NATIONAL ACADEMY OF SCIENCES

ARTHUR AMOS NOYES

1866—1936

A Biographical Memoir by

LINUS PAULING

Biographical Memoir

Arthur A. Noyes.

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September 13, 1866—June 3, 1936

BY LINUS PAULING

ARTHUR AMOS NOYES was a very good chemist; he was, at different times, interested in organic chemistry, analytical chemistry, inorganic chemistry, and physical chemistry; he carried on research with diligence throughout his life, and made some significant discoveries. But he was a *great* teacher of chemistry; and it is as a teacher of chemistry that he will be long remembered.

He was born in Newburyport, Massachusetts, on September 13, 1866. He was descended from Nicholas Noyes, who had come from England in 1633 and settled in the town (then called Newbury) in 1635. His father, Amos Noyes, was an able and scholarly lawyer. His mother, Anna Page (Andrews) Noyes, was interested in literature, especially poetry; after her husband's death in 1896 she became a close companion to her son, who never married.

Noyes's early interest in chemistry was developed by Oliver Merrill, a teacher in the Newburyport High School. With another boy, Samuel P. Mulliken, later Professor of Organic Chemistry in the Massachusetts Institute of Technology, Noyes carried out chemical experiments at home. When he graduated from high school Noyes found that he could not attend the Massachusetts Institute of Technology because of lack of money. He then studied at home all the first-year subjects except drawing, and was able to enter the sophomore class at M.I.T. the following year, when he was granted the Wheelwright Scholarship, which had been established for Newburyport students.

Noyes received his bachelor's degree in 1886. He had carried out

under the guidance of L. M. Norton an investigation in the field of organic chemistry, dealing with the action of heat on ethylene, which was presented as his bachelor's thesis, and which was published, with Norton, in 1886. He continued his research in organic chemistry, and received the M.S. degree in 1887. He was then appointed Assistant in Analytical Chemistry; it was during this period that he made a close friend of one of his students, George Ellery Hale, who was later to play an important part in his life.

In the summer of 1888 three M.I.T. graduates in chemistry, Noyes, Mulliken, and Augustus H. Gill, went to Europe together for advanced study. It was their intention to pursue graduate work in organic chemistry under the German chemist Adolf Baeyer in Munich; but on arrival in Rotterdam they received word that there would be no space for them in Baeyer's laboratory, and Noyes elected Leipsig as the alternative, with the intention of carrying on research in organic chemistry under Wislicenus. However, Wilhelm Ostwald had just begun to present lectures in the new subject physical chemistry, and Noyes became interested in this field. Physical chemistry was undergoing rapid development at that time: van't Hoff's theory of osmotic pressure had been proposed in 1886, and the Arrhenius theory of the dissociation of an electrolyte into ions in 1887. Noyes transferred his research to physical chemistry, and carried out an investigation of deviations from the van't Hoff laws of perfect solutions, for which he received his doctorate in 1890.

He returned to the Massachusetts Institute of Technology, and for a number of years was engaged in teaching analytical chemistry (instructor in this field, 1890–1892), organic chemistry (instructor, 1892–1894), and physical chemistry (assistant professor and associate professor, 1894–1899; professor of theoretical chemistry, 1899–1919).

He wrote a book on each of these subjects: *A Detailed Course of Qualitative Chemical Analysis,* published in 1895, following a preliminary edition *Notes on Qualitative Analysis* in 1892; *Laboratory Experiments on the Class Reactions and Identification of Organic Substances* (with S. P. Mulliken), 1898; *The General Principles of*

Physical Science, 1902. His textbook on qualitative analysis, which has gone through many editions, was widely used, and was of great importance in introducing concepts of physical chemistry into this field. After Noyes's death, the book on qualitative analysis was rewritten and revised by E. H. Swift. His first book on physical chemistry (*The General Principles of Physical Science*) was later expanded, with the collaboration of Miles Sherrill, into a textbook, called at first *The General Principles of Chemistry* and in later editions *A Course of Study in Chemical Principles,* which has been of much value in bringing precision into the teaching of this subject in the United States. A characteristic of the book *Chemical Principles* was the use of problems so phrased as to lead the student himself to derive the basic equations. These two books have been described as revolutionizing the teaching of both analytical chemistry and physical chemistry in America.

One of Noyes's important contributions to chemistry, carried out with many collaborators, was his thorough study of the chemical properties of the rarer elements and the development of a complete system of chemical analysis including these elements. This work, which extended over a period of twenty-five years, was summarized in the book *A System of Qualitative Analysis for the Rare Elements,* by Noyes and W. C. Bray, published in 1927.

An important series of researches on the properties of solutions of electrolytes was carried out by Noyes and his students in the Massachusetts Institute of Technology and the California Institute of Technology. Noyes was one of the first, perhaps the first, to surmise that the large deviations of the activity coefficients of ions from unity, even in rather dilute solutions, might be ascribed to the interaction of the electric charges of the ions. As early as 1903 (with W. D. Coolidge), while discussing some experiments on the small deviation from Beer's law shown by the color of salt solutions, he said, "It gives support to the idea that the decrease of conductivity . . . is due to a physical cause (probably in some way to the electrical charges on the ions)

and not to specific chemical affinity." He emphasized this point in an address given in 1904 in St. Louis (*Science,* 20; 577). The first contribution from the Research Laboratory of Physical Chemistry of the Massachusetts Institute of Technology was on the electrical conductivity of aqueous solutions at high temperature, by Arthur A. Noyes and William D. Coolidge. His interest in the properties of solutions of electrolytes continued throughout his life. It culminated in the work that he carried out in the period around 1920 in order to test the theory that had been proposed by Milner in 1911, a quantitative treatment, based on statistical mechanics, of the electrostatic interactions of ions in a solution and the resultant effect on their activities. The paper by Debye and Hückel on a simplified mathematical method of treating the same problem appeared in 1923, and Noyes was able to use the experimental material that he and his students had collected in making a thorough test of the Debye-Hückel equation.

Noyes was enthusiastic about physical chemistry, as providing an understanding of the principles of chemistry, and he was enthusiastic about research. During the first few years of his teaching career at M.I.T. he was largely dependent on undergraduate students to carry out the investigations in which he was interested. In 1901 he made a proposal to the President of the Massachusetts Institute of Technology for the formation of a research laboratory of physical chemistry, and in 1903 he renewed the proposal, which was that a research laboratory of physical chemistry be set up with an annual budget of $6,000, half of which was to be provided by the Massachusetts Institute of Technology and half by Noyes himself. This sum was to be used largely for the salaries of research assistants, research associates, and research professors. The laboratory was established in a temporary structure erected for the purpose and Noyes began his career as Director of the Research Laboratory of Physical Chemistry on September 20, 1903. A grant of $2,000 was made during that year to Noyes by the Carnegie Institution of Washington for his own investigations. The Carnegie Institution of Washington continued to support Noyes's investigations until 1927, with grants totaling $154,500. Noyes

was director of this laboratory for sixteen years, and during this period he himself provided half the money for its support.

It is hard to overestimate the importance of the Research Laboratory of Physical Chemistry in the development of science in America. Many of the leading American physical chemists of the past fifty years received training and inspiration in this laboratory, where Noyes set the high standard for American physical chemistry that contributed to its rapid progress to a preeminent position in the world. Among the workers in the laboratory were G. N. Lewis, W. R. Whitney, W. D. Coolidge, C. S. Hudson, C. A. Kraus, R. C. Tolman, W. D. Harkins, H. M. Goodwin, Edward W. Washburn, W. C. Bray, Yogoro Kato, Ming Chow, K. G. Falk, R. B. Sosman, John Johnston, F. G. Keyes, J. C. Blake, C. W. Kanolt, W. H. Whitcomb, R. Haskell, A. C. Melcher, H. C. Cooper, G. W. Eastman, E. B. Spear, H. T. Kalmus, M. A. Stewart, M. S. Sherrill, C. L. von Ende, A. Edgar, F. F. Rupert, W. J. Winninghoff, G. H. Burroughs, E. L. Connelly, F. L. Hunt, B. F. Brann, F. S. Farrell, C. R. Boggs, R. H. Lombard, J. A. Beattie, J. H. Ellis, D. A. MacInnes, E. S. Freed, L. B. Smith, and L. R. Westbrook.

Claude Hudson told me that Noyes once said to him, "Dr. Hudson, it has been a great satisfaction to me that so many of the leading chemists of today were once in our M.I.T. Research Laboratory."

Noyes was invited to become Acting President of the Massachusetts Institute of Technology in 1907, a critical time in the history of the Institute. He served as Acting President for two years. During this time he gave much thought to improving methods of instruction and to the social life of students.

In 1913 he became associated on a part-time basis, at the request of George Ellery Hale, with the California Institute of Technology (then called Throop College of Technology), and in 1919 he resigned his post in M.I.T. and moved to California. During the remaining years of his life he devoted himself to developing the California Institution into a great center of education and research in science and engineering. He and Hale, who was a member of the Board of Trus-

tees, succeeded in bringing the physicist Robert Andrews Millikan from Chicago to Pasadena to develop the field of physics and to serve as chief administrative officer of the Institute.

Noyes's personality was reserved, but he was not at all withdrawn from the general activities of the California Institute of Technology, nor of the scientists of the nation as a whole. He never sought publicity, and he was rarely mentioned publicly in connection with innovations or changes in policy that led to the progress of the California Institute of Technology. Millikan became a great public figure, who in the minds of the people of the country represented the California Institute of Technology; but Noyes was often the one who was responsible for the policies that were announced by Millikan. Noyes had strong feelings about administrative matters and he worked hard, in a very quiet way, behind the scenes, to get his ideas accepted by the other members of the administration of the Institute. It seems likely that he was primarily responsible for determining the policies of the Institute, including the emphasis on pure, rather than applied, science; the limitation of the number of undergraduate students to 160 (at the present time, 1956, 180) per annual class; and the emphasis on the humanities and undergraduate, graduate, and post-doctorate research.

Noyes's feelings about research may be communicated by a paragraph from his Nashville address as President of the American Association for the Advancement of Science, in 1928. He said, "While *science* has through daily experience come to be universally recognized as vitally important, yet it is often not realized that science does not 'just grow'—that it arises from *research,* and that research is a sensitive plant which will grow successfully only from carefully selected seeds—the best brains of the nation; and which must be protected against the frost of dogmatic intolerance, against the drought of administrative routine, against the flood of modern mass education, against over-forcing through the impatient demands of practical men, and against the blights of poverty and social neglect. Research will come to its own in any community only when its members, in the

words of Pasteur, regard their research laboratories as their temples."

Noyes believed that students of chemistry should be introduced to research as early as possible. He was always on the watch for "carefully selected seeds" and he was a good judge of young people. I may mention as an example that in 1925 he arranged that twelve freshman students in the California Institute of Technology spend the time that would otherwise be devoted to the general chemistry course in carrying out small investigations, which were directed by me, under Noyes's general supervision. One of these investigations, continued by the first-year student throughout the summer, led to a published paper ("An X-ray Study of the Alloys of Lead and Thallium," by Edwin McMillan and Linus Pauling, *J. Am. Chem. Soc.*, 49 [1927]:666). For many years a senior thesis was required of students graduating in chemistry in the California Institute of Technology, as well as in the Massachusetts Institute of Technology. Noyes himself published many papers with undergraduate students as coauthors; among these undergraduates may be mentioned K. S. Pitzer, C. D. Coryell, A. Kossiakoff, and C. S. Garner.

In Boston he had been fond of sailing, and he made trips on his yacht, with young friends. In Pasadena this interest was largely replaced by camping. He had a large touring car, and he liked to drive with the top down. It was his custom in the 1920s to invite new graduate students in chemistry to go with him on a camping trip to the desert, especially the Palm Springs region, or to stay for a day with him in his beach house at Corona del Mar. These trips gave him an opportunity to size up the new graduate students. The time was spent partly in enjoying nature, and partly in discussions of scientific interest. In the evening by the campfire, Noyes would often recite poetry at length, with evident pleasure and enthusiasm. He was also fond of tennis.

In Pasadena he lived only one block from the laboratory, and he was a familiar figure on San Pasqual Street, as he walked along swinging his green cloth bag stuffed with books and papers.

Noyes was intimately involved in the early history of chemical pub-

lication in the United States. In 1895 he founded a journal, *Review of American Chemical Research,* which he himself edited for several years, and which later became the important publication *Chemical Abstracts.* He was President of the American Chemical Society in 1904—the youngest man ever to hold this office. He struggled, but without success, to have the American Chemical Society primarily devoted to pure chemistry and controlled by university chemists. During World War I he served as Chairman of the National Research Council, an organization set up through the efforts of Noyes, Hale, and Millikan to aid the National Academy of Sciences in advising the government on scientific questions. He served as President of the American Association for the Advancement of Science in 1927. He was awarded the Humphry Davy Medal by the Royal Society of London in 1927, the Willard Gibbs Medal by the Chicago Section of the American Chemical Society in 1915, and the Theodore William Richards Medal by the Northeastern Section of the American Chemical Society in 1932 (first recipient), and he received honorary degrees from Harvard, Yale, Clark, Maine, and Pittsburgh. He was elected to the Academy in 1905 (editor of the Proceedings 1915–1916). He was a member of the American Philosophical Society, Deutsche Chemische Gesellschaft, Bunsen Gesellschaft, and a foreign Associate of the Royal Society, Edinburgh.

Despite his rather reserved personality, which was perhaps due to shyness, he had a great influence on students. He inspired them by his own unselfish devotion to science, his high principles, and his idealism, which was sometimes expressed in poetic selections that he read in class. He believed in the importance of a broad basic education, and was primarily responsible for the requirements that undergraduate students in chemistry in the California Institute of Technology receive good training in physics and mathematics also, and that all undergraduates devote about twenty percent of their time to courses in the humanities. Noyes strove to discover the most talented among his students as early as possible, and to encourage them by the provision of special instruction and other opportunities for rapid

growth, such as scholarships permitting summer travel in Europe. His estate was left to the California Institute of Technology for the support of research in chemistry; at the present time it provides stipends of several Arthur Amos Noyes Post-doctoral Fellows each year. In addition, the sum of $10,000 was left to the California Institute of Technology for support of a fellowship in radiation chemistry, called the George Ellery Hale Fellowship.

The qualities of Arthur Amos Noyes that impressed themselves most strongly on his associates were his gentlemanliness, his integrity, and his unselfishness. He was devoted to science and to education. His effectiveness in his work is attested by the great number of able scientists who came under his influence and received part of their training from him.

During the last fifteen years of his life he was troubled by illness. A false report of his death was published in the Pasadena papers and elsewhere in 1923 at a time when he had had a throat operation. He died of pneumonia, after a period of suffering from cancer, on June 3, 1936.

KEY TO ABBREVIATIONS

Am. Chem. J. = American Chemical Journal
Ber. d. deutsch. chem. Ges. = Berichte der Deutschen Chemischen Gesellschaft
Calif. Inst. Technol. Bull. = California Institute of Technology Bulletin
Chem. Rev. = Chemical Reviews
J. Am. Chem. Soc. = Journal of the American Chemical Society
J. Chem. Educ. = Journal of Chemical Education
J. Chim. Phys. = Journal de Chimie Physique
J. Wash. Acad. Sci. = Journal of the Washington Academy of Sciences
Phys. Rev. = Physical Review
Pop. Sci. Mon. = Popular Science Monthly
Proc. Am. Acad. Arts Sci. = Proceedings of the American Academy of Arts and Sciences
Proc. Nat. Acad. Sci. = Proceedings of the National Academy of Sciences
Riverside Jun. Coll. Bull. = Riverside Junior College Bulletin
Technol. Quart. = Technology Quarterly
Technol. Rev. = Technology Review
Throop Coll. Technol. Bull. = Throop College Technology Bulletin
Z. physik. Chem. = Zeitschrift für physikalische Chemie

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