NATIONAL ACADEMY OF SCIENCES

RICHARD CHACE TOLMAN

1881—1948

A Biographical Memoir by

JOHN G. KIRKWOOD AND OLIVER R. WULFEPSTEIN

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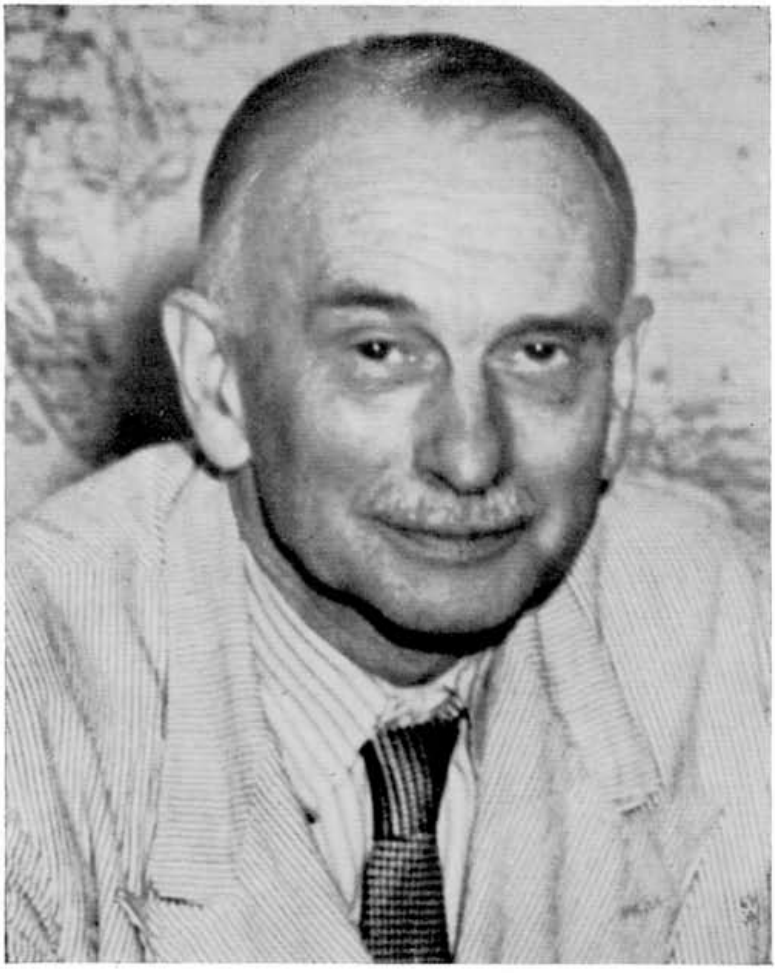

Richard C. Tolman

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BY JOHN G. KIRKWOOD, OLIVER R. WULF AND P. S. EPSTEIN

Richard Chace Tolman was born on March 4, 1881, in West Newton, Massachusetts, where he received his elementary and secondary school training in the Newton public schools. His father was a successful business man and his mother came from the Chace Quaker family of strong anti-slavery convictions. His mother's brother, Arnold Buffum Chace, for many years Chancellor of Brown University, exercised a major influence in Tolman's intellectual development.

After graduating from high school Tolman entered the Massachusetts Institute of Technology, from which he received the degree of Bachelor of Science in chemical engineering in 1903. He spent the following year in Germany, first studying at the Technische Hochschule in Charlottenburg, Berlin, and then in an industrial laboratory at Crefeld in northwest Germany. Returning to the Massachusetts Institute of Technology for graduate work he became Research Assistant in Theoretical Chemistry (1907-1909) and Research Associate in Physical Chemistry (1909-1910). During this period he came under the stimulating influence of Arthur A. Noyes, who pioneered the new science of physical chemistry in the United States. After receiving his Ph. D. in 1910, he served as Instructor in Physical Chemistry at the University of Michigan, 1910-1911, as Assistant Professor of Physical Chemistry at the University of Cincinnati, 1911-1912, and as Assistant Professor of Physical Chemistry at the University of California, 1912-1916. In 1916 he was appointed Professor of Physical Chemistry in the University of Illinois, where he remained for two years.

During World War I, Tolman served as Chief of the Dispersoid Section of the Chemical Warfare Service with the rank of Major. At the close of the war he remained in government service for three years, holding the posts of Associate Director and Director of the Fixed Nitrogen Research Laboratory of the

Department of Agriculture. In 1922 he was appointed Professor of Physical Chemistry and Mathematical Physics in the California Institute of Technology. Here he renewed his association with his friend and teacher A. A. Noyes, who had in the meantime come to California to participate in the founding and development of the new Institute. As Dean of Graduate Studies, a post which he held until shortly before his death, Tolman played an important part in the administration of the Institute for many years.

At the California Institute, Tolman began a long and productive phase of his scientific career. During this period he published many articles reporting the results of his experimental and theoretical investigations in physics and physical chemistry. He wrote four authoritative books, two on Statistical Mechanics (1927, 1938) and two on the Theory of Relativity (1917, 1934). His lectures in statistical mechanics, thermodynamics, and relativity were distinguished by their clarity, precision, and deep insight into the subjects. In recognition of his scientific achievements Tolman received many honors and academic distinctions. These included membership in the National Academy of Sciences, the American Philosophical Society, and the honorary degree of Doctor of Science from Princeton University in 1942.

Tolman was again called to national service in 1940. As Vice-Chairman of the National Defense Research Committee and Chairman of the Armor and Ordnance Division of that Committee, he played an important role in the organization and administration of the vast scientific program of the nation during World War II. As scientific adviser to General Groves, he was closely associated with the development of the atomic bomb. At the conclusion of the war, he contributed to the effort to solve the problems of international control of nuclear energy as scientific adviser to the United States representative on the United Nations Atomic Energy Commission. His distinguished service to the nation and to the world during World War II was recognized by the award of the United States Medal for Merit and the Order of the British Empire.

His war and postwar duties at an end, Tolman returned to

Pasadena in 1947 to resume his scientific work. After a tranquil and productive year, in which he completed several important papers on the thermodynamics of surface phases, he died on September 5, 1948, following a cerebral hemorrhage suffered without warning three weeks earlier.

Tolman's scientific interests were wide and varied. His rigorous and logical approach to scientific problems was reflected in the clarity of his writings and in the profundity of his physical insight which they reveal. His scientific legacy is unquestionably impressive and of permanent value. Tolman's first important contribution to science was the demonstration of the effect of centrifugal acceleration on the electromotive force of galvanic cells in experiments carried out at the Massachusetts Institute of Technology. Although this work grew out of the interest in applications of thermodynamics to chemistry characteristic of the time, it is worth noticing that the first paper contained both a thermodynamic and a kinetic derivation of the effect. Thus even these early investigations show the awakening of Tolman's interest in statistical mechanics, and foreshadow the later trends of his scientific thought in which the development of statistical mechanics played such an important role. It was precisely his deep understanding of the kinetic mechanism of the phenomenon that suggested to Tolman that not only the centrifugal acceleration of rotating conductors can produce an electromotive force (this fact was not new) but also the angular acceleration. In this way was discovered a new and more powerful method for measuring the inertia of the carrier particles of the electric current. At the University of California he performed in collaboration with Stewart the famous experiment demonstrating by this method the inertia of electrons in metals. The measurements were refined and extended in accuracy at the Fixed Nitrogen Research Laboratory in collaboration with Sebastian Karrer and E. W. Guernsey and at the California Institute of Technology in joint work with Mott-Smith. At the close of the article in which the results of the work at the Fixed Nitrogen Research Laboratory were described there is an acknowledgment characteristic of Tolman. The

authors, after expressing their thanks to three sources that had given support to the work, add that they desire "in particular to express to the Government their appreciation of the policy of encouraging the staff of a government laboratory to devote a portion of their time and facilities to the investigation of fundamental scientific questions which have no immediate bearing on the main problem of the laboratory. It is believed that such a liberal policy is of great importance in maintaining a proper scientific attitude on the part of the staff of a research laboratory."

Other work in his early years at the California Institute of Technology consisted in many important theoretical and experimental contributions to the solution of problems of chemical kinetics. His papers in this field included a treatment of the problem of rates of molecular activation adequate to explain observed rates of reaction. They particularly clarified the meaning of the energy of activation. Important to this treatment was the behavior of monomolecular reactions of which no quite satisfactory example had been known. He took great interest therefore in the researches of Farrington Daniels and his colleagues on the decomposition of nitrogen pentoxide, which uncovered the fact that this now famous and much studied reaction, over a wide range of conditions, maintains its apparently monomolecular course. To account physically for the rates of molecular activation indicated by the observed rates of reaction presented considerable difficulty and the possible role of radiation in this process was much discussed. Several of Tolman's theoretical contributions concerned the analysis and development of the radiation theory of chemical reaction rate. It was in large measure due to this clarification that the inadequacy of the radiation hypothesis became quite clear.

These papers on chemical reaction rate pointed the way to further experimental researches, notably those of Daniels and of Tolman himself with his students in the years that followed. Particularly significant was further work on the nitrogen pentoxide decomposition with H. C. Ramsperger in which this reaction was studied at moderately low, and finally at very low,

pressure where activation depending on collisional processes should occur at a much reduced rate. Under the latter conditions a falling off in the first order rate of this reaction was discovered. He also gave a theoretical treatment of the temperature coefficient of photochemical reaction. In 1932 there was published the results of a unique experimental study, with P. D. Brass, of the thermal reaction rate of an extremely rapid reaction, the dissociation of nitrogen tetroxide.

In his monographs on statistical mechanics, Tolman gave the most searching analysis of the foundations of this important field since the work of Willard Gibbs. In many papers on the subject, he added to the structure of statistical mechanics. He was influenced by the work of P. and A. Ehrenfest in placing emphasis on the necessity of distinguishing between fine-grained and coarse-grained probability densities in the definition of entropy and in the proof of the Boltzmann H-theorem. Tolman's interests in statistical mechanics and thermodynamics went hand in hand. Shortly before his death, he had completed an important extension of the Gibbs theory of surface phases.

Tolman's early interest in the theory of relativity, which he shared with his friend G. N. Lewis, grew with the years. In 1917 he published a book on special relativity which made this important subject available to the English speaking reader. Later he became interested in the cosmological implications of general relativity. In a series of papers he developed important theoretical results which helped to establish the theory of the expanding universe. This work culminated in his monograph on relativistic thermodynamics where his results were summarized and extended. The consequences of this theory and the interpretation of observational results in terms of it were worked out by Tolman in collaboration with E. P. Hubble.

Tolman was a man of broad intellectual interests which extended far beyond his field of specialization. Through his wife, Ruth Sherman, whom he married in 1924, he developed an interest in psychology and in the social sciences. He was deeply concerned with the philosophical, cultural, and social

implications of science. His wisdom and humanism are well expressed in the following quotation from an address which he delivered at Brown University in 1947:

"It is my faith that the ethical insight and scientific intelligence of man are such that the control of evil is possible. I am sure that humanity will continue to encounter great troubles, but I do not think that civilization will destroy itself. To surmount our troubles, we shall need courage, and patience, and clarity of thought, and sincerity in the advocacy of fair and reasonable courses of action. For these virtues we may pray, each in his own fashion."

In the death of Richard Tolman, many have lost a wise and generous friend. The nation and the world have lost a distinguished scientist, a profound scholar, a great man.

KEY TO ABBREVIATIONS USED IN BIBLIOGRAPHY

Astrophys. Jour. = Astrophysical Journal
Bull. Amer. Math. Soc. = Bulletin of the American Mathematical Society
Calif. Inst. For. = California Institute Forum
Chem. Metal. Eng. = Chemical and Metallurgical Engineering
Gen. Elec. Rev. = General Electric Review
Jour. Amer. Chem. Soc. = Journal of the American Chemical Society
Jour. Chem. Phys. = Journal of Chemical Physics
Jour. Frank. Inst. = Journal of the Franklin Institute
Jour. Infect. Dis. = Journal of Infectious Diseases
Jour. Opt. Soc. Amer. = Journal of the Optical Society of America
Jour. Proc. Ad. Assoc. Amer. Univ. = Journal of Proceedings and Addresses of the Association of American Universities
Phil. Mag. = Philosophical Magazine
Phys. Rev. = Physical Review
Proc. Amer. Acad. Arts Sci. = Proceedings of the American Academy of Arts and Sciences
Proc. Nat. Acad. Sci. = Proceedings of the National Academy of Sciences
Rev. Mod. Phys. = Reviews of Modern Physics
Rev. Sci. Instru. = Review of Scientific Instruments
Sci. Mo. = Scientific Monthly
Univ. Calif. Chron. = University of California Chronicle

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