecular collisions, but came instead from radiation, probably infrared radiation from the walls of the reaction chamber. Although Farrington's results indicated clearly the fallacy of the radiation hypothesis, he hesitated to denounce it completely because in 1920 he felt there were a number of things about the reaction that he did not understand. In 1928, Farrington summarized the evidence against the radiation hypothesis in an article published in *Chemical Reviews.* In the 1950s the reaction was found to be more complex.[2]

Farrington continued to be interested in nitrogen fixation for many years. He worked with students on nitrogen oxides, and in 1939 Frederick Gardner Cottrell (1877–1948), inventor of electrostatic precipitation and founder of the Research Corporation in 1911, came to see him and proposed that Farrington work on a heated pebble-bed method for making nitric acid from nitrogen and oxygen of the air. Farrington accepted the challenge and secured support from the Wisconsin Alumni Research Foundation and the Food Machinery and Chemical Corporation for research and development until it became clear that the Haber process was more economical.

THE UNIVERSITY OF WISCONSIN BEFORE WORLD WAR II

Farrington was invited to be an assistant professor at the University of Wisconsin in 1920 by J. Howard Mathews (Ph.D., Harvard, 1908, also with Richards), who had been appointed head of the department in 1919. Farrington accepted because he wanted to get back into academic work and had always had a high opinion of the University of Wisconsin. In Madison, Farrington developed a research program in kinetics and photochemistry and taught in the physical chemistry instructional laboratory and in the physical chemistry lecture course for undergraduates. The challenges he saw in teaching quickly led to textbook writing. His first textbook, *Mathematical Preparation for Physical Chemistry* (1928), was in some ways a result of a comment of G. N. Lewis (University of California, Berkeley) that Richards and Daniels could have gotten more out of their thallium amalgam data if they had understood how to use partial molar quantities. Farrington had never had any formal training in calculus, and so he began to teach himself and to develop a course on the mathematical preparation for physical chemistry. By his own admission, Farrington was only one step ahead of his students the first time he taught the course, but his book was an immediate success and was a consistent seller for fifty years. His missionary zeal in this area led him to write several articles for the *Journal of Chemical Education* and in 1931 to organize an American Chemical Society Symposium on mathematics in physical chemistry involving R. H. Fowler, R. S. Mulliken, and Henry Eyring. As a result of Farrington's urging, calculus was early made a prerequisite for physical chemistry at Wisconsin.

Farrington was in charge of the physical chemistry laboratory, and a joint effort with J. H. Mathews and J. W. Williams produced *Experimental Physical Chemistry* (1929), which has continued through seven editions (1968) with younger coauthors.

Farrington's third book was a result of an enquiry from Frederick H. Getman, professor of chemistry at Bryn Mawr, as to whether Mathews and Daniels would be interested in revising his *Outlines of Theoretical Chemistry*, which had first appeared in 1913 and which was based on Walter Nernst's well-known *Theoretical Chemistry.* In 1931, the fifth edition of *Outlines of Theoretical Chemistry* appeared under the names Getman and Daniels. I studied physical chemistry from the sixth edition, which appeared in 1937. With the seventh edition of 1943, the title was changed to *Outlines of Physical Chemistry.* The 1948 edition was the first and only one where Farrington's name appeared as sole author. In 1952 Farrington invited me to help him introduce new problems and revise some sections, and was paying me by the hour. My responsibilities in connection with the new edition grew with time, but it was not until we were reading proof that Farrington decided to put my name on the 1955 edition and to shorten the title to *Physical Chemistry.* I have continued with the book through eight editions, and the most recent edition (1992) is with Robert J. Silbey is in preparation. Many students learned physical chemistry from Farrington's books, and it is quite remarkable to see this continuity in a textbook over eighty years. His book *Chemical Kinetics* (1938) was written while he was the George Fisher Baker Non-Resident Lecturer at Cornell in the spring of 1935.

Farrington played an important role in the faculty of the University of Wisconsin at Madison. He served on important faculty committees such as the Regent-Faculty Conference Committee during the time of President Glenn Frank's ouster by the regents of the university in 1937. His interests were very broad, and he collaborated with Harry Steenbock in 1928 on the quantum yield of the production of vitamin D by irradiation of sterols, and with Benjamin Duggar in 1938 on the quantum efficiency of photosynthesis.

WORLD WAR II

In the summer of 1944 Farrington joined the staff of the

Metallurgical Laboratory at the University of Chicago as associate director of the chemistry division. On July 1, 1945, he became director of the Metallurgical Laboratory, a post he held until May 1946. These were momentous times. The first test atomic bomb was exploded at Alamogordo on July 16, 1945, and the bomb fell on Hiroshima on August 6th. Even before Farrington arrived at the Met Lab, questions about the use of the bomb were being discussed. Four days before the Alamogordo test, Arthur Compton asked Farrington, as director of the laboratory, to take an opinion poll of the scientists in the Met Lab as to how any new weapons should be used in the Japanese war. There was considerable sentiment for a non-military demonstration in Japan followed by a renewed opportunity for surrender before full use of the weapon was employed. Farrington agreed, reluctantly, that the bomb should be used. During the next several years, he spoke and wrote a good deal about the atomic bomb and its social implications.

When the war was over, the Met Lab looked ahead, and Farrington became a leader in the first active program to design a nuclear reactor to produce power for civilian uses. John E. Willard, who had written his doctoral dissertation with Farrington in 1935, was brought to the Met Lab to take charge of the "Power Pile" section. He had been the associate section chief of the plutonium section of the Met Lab (1943–44) before going to the Hanford Engineer Works. The Daniels Pile, as it came to be called, was to be moderated with beryllium oxide and cooled with high pressure helium. But in July 1947 the Atomic Energy Commission decided that the investigation of the Pile's basic problems should continue at the Clinton Laboratories at a lower priority. According to Olive Daniels, Farrington was devastated. In his *Oral History*,[3] Farrington said, "Admiral Rickover saw the power vacuum, sailed in with the Navy, and went off with the atomic submarine and did a grand job."

When the Met Lab had to find completely new quarters, Farrington was very much involved in the establishment of the Argonne National Laboratory, where he was chairman of the Board of Governors from 1946 to 1948 and then a member of the board until 1949.

UNIVERSITY OF WISCONSIN AFTER WORLD WAR II

In 1947 Farrington returned to the University of Wisconsin and started a research program on solar energy. In an address at the centennial celebration of the AAAS on September 15, 1948, he described the state of solar energy research at that time and looked ahead. He felt that when coal and oil had been used up, solar energy could satisfy our needs for food, fuel, and power, but he foresaw a long, challenging road of research and development ahead. He worked with the College of Engineering to establish a Solar Energy Laboratory in 1955. He also developed a research program on thermoluminescence, which led to applications in radiation dosimetry.

Farrington founded the Contemporary Trends course offered to seniors, and in 1949 edited a book, *Challenge of Our Times,* based on the lectures in the course, which dealt with the impact of science and technology on society. When he had trouble in getting a publisher, Farrington borrowed on his life insurance to help subsidize the printing of the book.

Farrington served as chairman of the Chemistry Department from 1952 to 1959. This was a strong department, and Farrington enhanced its distinction in all areas. He raised money for a new building on the other side of University Avenue, which provided enlarged and improved facilities and which was named the Farrington Daniels Chemistry Building by the regents of the university at their June 9, 1972, meeting. In 1958, the Naval Research Laboratory in the department, which was directed by Joseph O. Hirschfelder, was renamed the Theoretical Chemistry Laboratory.[4] These were busy years for Farrington because he was elected president of the American Chemical Society for 1953 (and gave fifty-seven lectures to local sections), vice president of the National Academy of Sciences for 1957–61, and president of the Geochemical Society in 1958. In 1957 Farrington received the James Flack Norris Award for excellence in the teaching of chemistry from the Northeast Section of the American Chemical Society. The Priestly Medal, the highest honor awarded by the American Chemical Society, was presented to Farrington for distinguished service to chemistry at the 131st National Meeting in April 1957. Farrington used the opportunity to challenge chemists of the present and future to solve the problem of the ever larger demands for cheap energy by a world population that was increasing rapidly. He urged more work on solar energy, so that it would be ready to take over more of the energy load as fuel reserves run low.

In 1959 Farrington received the Willard Gibbs Medal of the American Chemical Society's Chicago Section. His acceptance speech was on "Nitrogen Oxides and the Development of Chemical Kinetics," a field to which he had contributed for nearly forty years.

Farrington's first contact with the National Academy of Sciences was at the 1925 fall meeting, where he was asked to read a paper on "Chemical Decomposition by Collision of Activated Molecules," under the sponsorship of Charles E. Mendenhall. In 1938–41 he served on the Committee on Photochemistry and the Committee on Applications of Mathematics to Chemistry. In 1947 Farrington was elected to the National Academy of Sciences. He served on more committees than can be mentioned here, including the Committee of the International Union of Pure and Applied Chemistry that negotiated an important compromise in notation where the Helmholtz free energy was represented by A and the Gibbs free energy by G. In 1956 he was elected to the Executive Committee. He served as vice president of the National Academy of Sciences, 1957–61. During this period he was involved in the exchange of scientific visitors with the USSR.

In 1959, Farrington became an Emeritus Professor, and was succeeded as chairman of the department by John D. Ferry.

SOLAR ENERGY RESEARCH

After leaving the departmental chairmanship, Farrington moved his research activities to the Solar Energy Laboratory, which he had helped organize and fund, in the Engineering Experiment Station. The laboratory was directed by John A. Duffie. The Rockefeller Foundation made an initial grant of $250,000 to help non-industrialized developing countries use solar energy, and Farrington liked this emphasis. Over a ten-year period the Rockefeller Foundation provided $630,000, which was augmented by grants from other sources. The research produced focussing collectors, solar cookers, solar motors, and solar refrigerators. In 1954 Farrington made his first trip around the world with UNESCO support, discussing and demonstrating solar energy devices. He was also involved in the new Solar Energy Society, wrote for the *New York Times Magazine*, and was involved in the television program, "Our Mr. Sun," directed by Frank Capra. During this time Farrington was very much in the mode of survey and prophecy. In 1961 he completed the supervision of his sixty-first, and last, Ph.D. thesis. In the same year he published five papers on specific researches.

In 1964 he published his book *Direct Uses of the Sun's Energy.* In all, he made three trips around the world in the interest of solar energy. In 1971 Farrington presented his last scientific paper, before the American Philosophical Society, where he had been a member since 1948. In it he outlined the status of solar energy research to date and stated once again his unwavering faith in the future importance of solar energy. In view of the fact that the amount of research currently in progress was not very large, he concluded that solar energy, in 1971, was perhaps twenty-five years ahead of its time.

Farrington Daniels died on June 23, 1972, four months after being diagnosed as having cancer of the liver. He joked with his physician that alcoholics often have the same problem, but he was a life-long abstainer. A decision was made to operate, but while Farrington was receiving a blood transfusion the day before the projected operation, he suffered pulmonary edema, and the operation was abandoned. He was then given a course of chemotherapy with 5FU, but his situation deteriorated. A memorial service was held in the First Congregational Church. Farrington was survived by his wife, four children, and twelve grandchildren.

Farrington Daniels made major contributions in advancing the fields of kinetics and photochemistry and in educating students all around the world in physical chemistry. During his scientific career, he published over 300 papers. He was a statesman in science and education. He was dedicated to bettering the lives of individuals and of mankind, and in the latter part of his life he worked tirelessly to educate people to the need to develop solar energy for long-term energy needs.

I AM INDEBTED to Olive Bell Daniels for a biography, *Farrington Daniels, Chemist and Prophet of the Solar Age,* which she published in

September 1978, and which, in 540 pages, gives a loving and detailed account of Farrington's life and her role in it. I have also used the biographical memoir written by John E. Willard (*Year Book of the American Philosophical Society*, 1972, pp. 149–52) and the recollections of Farrington Daniels, referred to in a footnote.

NOTES

1. Olive Bell Daniels, *Farrington Daniels, Chemist and Prophet of the Solar Age* (Madison: 1978).
2. R. A. Ogg, *Journal of Chemical Physics*, 15(1947):337–38, 613; 18(1950):770.
3. "Recollections of a Career in Science and Teaching," *University Archives Oral History Project*, University of Wisconsin, 1972 (interview conducted by Steven Lowe).
4. In 1972, it became the Theoretical Chemistry Institute.

SELECTED BIBLIOGRAPHY

1912

With T. W. Richards. The electrochemical behavior of very concentrated thallium amalgams. *Trans. Am. Electrochem. Soc.* 32:343.

1919

With T. W. Richards. Concentrated thallium amalgams: Their electrochemical and thermochemical behavior, densities, and freezing points. *J. Am. Chem. Soc.* 41:1732–66.

1921

With E. H. Johnston. The thermal decomposition of gaseous nitrogen pentoxide. A monomolecular reaction. *J. Am. Chem. Soc.* 43:53–71.

1922

With O. R. Wulf and S. Karrer. The oxidation of nitrogen tetroxide by ozone. *J. Am. Chem. Soc.* 44:2398–401.

1925

With J. W. Williams. The specific heats of binary mixtures. *J. Am. Chem. Soc.* 47:1490–503.

1926

The photochemical inactivity of infrared radiation with special reference to the decomposition of nitrogen pentoxide. *J. Am. Chem. Soc.* 48:607–15.

1928

The radiation hypothesis of chemical reaction. *Chem. Rev.* 5:39–66.

Mathematical Preparation for Physical Chemistry. New York: McGraw-Hill.

1929

With J. H. Mathews and J. W. Williams. *Experimental Physical Chemistry.* New York: McGraw-Hill.

1930

With H. Eyring. The decomposition of nitrogen pentoxide in chemically active solvents. *J. Am. Chem. Soc.* 52:1486–92.

1931

With F. H. Getman. *Outlines of Theoretical Chemistry.* New York: Wiley.

1932

With W. H. Bauer. The Einstein relation and temperature coefficient in the photobromination of cinnamic acid. *J. Am. Chem. Soc.* 54:2564–65.

1934

With P. C. Cross. The influence of foreign gases on the intensity of infrared absorption. *J. Chem. Phys.* 2:6–10.

With B. M. Duggar and F. Stauffer. Quantum relations in photosynthesis with chlorella. *Science* 79:435.

1935

With J. Willard. The photobromination of tetrachloroethylene and of chloroform with special reference to the effects of oxygen. *J. Am. Chem. Soc.* 57:2240–45.

1938

Chemical Kinetics. Ithaca, N.Y.: Cornell University Press.

1947

With C. R. McCullough. Summary report on design and development of high temperature, gas-cooled power Power Pile. Oak Ridge Natl. Lab. Mon-N-383, declassified 1958.

1948

With A. H. Compton. A poll of scientists at Chicago, July, 1945. *Bull. At. Sci.* 4:44.

1949

With T. H. Smith, ed. *Challenge of Our Times.* Minneapolis: Burgess.

1953

With W. G. Hendrickson. Fixation of atmospheric nitrogen in a gas heated furnace. *Ind. Eng. Chem.* 45:2613–14.

A challenge to chemists. *Chem. Eng. News.* 31:3868–71.

1955

With J. C. Treacy. Kinetic study of the oxidation of nitric oxide with oxygen in the pressure range 1 to 20 mm. *J. Am. Chem. Soc.* 77:2033–36.

With R. A. Alberty. *Physical Chemistry.* New York: Wiley.

1957

With F. F. Morehead. Thermoluminescence and coloration of lithium fluoride produced by alpha particles, electrons, gamma rays, and neutrons. *J. Chem. Phys.* 27:1318–24.

1958

Teaching physical chemistry. *J. Chem. Ed.* 35:322–25.

1964

Direct Use of the Sun's Energy. New Haven: Yale University Press.

1971

Utilization of solar energy—progress report. *Proc. Am. Phil. Soc.* 115:490–501.