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DUNCAN ARTHUR MACINNES

1885—1965

A Biographical Memoir by

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LOVSKY

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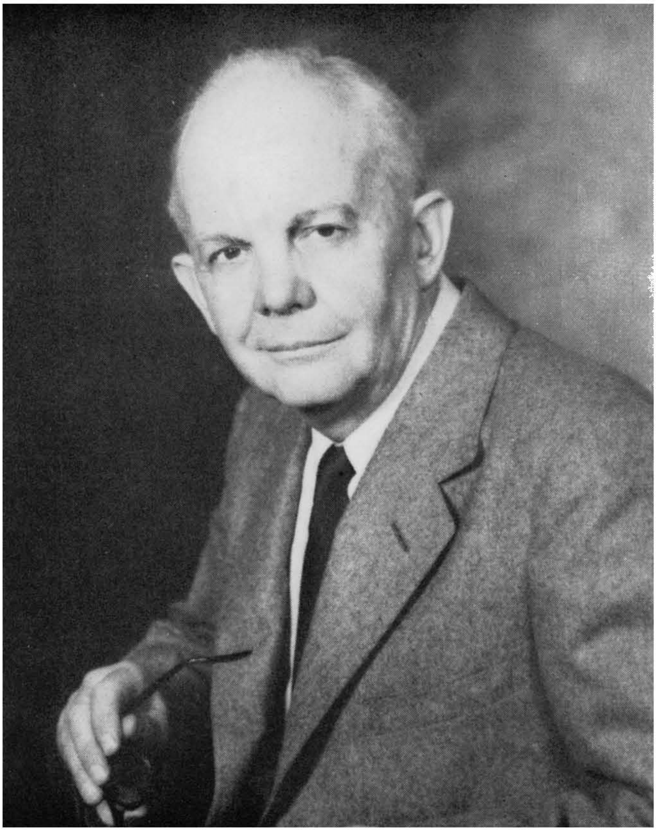
Biographical Memoir



D. A. MacInnes

DUNCAN ARTHUR MacINNES

March 31, 1885–September 23, 1965

BY LEWIS G. LONGSWORTH AND
THEODORE SHEDLOVSKY

IN THE DEATH of Duncan Arthur MacInnes on September 23, 1965, America lost one of its outstanding electrochemists. He was a dedicated scientist and experimentalist, with a passion for precision, whose main interest and whose most important contributions were concerned with solutions of electrolytes. The authors were closely associated with him throughout nearly the entire period of his distinguished career at the Rockefeller Institute and University, and the preparation of this memoir affords us a most welcome opportunity to acknowledge our indebtedness to him for the guidance and encouragement that he so generously accorded us, first as his research assistants and later as his associates. Two years before his death, Dr. MacInnes prepared for the National Academy of Sciences an autobiographical sketch which we shall follow rather closely, except for his too modest appraisal of the significance of his own work.

Duncan Arthur MacInnes was born in Salt Lake City, Utah, on March 31, 1885. His father was a merchant whose prosperity depended upon the violently fluctuating economy of the far West of the time. When Duncan was ten the family moved to

Bingham, Utah, then a small mining town, where his father was engaged in business with his uncle. This was the first of many moves necessitated by such conditions as the varying prices of metals, the exhaustion of mines, and the accompanying economic instability. The depression of 1893 was particularly hard on the West since this area was not self-supporting and depended largely upon the flow of investments from the East. Such a flow naturally dried up during a recession and brought on a protracted period of straitened circumstances for the family. Duncan's father succeeded in finding employment in Evanston, Wyoming, then in Park City, Utah, and finally in Mercur, Utah. There, between his twelfth and sixteenth year, Duncan became aware of the subject of electricity and, with the aid of local electricians, carried out such simple experiments as were possible with the crude materials at hand. Galvanic cell batteries particularly aroused his interest and continued to do so throughout his life. The Daniel cell, then widely used in railway signal systems, had many features, such as its liquid junction, that later provided areas of research in which he made probably his most significant contributions.

An event that greatly influenced Duncan's life was a nearly fatal streetcar accident at the age of thirteen. In addition to the loss of two fingers of his left hand, one leg was seriously injured, incapacitating him for athletic activities for a number of years. Thus, restricted in his contacts with fellow students and dissatisfied because the public schools of the towns in which the family lived absorbed little of his energy, he spent much time on books of popular science. His mother, although having little formal education, was widely read in English and American literature and her intellectual interests were naturally communicated to her two children, Duncan and his younger sister, Jean. Mrs. MacInnes did not oppose her son's early attempts at experiments in science, but there is good reason to believe that she would have been better pleased if he had chosen something other than a scientific career.

At the age of sixteen, Duncan entered the preparatory school of the University of Utah with the idea, prevalent among many youths of the time, of becoming an electrical engineer. He had the good fortune to board at the same house with S. F. Acree, who later became head of the pH Standards Division of the National Bureau of Standards, and this intimate contact with a man actively engaged in research had a most significant influence on him. With Dr. Acree's aid he was allowed to enter the college freshman course in chemistry during the second year of his preparatory work, and despite some disapproval by his parents, who had little knowledge or understanding of chemistry as a career, he decided to become a chemist. On entering the freshman class at the University of Utah in 1903, he found his excellent chemistry teacher, Dr. W. C. Ebaugh, helpful in many ways that aided in confirming his growing desire to prepare himself for scientific chemical investigations.

Just before Duncan was to enter college, the town of Mercur was almost completely destroyed by fire, and with Mr. MacInnes' business gone, the family moved to Salt Lake City. By serving as a student assistant in the chemical laboratories of the University in his junior and senior years, Duncan was able to contribute to the support of the family while paying for his tuition. Although this work, in addition to his regular studies, proved arduous, it gave him familiarity with the details of elementary chemistry. It was Dr. Acree, however, who aroused his interest in physical chemistry.

After his graduation from the University of Utah in 1907 with the degree of B.S. in chemical engineering, Duncan found it difficult to obtain employment because the country was in the midst of another depression, but he finally secured a position with the Phelps-Stokes Company at Berlin, Nevada. Here he encountered what was probably the last of the frontier in the United States and his subsequent development as an effective and ardent supporter of the conservation of the beauties of nature was doubtless kindled by this experience. Although the work was not uninteresting, there was little in the life associated with mining operations that attracted him. In any case the mine was soon closed and he returned to Salt Lake City in search of further employment. This he found at a mine located on the border of Utah and Nevada, but again the job was of short duration and the summer of 1908 found him with his family in American Falls, where his father had once more become established in business.

During the year that he was out of college young MacInnes applied for fellowships at a number of eastern schools and considered himself most fortunate in obtaining one at the University of Illinois, where the Department of Chemistry had been recently reorganized under the leadership of Professor W. A. Noyes. He arrived in Urbana in the autumn of 1908 and, having chosen physical chemistry as his major interest, he started study and research under Dr. E. W. Washburn, who had just come to Illinois from the Research Laboratory of Physical Chemistry at the Massachusetts Institute of Technology in Boston. After a brief, but difficult, period of adjustment, MacInnes found the atmosphere of the Chemistry Department most stimulating, from the point of view of both study and research.

The renaissance in physics had not yet begun, however, and the graduate courses in that area were less stimulating to him than those in chemistry. In later years he regretted his failure as a graduate student at Illinois to take advantage of the excellent facilities that were available in mathematics, an oversight that may account, in part at least, for his subsequent main concentration on experimental research. His graduate work, a study of moderately concentrated aqueous salt solutions, was conducted under the direction of Professor Washburn and led to the Ph.D. degree in 1911. Although this work failed to answer a question that it raised, namely, the magnitude of ion hydration, it did provide a background for the recognition of the complete dissociation of strong electrolytes in aqueous solution that came a few years later.

On completion of his doctoral work in 1911 MacInnes was appointed instructor in physical chemistry and three years later was advanced to associate. On obtaining, with some struggle, permission to do research on a problem of his own choosing, he started work on the application of simple galvanic cells to the determination of the properties of salt solutions. Although the title of his first independent publication, "The Mechanism of the Catalysis of the Decomposition of Hydrogen Peroxide by Colloidal Platinum," does not suggest an interest in galvanic cells, this excursion into surface and interface chemistry provided the necessary background for his subsequent work on hydrogen overvoltage. It was followed, however, by a paper with Karr Parker entitled "Potassium Chloride Concentration Cell" in which the experimental results were theoretically interpreted in terms of ion activities, rather than simple concentrations, a view that held his interest in later years, as it continues to do for electrochemists to this day. Of the nine papers that he published during his six years on the staff of the University of Illinois, five were in collaboration with others, and the same number were concerned directly with galvanic cells.

In 1917 he left Illinois, presumably for a year of study at the Research Laboratory of Physical Chemistry at the Massachusetts Institute of Technology, now no longer in Boston but in Cambridge. There he was appointed assistant professor and in 1921 was promoted to associate professor. Although the founder and director of the Laboratory, Professor Arthur A. Noyes, was dividing his time between M.I.T. in Cambridge and Throop College (now the California Institute of Technology) in Pasadena when MacInnes arrived, Duncan found the research atmosphere stimulating indeed since he had many interests in common with the director. An early research project at M.I.T. was concerned with X-rays and crystal structure but the results of this work did not appear until 1924-1926. X-ray crystallography was then in its early phases and MacInnes was inclined to ascribe his failure to grasp the opportunity that this work afforded to his insufficient background in physics and mathematics. It should be noted, however, that his bibliography for the interval from 1919 to 1924 lists fourteen publications originating at M.I.T., all of which are in the area of electrochemistry, suggesting, as later work confirmed, that his X-ray investigations were a digression. They did, however, result in the initial association of one of us with him, a relationship that remained close throughout the rest of his life.

The work with X-rays brought MacInnes into contact with W. R. Whitney of the General Electric Company and he accepted, somewhat reluctantly, an offer, made through Dr. Whitney, to supplement his academic income by organizing research work for the F. C. Huyck Company in Rensselaer, New York. The main business of the company was the manufacture of papermakers' woolen felts. Accordingly, in conjunction with a control laboratory at the factory, he conducted pertinent experimental work with a few assistants at M.I.T. on a part-time basis. At this time textile manufacturers in the United States had employed few chemists or physicists, for whom a proper approach to a number of practically useful problems was relatively simple. Although some useful and profitable results were obtained, MacInnes had little heart or interest in industrial research and resented the time and energy that it required.

He found his close contact with the top management of the rather small company to be rewarding in other ways, however, such as providing some insight into the modern business world and disclosing that liberal views which he held, but perhaps not as strongly as did his mother, were not necessarily inconsistent with sound business. F. C. Huyck was one of the early companies to adopt profit sharing, medical and dental care of employees, and, in general, a liberal labor policy. But, on the whole, this experience in industrial research had little, if any, effect on his scientific work, except possibly to retard it somewhat.

In 1925 MacInnes obtained a sabbatical leave from M.I.T. for study and travel in Europe. He would have preferred to work with Peter Debye, whose theory of interionic attraction had been published with Hückel two years previously. But Debye was in America in 1925. Consequently much of the year was spent in Paris, where concern with mathematics and thermodynamics was pleasantly supplemented by visits to museums, churches, and galleries and, of course, in learning French. With Paris as a center he visited Holland, Switzerland, and Italy. His longest visit, of about two months, was to England where he met many of the workers in physical chemistry and where he particularly enjoyed the friendship and hospitality of F. G. Donnan. Although he was entertained more in England than in the other countries he visited, he was least happy there. It was a period in which the war debts were under discussion and, although he found the English to be kind as individuals, he left with the impression that Americans were not too popular and that the general atmosphere was somewhat hostile, an impression that was to be dispelled on subsequent visits.

Back at the Massachusetts Institute of Technology in the autumn of 1925 he continued his research on electrolytes. His experimental work dealt with the development of the moving boundary method for determining transference numbers and the measurement of the potentials of galvanic cells containing liquid junctions. It was also during this period that he started to write a treatise on electrochemistry that appeared some twelve years later.

During his absence abroad he had been assigned to the teaching of a course in colloid chemistry. At that time this was a subject in which reproducible and precise measurements were difficult to realize, and his lack of enthusiasm for the assignment may have been a consideration in his acceptance of a position at the Rockefeller Institute for Medical Research in New York in 1926. During his years in Cambridge he had become acquainted with W. J. V. Osterhout, a professor at Harvard who had transferred to the Rockefeller Institute in 1925. Dr. Osterhout was a physiologist who was convinced that his science could benefit from advances in fundamental electrochemistry, and it was through his influence that MacInnes was offered a position as Associate Member at the Rockefeller Institute, where he worked for the remainder of his life, becoming a Member in 1940 and Member Emeritus in 1950. The arrangement was not that he should do biological work but that he should continue his researches on the electrochemistry of solutions and be available for consultation on physicochemical problems. On the positive side the change offered him freedom from formal teaching, a generous budget, technical assistance, as well as the welcome abandonment of his industrial consultative work. On the negative side there was relative isolation from workers in related fields. This was relieved somewhat by contacts with chemists at Columbia and New York universities, and associations with colleagues who were soon added to the staff of the Rockefeller Institute and who formed a small group of researchers in physical chemistry. This group included his present biographers, one of whom came in 1927 to work on electrolytic conductivities and the other in 1928 as a Fellow of the National Research Council to work on the moving boundary method. Both have remained at Rockefeller to the present and have continued work, for the most part, in areas pioneered by MacInnes.

The work at Rockefeller involved transference numbers by the method of moving boundaries, concentration cells with transference, and electrometric titrations. It was in the course of studies in the last field that he hit upon a method for making small and sensitive glass electrodes for measuring the pH values of solutions. Later, with Malcolm Dole, a successful search was made for a suitable glass that soon became commercially available. These results, based on the earlier researches of Haber and Hughes, attracted attention quite out of proportion to their scientific importance, but they did have the virtue of being decidedly useful for biological and medical purposes. One such application was the adaptation of automatic pH control in bacterial cultures with the aid of a Compton electrometer as a potentiometric detector. The present widespread use of the glass electrode for pH control, however, had to await the development of electronic technology.

MacInnes considered perhaps his most important scientific contribution to be the experimental confirmation of the Debye-Hückel theory of ionic interaction afforded by the work of his group. As an early exponent of the conjecture that strong electrolytes are completely dissociated in aqueous solutions, he recognized the significance of this theory for electrochemistry and of its extension to transport processes by Onsager and Fuoss. The confirmation involved both strong and weak electrolytes. For strong electrolytes the potentials of concentration cells were combined with transference numbers, measured by the method of moving boundaries, to obtain the salt activity. Since these cells required but one type of electrode, it was possible to make measurements on solutions so dilute that the finite sizes of the ions could be neglected and the theory thus confirmed in the limit of small concentrations. In the case of weak electrolytes, conductivity measurements were made at still lower ion concentrations, and these afforded an even more convincing test of the Debye-Hückel limiting law.

With the appearance, in 1937, of Tiselius' work on the electrophoresis of proteins, the activity of the laboratory shifted to that field. The change was made relatively easily since much of the experience gained in the development of the moving boundary method for strong electrolytes could be adapted to materials of high molecular weight. Following improvement of the optical procedure for observing the boundaries, studies were made of naturally occurring protein mixtures such as egg white and normal and pathological human sera and plasmas. Many cooperative researches were carried out with workers both in and outside the Rockefeller Institute, a summary of which formed the core of a Sigma Xi lecture that was given in 1940.

A field of research in which MacInnes maintained an interest for many years was the EMF centrifuge, the earlier work with which was done by des Coudres and Tolman. Aside from its theoretical interest he considered the instrument to have decided possibilities as a tool for investigating solutions of electrolytes in nonaqueous solvents. The work on sedimentation potentials was undoubtedly triggered by the conviction that transport data could thereby be obtained for nonaqueous systems approaching the complexity of those encountered at the membranes and phase boundaries of biological material. The research in this area was done in collaboration with Drs.

Roger Ray, Margaret Dayhoff, and Robert Kay. Simultaneously he initiated an experimental study of the iodine coulometer with the objective of obtaining a more accurate value of one of the fundamental constants, the Faraday equivalent. This was a natural outgrowth of his other interests since it involved precision current control, already used in the determination of transference numbers, and accurate electrometric titrations. The closing years of his life were spent in active work on this research, which was unfortunately interrupted by his death.

For a number of years he worked with the New York Academy of Sciences, helping to arrange a series of small conferences designed to promote active discussion of different scientific topics; in 1944 he became president of that organization. For the conferences to achieve their objective, he considered it essential that the topics be in areas in which actual work was in progress and that participation be restricted to currently active investigators in the designated fields. Although the early conferences sponsored by the New York Academy achieved this objective, he felt that the effectiveness of later ones was impaired by their success in attracting too large a crowd. Profiting by this experience he suggested to Dr. Jewett, then president of the National Academy of Sciences, that conferences on topics of active research interest be arranged under the auspices of that Academy, limiting the maximum number of participants to twenty-five, and providing as much time as possible for informal discussion. With the enthusiastic support of Presidents Richards and Bronk, thirteen conferences following this plan took place in the years 1945 to 1953. Of these, eight were for periods of three days at Rams Head Inn, Shelter Island, Long Island, where distraction from scientific matters was minimal. In MacInnes' view, these conferences filled several needs for the following reasons: (*a*) meetings of scientific societies have become so huge that workers in specific fields have difficulty in getting in touch with one another; (*b*) the time for discussion is never sufficient; (*c*) the United States is so large that it is better to organize the key men in a field rather than to leave the matter to chance; and (*d*) adequate discussion of any topic invariably cuts across the artificial divisions of science as represented by the many societies. He derived much satisfaction from the vital role that he played in the development of these conferences and justifiably considered his achievement a major contribution to American science. The stimulus provided by these conferences, and by the published reports resulting therefrom, has invariably served to catalyze advances in the given area. A glance at the current calendar of scientific meetings reveals that many of them are modeled after the conferences initiated by MacInnes and thus indicates the continuing value of his plan.

Although published nearly thirty years ago, his book *Principles of Electrochemistry* is still widely used and references to it are to be found in scientific journals published throughout the world. In common with classics from other branches of science it is available in paperback edition.

As its President, 1935-1937, and as the recipient of its Acheson Medal, 1948, MacInnes was recognized by the Electrochemical Society for his outstanding contributions to the science to which he devoted much of his life. The award of the Nichols Medal by the American Chemical Society in 1942 indicates that his interests included areas of physical chemistry other than electrochemistry. During World War II he was active in the field of chemical warfare as director of a group of investigators at the Rockefeller Institute. For this work he was granted the Presidential Certificate of Merit in 1948. On another OSRD contract he also participated in an early study directed toward isolation of uranium 235. The honors that he cherished most highly were his election to the National Academy of Sciences (1937) and the American Philosophical Society (1942).

Born in mountainous country, he returned to such surroundings for recreation whenever possible. His outdoor activities included hiking, canoeing, skiing, and mountain climbing. In the practice of this last avocation he developed considerable technical skill and on at least one occasion his judgment and mountaineering experience saved his party from a potentially serious mishap. It was doubtless inevitable that his love of the wilderness should make him an ardent and effective conservationist. He was a member of the American Alpine Club and the Appalachian Mountain Club, and in working with the latter organization he took part in active propaganda for the preservation of the natural beauty of our environment, especially for the national park system.

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KEY TO ABBREVIATIONS

Ann. N.Y. Acad. Sci. = Annals of the New York Academy of Sciences
Chem. Rev. = Chemical Reviews
Cold Spring Harbor Symp. Quant. Biol. = Cold Spring Harbor Symposia on Quantitative Biology
Ind. Eng. Chem. Anal. Ed. = Journal of Industrial and Engineering Chemistry, Analytical Edition
J. Am. Chem. Soc. = Journal of the American Chemical Society
J. Bacteriol. = Journal of Bacteriology
J. Chem. Phys. = Journal of Chemical Physics
J. Exp. Med. = Journal of Experimental Medicine
J. Gen. Physiol. = Journal of General Physiology
J. Phys. Chem. = Journal of Physical Chemistry
Phys. Rev. = Physical Review
Proc. Nat. Acad. Sci. = Proceedings of the National Academy of Sciences
Rev. Sci. Instr. = Review of Scientific Instruments
Trans. Am. Electrochem. Soc. = Transactions of the American Electrochemical Society (later, Trans. Electrochem. Soc.)
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