LUDWIG BOLTZMANN. 1844—1906.

Ludwig Boltzmann was born on February 20, 1844, and was the son of Ludwig Boltzmann, Fin.-Bez.-Kommiss., and Katherina Paurenfeind. He was educated at the Gymnasium at Linz, from whence he proceeded to the University of Vienna. He appears to have been early attached to the study of molecular mathematical physics, for his paper, "Ueber die mechanische Bedeutung des zweiten Hauptsatzes der Wärmetheorie," was read on February 8, 1866, and was thus written at the age of 21. Boltzmann obtained the Doctorate, and became Privat-Dozent, and in 1867 was appointed Assistant in the Physical Institute of the University of Vienna. This Institute, where much of Boltzmann's best work was done, was a large and dingy-looking house in the Türkenstrasse, and formed a striking contrast to the palatial edifices without which no physical department is content nowadays. But, if the bricks and mortar looked uninviting, the brains inside more than made up for the deficiency. In or before 1875, Boltzmann became corresponding member of the Vienna Academy of Sciences, and, about a year later or thereabouts, he obtained a chair at the University of Graz, where he remained till about 1891. In 1876 he married Henrietta von Aigentier, and in 1885 he was promoted from corresponding to ordinary membership of the Vienna Academy. In 1891 he was called to fill a vacant chair at Munich, and four years later was appointed Professor of Physics at Vienna. In 1904 he was called to Leipzig. He was not happy in the new surroundings, and the longing to return to his old University resulted in his stay at Leipzig being an extremely short one—a matter of a few months, we believe. In addition to the duties attaching to the Chair of Physics, the authorities placed a course of outside lectures in his hands, and with this and other work he was able to earn an income of about £800 a year. His election as corresponding Fellow of our Society dates from 1899.

In estimating the value of Boltzmann's work in that branch of mathematical physics with which his name is so intimately associated, it would be a difficult and unproductive task to discuss claims of priority on mere matters of details. The groundwork of the Kinetic Theory of Gases, and in particular the opinion that temperature is a quantity of the same kind as molecular kinetic energy, had of course remained buried in the manuscript of Waterston long before Boltzmann's first paper was published. But while others were working side by side with Boltzmann during a great part of the time that he was publishing his best work, it cannot be said that this concurrence in any way lessened the importance of Boltzmann's work. It is certain that his first paper on the Second Law antedates by several years the first of the Clausius-Szily series of papers on the same subject. If Boltzmann's original proposal to establish that law on a purely deductive basis, and to penetrate beyond the inevitable assumption, which seems to present itself at every step as a bar to further progress, formed the work of a lifetime, certainly Clausius and Szily did not do much, if anything, in attempting to unearth and, if possible, root out the assumption in question. In fact, the assumption underlying the Second Law has been a stumbling block and at the same time a stimulus to progress which has played much the same part in the development of statistical thermodynamics that Euclid's axiom has played in the development of geometry.

In the first place the notion of temperature leads to the conception of a law of partition of energy. Boltzmann was not long in following up in the direction started by Maxwell, and his criticisms and further developments, leading in turn to further work from the pen of Maxwell—Boltzmann was only 24 at the time—must be regarded as striking achievements on the part of two young physicists of that period. Next comes the difficult question of irreversibility, and in the theorem known as Boltzmann's Minimum Theorem we have a remarkable contribution indeed. If any element of chance is assumed to enter into the question of molecular motions, this theorem establishes a definite tendency to a state of energy equilibrium. That it does not dispense with the inevitable assumption is shown by imagining the motion reversed. It is true that this would lead to a highly improbable hypothesis, namely, that the probability of a collision between two molecules depended on their motions after instead of before collision. But even so, the matter is not a question of pure particle dynamics. Later discussions of the minimum theorem viewed in the present aspect have led to an output of much good work on the part of Boltzmann.

A fresh line of thought was opened up by an idea previously suggested by Dr. Oskar Emil Meyer in the application of the theory of probability to problems of statistical dynamics. Boltzmann proved that in a molecular dynamical system if for a single molecule all values of the coordinates and corresponding momenta are *a priori* equally probable, then the most probable distribution in an aggregate consisting of a large number of molecules is the well-known Boltzmann-Maxwell distribution. He also established relations between the probability function and entropy. This method of investigation was applied quite recently to quite a different purpose, namely, the irreversible problems of radiation, by Planck, and, though Planck's book has only been out a short time, it has already received discussion at the hands of Dr. Paul Ehrenfest, of Goettingen. The publication of Helmholtz's paper on monocyclic systems gave Boltzmann another method of attack, and led to a detailed examination of the conditions that a system should be "statistically monocyclic," a point of view which does not seem to have been foreshadowed to any great extent by Helmholtz.

Of other subjects on which Boltzmann wrote, we need only refer to his lectures on Maxwell's electrical and optical theories, his studies of the Lagrangian equations for non-holonomic systems, and his papers on Hertz's experiments.

Boltzmann attended the British Association at Oxford in 1894, and was also present for a short time at the Southport Meeting in 1903, and many English workers were thus brought into personal touch with the Vienna physicist. His visit to Oxford will long be remembered. He was greatly struck with the reception accorded him and, in returning thanks for the foreign guests, he expressed a wish to "often come at England."

Since Boltzmann first came to the front the trend of physical thought has shifted from molecules to the ether, and from the ether to electrons. We have thus come back to kinetic theories, and have merely extended the order of smallness of the particles of which these theories take cognisance. But, while students of reversible phenomena have had fairly straightforward problems to solve, the problem of irreversibility still remains to a great extent a mystery, and nobody seems as yet to have got to the bottom of it. The irreversible phenomena of the universe all have a certain definite trend, and lead to the transformation of energy into certain definite forms. We say that certain forms of energy are less available than others, but why the less available forms are those associated with what are commonly called heat phenomena is a riddle which Boltzmann went far to solve, but which still presents difficulties.

In 1904, on the celebration of Boltzmann's sixtieth birthday, physicists in all parts of the world worked together to honour the occasion by producing as a *Festschrift* a monumental volume dealing with every aspect of physical thought.

The news that Boltzmann had committed suicide while away on his summer holiday last August came as a terrible shock to those who knew him. Of the details of the incident the present writer knows nothing, but surely it suggests several serious reflections. Is it not probable that Boltzmann's ever-active brain had been taxed too heavily by the difficult and elusive problems which he was endeavouring to solve? Mathematical research is a dangerous occupation if carried too far, and the consequences that may have been the result of this intense concentration of thought should prove a warning to others not to allow themselves to be too deeply absorbed in any particular investigation. The difficulty of tearing oneself away from a particular line of work till it has been finished constitutes a grave danger. There are few mathematicians and physicists who would not gladly accept life-fellowships that would enable them to devote their whole time to research, but would they live to do their best work under such artificial conditions? It may be that such obstacles and difficulties as the necessity of undertaking some elementary teaching constitute an analogue to the refrigerator which is necessary for the continuous and efficient working of a thermodynamic engine.

Boltzmann leaves behind him four children, and when last the present writer visited him at Vienna in 1903, his eldest son and daughter were studying for the University. It need hardly be added that the honorary [illegible] conferred on him by the Austrian Government.

G. H. B.