LORD RUTHERFORD

by

T. H. LABY

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Exhibition of 1851 Scholar from Australia to the Cavendish Laboratory, Cambridge
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PREFACE

This pamphlet is published in New Zealand and Australia as a tribute to Lord Rutherford, one of the greatest scientists and men of his age. No doubt it is a very inadequate one, but it may be of value to those interested in the lives of great leaders of thought or in modern physics. New Zealand is justly proud of its greatest son. I had the privilege of knowing Lord Rutherford from 1910 to his death. Great as he was as a physicist, to me he was a still greater man; he rendered most valued service to science in all the member nations of the British Commonwealth.

If this tribute should commend itself to its readers I hope, on a later occasion, to add to it some of his letters to me, and an account of the no small part which young Australian and New Zealand scientists, under Rutherford's leadership, took in the scientific discoveries of the Cavendish Laboratory.

Apology is needed for the quality of this paper. Nothing better was forthcoming. I am indebted to the printer for surmounting every difficulty within his power in producing this small book.

T. H. Laby.

Melbourne,
February, 1944.

LORD RUTHERFORD.

Ernest Rutherford, born at Brightwater, near Nelson, in the South Island of New Zealand in 1871, was the son of Martha and James Rutherford, a farmer. When Lord Rutherford was buried on October 25th in Westminster Abbey beside Newton, Darwin and other great scientists, England paid amply and fully her highest tribute to his genius, and paid it to one whose "death removed from science the most outstanding personality of the age."*

In what follows an attempt is made to describe some of his scientific discoveries, to give an indication of his life and public services. †

IN 1887 he went to Nelson College, a leading New Zealand school of which W. S. Littlejohn, later to become headmaster of Scotch College, Melbourne, was then third master and taught mechanics and chemistry. The headmaster of the school, W. J. Ford, had been a classical master at Marlborough. Rutherford, specially coached by Littlejohn, gained in 1889 a Junior University Scholarship in mathematics and classics at Canterbury College, Christchurch, a constituent College at the University of New Zealand.

Professor A. Bickerton was professor of physics and was the rather eccentric advocate of a theory of stellar collisions. Rutherford in 1893 obtained his B.A. degree and a senior scholarship in mathematics, and in the following year his M.A. degree. A contemporary of Rutherford's at Canterbury College says he played a prominent part in the College football team as a hard-working forward.

He was a candidate for the Exhibition of 1851 science travelling scholarship, but he was not placed first for that scholarship, and it was not until the candidate so placed had withdrawn that he was awarded it. It is desirable to explain that it was to Albert, Prince Consort, that the idea of establishing the "Exhibi-

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* His mother lived until a few years ago, being 92 when she died.

† Reprinted from the "Australian National Review," January issue, 1938.

tion of 1851 Scholarships" was due. The scholarships are paid from the profits derived from the first international exhibition held in London in 1851.

It was, I believe, at Canterbury College that he met Miss Mary Newton, his future wife. Rutherford proceeded to Cambridge, where he entered as the first "advanced" student under a new regulation of that University, which admitted students from other universities as research students. This was a most important innovation, as those who have read that most interesting of scientific autobiographies, Pupin's *From Emigrant to Inventor*, will appreciate if they compare the experience of Pupin at Cambridge in the previous decade with that of Rutherford. Pupin found Cambridge uninspiring and sterile, and in mathematics dominated by the Tripos examination.

Rutherford came under Sir J. J. Thomson, a great physicist and mathematician, who was at the height of his powers, and he worked beside J. S. Townsend, C. T. R. Wilson, P. Langevin and others, all of whom were to make scientific history.

ELECTROMAGNETIC WAVES

Several of those who knew of Rutherford's experiments which he made as a student at Canterbury College have stated that he transmitted electromagnetic waves through the walls of buildings and detected them by means of a magnetic receiver of his own construction. In his paper of 1897 on a "Magnetic Detector of Electric Waves" he states that it describes results obtained at Cambridge, but I have found no account by him of his New Zealand experiments.

In his Cambridge experiments, which he began on his arrival there in 1895, he used a Hertzian oscillator set up on the top floor of the Cavendish Laboratory. His magnetic receiver was so sensitive that it detected, at his rooms in Park Parade, the electrical waves (of some six or seven metres wave-length) which had been transmitted through six solid walls and a distance of half a mile. Both the New Zealand and Cambridge experiments were a record for the transmission of true electromagnetic waves.

The principle of the detector had been discovered in 1842 by Henry, who observed that the current from a discharging Leyden jar demagnetised a needle previously highly magnetised. Rutherford, not knowing of Henry's work (it seems not to have been known even in England where the records of this discovery were available), devised a very highly sensitive magnetic detector, after having investigated the whole of the physical processes involved. As he did so as a beginner at research in New Zealand over forty years ago, with very slender experimental resources, and on his own initiative, it was a considerable achievement.

This first research was a fertile one, for it led to the invention of many other magnetic detectors of wireless waves and to a large number of patents, including one taken out by Marconi in 1902. These inventions were usually announced in the press as entirely new, without any reference to what had gone before. I remember reading to Lord Rutherford a paragraph of this kind from the London *Times*.

RADIOACTIVITY

The French physicist Becquerel, in 1896, discovered by accident that salts of uranium emit a radiation which passes through black paper and acts on a photographic plate. M. and Mme. Curie, in following this up, discovered that certain uranium minerals were more radioactive than the element uranium itself. With great courage and energy they subjected a ton of pitch-blende to chemical treatment, and isolated from it in 1898 two new radioactive elements, polonium and radium.

The discovery of radium attracted widespread attention, and many scientists must well remember the wonder with which it was regarded, and the mystery its unusual properties were to physicists and chemists. In its property of being hotter than its surroundings, demonstrated by Curie and Laborde in 1903, it behaved contrary to all previous experience, and apparently this phenomenon contradicted the important principle of the conservation of energy.

In the discoveries relating to radioactivity Rutherford shared, and he was not prevented from doing so even though his experiments on the subject which he began in 1896 were interrupted by his transfer from Cambridge to Montreal in 1898, where he went as professor of physics to McGill University. He began his study of radioactivity by showing that uranium emits two kinds of radiation, one kind, which he called the alpha, being absorbed by some millimetres of air, while the other radiation, which he called the beta, penetrated many times that thickness of air. Two French physicists discovered later that radium gave a third very penetrating radiation which was called gamma-rays.

Rutherford was doubly fortunate in his appointment at McGill, in that the physics laboratory there had a tradition of research, and his colleagues were ready to assist him. There were two professors of physics; Professor Cox was one of them and, recognising the genius of his young colleague, generously relieved him largely of his teaching, thus enabling Rutherford to devote himself to his researches. In the Chair of Chemistry Rutherford had in Professor Soddy a colleague who was a skilled experimenter. They worked together from 1900 for two years, and in a joint paper formulated the atomic disintegration theory of radioactivity.

Rutherford first showed here the capacity to inspire men to work with him which was later to be seen at Manchester, at Cambridge, in his war work, and at international scientific gatherings. He not only attracted to his laboratory young men who wished to be trained in research, but experienced investigators were equally glad to work with him.

One of his first discoveries at Montreal was one that has been mentioned, namely, that if a solid surface is placed close to the radioactive element thorium, then the surface itself becomes radioactive. Rutherford was able to explain this because he had discovered that the element thorium produces when it disintegrates a gas which is called thorium emanation. This gas itself is radioactive and when its atoms break up they deposit radioactive atoms on adjacent solid surfaces. Rutherford discovered this phenomenon known as "excited radioactivity" in the middle of 1899, and had by the following year disentangled the complicated process by which it takes place.

M. and Mme. Curie simultaneously discovered that this effect was produced by the element radium, but they did not at first accept Rutherford's explanation of the process.

Rutherford and Soddy, in 1902, made the remarkable suggestion that helium might be one of the products of the disintegration of radioactive substances. This was fully confirmed in the following year, when the continuous emission of heat by radium was demonstrated, and Rutherford and Soddy put forward their theory of the disintegration of the atoms of radioactive elements. The year 1903 was then a decisive year in the development of the science of radioactivity.

Rutherford and Soddy had established by their experiments that radioactivity is accompanied by the formation of a series of new substances, each with distinct physical and chemical properties. For example, thorium produces from itself an intensely radioactive substance, which can be separated by its solubility in ammonia. This in turn gives a radioactive gas, and it in turn deposits a radioactive solid upon surfaces with which it is in contact.

To explain these observations they put forward an entirely new and startling theory. Atoms were no longer to be regarded, as they had been for over a century, as permanent, everlasting and indestructible. They could disintegrate into simpler atoms and give out energy in doing so. The atoms of radioactive elements broke up by chance, independently of their age or their physical condition (such as temperature), or of their chemical combinations. The rate of mortality was the same for one species, but varied widely between different species. Some had short lives and merry (energetic) ones, others had long lives of lethargy. When an atom disintegrated part of the atom was projected as an alpha particle, or alternatively an electron was ejected and so the atom lost some of its great internal store of energy.

While we have seen that the French and British scientists each contributed to the discoveries which form the phenomena of radioactivity, the French physicists did not at first agree with Rutherford that radium emanation was material and a gas, nor that the energy given out as heat by radium came from inside the radium atoms; they looked, instead, for some process by which it could come from outside the radioactive atom. Nor were the French scientists alone in rejecting these new theories. Lord Kelvin died in disbelief that atoms could disintegrate.

It is most remarkable that Rutherford had written by February, 1904, the first edition of his *Radioactivity*, and in it is to be found a complete exposition of the science of radioactivity; the details have since been added to, but all the essential principles are to be found in it. This incredible record of discovery relating to radioactivity was achieved in a period of seven years. Many discoveries had been made, complicated processes unravelled, a comprehensive theory formulated, and an account of all these had been embodied in a complete and lucid textbook.

These new ideas were to be very fertile ones. There had long been a controversy betwen Kelvin and the geologists as to the age of the Earth. Kelvin would not allow as possible the great age which the geologists assigned to it. The heat emitted by radioactive substances in the Earth's crust entirely changed the basis of Kelvin's estimate. The geologists were given, as Rutherford said, a blank cheque for the age of the earth. Later, radioactivity, by a still further development, was to enable an exact age to be placed on many rocks and minerals.

Soddy was to show how Rutherford's and his theory enable the radioactive elements to be classified in the periodic law of the chemical elements. These ideas led to the new conception of chemical isotopes: that is, elements or atoms which are chemically identical but physically different.

Rutherford's own developments of his discoveries in radio-activity fall into three periods, namely, his enunciation of the nuclear theory of the atom, the disintegration of atoms by alpha-ray bombardment, and, lastly, the transmutation of elements by artificial agencies and the study of the structure of the nuclei of atoms. The first of these periods falls within the time he was at Manchester, and during the second two he was at Cambridge.

ALPHA RAYS AND THE NUCLEAR ATOM

In 1908 Rutherford succeeded Schuster as professor of physics at Manchester, and he soon attracted to his laboratory distinguished physicists, including Hans Geiger, Niels Bohr, and Darwin. These, with his own research students, including Marsden, Royds, Chadwick and others, were soon to establish a new conception as to the structure of the atom.

As we have seen, Rutherford discovered in 1898 the alpha radiation emitted by uranium, but it was some years before the exact nature of the radiation was established. To this elucidation of its character Rutherford made the principal contribution. By 1909 it had been established that the alpha particle is a helium atom charged with two atoms of positive electricity, or, as it would now be stated, it is a helium atom which has lost its two electrons. It is ejected from radioactive substances with great energy, and Rutherford was to use for some twenty years alpha rays as a means of investigating the interior of atoms until still more effective means had been devised in his and other laboratories for the purpose.

Rutherford and Geiger, in 1908, devised a "counter" which enabled individual alpha particles to be detected. I was at the time a research student at the Cavendish Laboratory, and I noticed that this very novel and valuable device was not demonstrated at Rutherford's lectures at the Royal Institution. I ventured to ask him for permission to show it at the Royal Society *Soiree* and, with characteristic generosity, he consented to my doing so. I exhibited it at the *Soiree* of 1908 to show the counting of alpha-particles, using with it a special electrometer which I had devised. It proved much the most difficult experiment I have ever attempted to demonstrate. Counters of this kind are now widely used, but they are called "Geiger-Muller" counters, although they differ in no important respect from the original one described in 1908. Thirty years of experience in many laboratories have not eliminated all their vagaries.

Following the discovery of the electron, a theory had been put forward by Kelvin and J. J. Thomson as to the structure of the atom. This conception has been called the "plum-pudding atom," for according to it the atom is a sphere of positive electricity with electrons (like the fruit in a pudding) dotted about in the sphere. The theory did not meet with success. Two great steps needed to be taken before a structure could be given to the atom which accounted for its spectroscopic, chemical and other properties. Rutherford and his co-workers took the first in showing that atoms have concentrated at their centres nuclei which bestow on them many of their characteristic properties. The other great step was taken by Niels Bohr, then a student in Rutherford's laboratory, who showed that the electrons in an atom describe orbits round this nucleus like the planets describe their orbits round the sun.

Geiger and Marsden, by firing alpha particles into gold foil and other metals, clearly showed that these particles in their collisions with atoms were sometimes deflected through large angles. Some even recoiled straight back after a head-on collision. Rutherford gave a complete mathematical interpetration of these experiments, which showed that the positively electrified and massive part of an atom known as its nucleus must be very small in comparison with the rest of the structure. When to this conception Bohr in 1913 added his theory of the electron, the modern conception of the atom was launched and a new era in physics began.

Important as these ideas were, they were very slowly accepted, and I remember travelling in 1914 from Manchester with Rutherford to attend a meeting of the Royal Society where the quantum theory was to be discussed. Rutherford predicted before the meeting that there would be few who would accept it, and that proved to be the case. Ideas, which first-year students of physics to-day are expected to learn in a few lectures, many physicists at the beginning of this century took decades to accept.

TRANSMUTATION OF THE ELEMENTS

In the following account of Rutherford's investigations of the transmutation of the elements considerable use has been made of an article by Dr. Chadwick, the discoverer of the neutron and a distinguished pupil and colleague of Rutherford.

Rutherford was appointed in 1919 to succeed Sir J. J. Thomson in the Cavendish Chair of Physics at Cambridge. Two of the most distinguished British physicists, Clerk Maxwell and Lord Rayleigh, had filled that Chair before Thomson, and it fell to Rutherford to maintain, and raise, the great reputation of the Cavendish Laboratory as a centre of research which Thomson had gained for it.

Before he left Manchester Rutherford, using alpha-particles to bombard nitrogen atoms, had succeeded in disintegrating that atom. The significance of this was not at all fully appreciated at the time. On moving to the Cavendish Laboratory, he invited Dr. Chadwick to join him there in his experiments on the disintegration of atoms by bombarding them with alpha-particles. Rutherford "had long had a special love for the alpha particle, but now the nucleus also was admitted to the same intimacy, and the experiments on nuclear structure were his main interest." The advance was at first rapid, but later was slower, and the technique then used in experiments on splitting the atom required a larger number of very faint scintillations to be counted—a long and tiring matter. Gradually other techniques were developed. Thermionic valve amplifiers were made to record the impulses from Rutherford-Geiger counters. The cloud expansion chamber was used to make visible the collisions between atoms. Great electrical generators were built to produce artificially the equivalent of intense beams of alpha particles.

Dr. Chadwick writes: "The real reward for Rutherford's efforts to develop this field of work came in the spring of 1932, first with the discovery of the neutron, a particle the properties of which he had anticipated several years before and for which he and I and others, in the laboratory, had previously searched in vain, and shortly afterwards in Cockroft's and Walton's disintegration of elements by protons (the proton is the nucleus of the hydrogen atom)—disintegration for the first time by means under human control. I mention these two discoveries particularly, not only because of their special significance, but also because they are the fruit of his policy and direction. If they do not bear his name, these discoveries bear the stamp of his laboratory, and his delight in them was as great if he had made them himself."

One sometimes hears the view that if a university laboratory is to be effective in research it should have a few senior and experienced investigators rather than spend its effort in training younger workers in methods of research. The following is relevant to that view.

In Manchester Rutherford, assisted by a few distinguished investigators, met with great success in research. Dr. Chadwick, who had worked with him there, says: "In Cambridge conditions were different. There were, of course, a number of senior workers, but the young men with little or no previous training far outnumbered them. Rutherford recognised very clearly that the training of such large numbers of students would hamper the progress of his own work, but he accepted this as his duty. He gave the most careful thought to the problems on which he put his students, so that these would begin within their powers and lead to a well-marked and profitable line of research. He kept his eye on every man, expecting, and at times demanding, the best the man could do, and inspiring him with his own enthusiasm."

PUBLIC AND STATE SERVICES

Rutherford's work for the State is scarcely less interesting than his scientific discoveries, but owing to the lack of adequate records it is impossible to give any complete account of this side of his activities.

The first mention I have found of his work for the State is his connection with the Board of Invention and Research instituted by Mr. Arthur Balfour in July, 1915, at Admiral Fisher's instance. This Board had a large programme of work, but its most important initial problem was to find a method for the detection of submarines. The B.I.R. obtained from Rutherford a report on the various methods which had been employed, or suggested, for detecting sounds in water. He reported that the use of a submarine microphone was by far the most promising one, an opinion which was fully verified by subsequent experience.

Rutherford visited the United States in order to bring the activities of the Board of Invention and Research into touch with those of American bodies responsible for work similar to that which it was doing. The high regard in which Rutherford was held personally, as well as scientifically, by American physicists, made him ideal for that purpose.

The relation of the scientific activities of the State in Great Britain to pure science is very different from what it is here. Governments in Australia rarely seek the advice of any scientific society, but in England the position is very different. There the

Government has for long relied upon the advice of the Royal Society of London, and to such an extent at times that administrative work for the State has been almost an embarrassment to the Society. The Society takes a large share in the management of the National Physical Laboratory, and Rutherford, Sir Joseph Thomson and Sir William Bragg for many years guided the scientific work of that great laboratory.

The Royal Society, although its name is almost unknown to the man in the street, possesses valuable endowments (in 1936 the Society recorded the receipt of a quarter of a million in benefactions) which enable it to undertake many kinds of scientific activity.

Rutherford was elected in 1925 President of the Royal Society for the usual term of five years. This office is reserved for the most distinguished of English scientists; it is one of great influence and calls for ability in public affairs. Rutherford came to the position when the British Government's post-war plans for the application of science to industry had met with success and were being further developed. As President of the Royal Society, and then as Chairman of the Department of Science and Industry for seven years before his death, he was increasingly consulted as to these plans, and had latterly in this respect the work of a Cabinet Minister. One evening in the year 1936 he handed me some of the papers which he had received for his consideration. I spent the whole evening reading them, and then did so only incompletely. He was able to handle such documents with a speed which I never succeeded in fathoming, although I had several opportunities of studying his methods of work.

At the time of his death Rutherford was a member of a committee which was reviewing the work and organization of the National Physical Laboratory. Sir Frank Smith, Secretary of the Department of Science and Industry, who had a long association with Rutherford, writing recently, said that Rutherford had "a profound conviction that in the effective application of science in industry lies the future of the country."

Those who know the Cavendish Laboratory may remark that that laboratory under Lord Rutherford's direction gave most of its attention to the investigation of modern physics, but that his work for the State was generally concerned with applications of the older branches of physics, with which for a long period the laboratory did not concern itself. The first departure from this was when, at Rutherford's instance, the British Government and the Royal Society enabled Dr. Kapitza, the brilliant Russian physicist, to use intense magnetic fields and very low temperatures in the investigation of atomic phenomena. The equipment required for this purpose was very expensive. It was characteristic of Rutherford that he should be prepared to make this departure and incur the great expenditure to enable a brilliant foreign scientist to open up new fields of investigation. There can be little doubt that there was a good deal of criticism in England of Kapitza's appointment, probably more outside Cambridge than within.

RELATIONS WITH THE DOMINIONS

Although he left New Zealand as a young graduate, Rutherford never forgot his native land, and he rendered it many scientific services. This attitude was expressed, too, in the numerous connections which he maintained with physicists in the Dominions: the many helpful letters which he wrote to them must have been no small tax on his energies. His experience in Canada, his visits to Australia, New Zealand, and South Africa, gave him a quite rare perception of the difficulties of scientific work in the Dominions. He went to great pains to accept in his laboratory research students from the Dominions, and few were so quick to recognize in them real ability, if they possessed it, than he.

Lord and Lady Rutherford at their house in Cambridge, made Cavendish Laboratory students and visiting scientists welcome at informal receptions.

To their cottage in Wiltshire they would invite their more intimate friends. It was on such occasions that Rutherford was, in some ways, at his best.

It is conventional to speak of the loss which a man's death creates, but it is no mere tribute of that kind to say Rutherford's death is a very real loss to physics in the Dominions.

PERSONALITY

Rutherford was a big man of florid complexion, more like a farmer than an intellectual, and as a young man it will be remembered that he played as a Rugby forward. He must have been the despair of artists attempting to portray his real characteristics. He was of a most generous spirit, and boyish in many things. He excited the affection, as he commanded the respect, of both young and older men. Contrary to his appearance and behaviour, he was highly strung. A forerunner in science, his sense of values, which accounted in large measure for his great and valued influence, was, if anything, old-fashioned. He had an unusual integrity of mind, and was careful to give his collaborators full credit for their work.

The record given above, far from complete, of his many activities, scientific and public, may indicate the incredible amount of work which he accomplished each day. I had a number of opportunities of seeing how he spent it, and the impression left was that he worked unhurriedly and without apparent effort. Lecturing was the only part of his activities which seemed to disturb him. I studied his methods very closely, for they were an inspiration, but I was left entirely puzzled by the rapidity and ease with which he did his daily task. His powers of intuition were of a most unusual order, and he seemed to keep his mind concentrated on a few essential problems.

Rutherford laid no claim to great mathematical powers, but in his papers there will be found all mathematics that are essential. While there may have been experimenters with fingers more clever, none surpassed him in judgment as to the correct experimental methods to use or what problems were capable of solution. He was a great rather than a clever man. It has been said "his well-built but seemingly not exceptional intellect appeared as if brilliantly illuminated by a tremendous inner light." He appeared to know the answer to an experiment before it was performed. He confined himself to fundamental problems which he attacked directly, with tireless interest and energy not to be deflected by false scents. These qualities made him the greatest experimental physicist since Faraday.

The death at an early age of their only child Eileen, a vivacious personality, the wife of Professor R. Fowler, F.R.S., was to Lord and Lady Rutherford a very severe loss. Four children survived her.

Lord Rutherford received every imaginable honour—Knighthood, the Nobel prize, the Copley medal, the Order of Merit and honorary degrees of innumerable universities.

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Lord Rutherford

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