FEATURE

Ernest Rutherford: scientist supreme

John Campbell[1]

Physics World, Volume 11, Number 9

[1] Physics Department, Univeristy of Canterbury, Private Bag 4800, Christchurch, New Zealand

John Campbell 1998 *Phys. World* **11** (9) 35

https://doi.org/10.1088/2058-7058/11/9/27

Abstract

Ernest Rutherford is one of the most illustrious scientists that the world has ever seen. He achieved enduring international fame because of an incredibly productive life, during which he altered our view of nature on three separate occasions. Combining brilliantly conceived experiments with much hard work and special insight, he explained the perplexing problem of naturally occurring radioactivity, determined the structure of the atom, and was the world's first successful alchemist, changing nitrogen into oxygen.

Ernest Rutherford: scientist supreme

One hundred years ago this month, Ernest Rutherford – a talented young New Zealander who had just spent three years as a postgraduate student in Britain – left for Canada, where he was to do the work that won him a Nobel prize. All three countries can justifiably claim this great scientist as their own

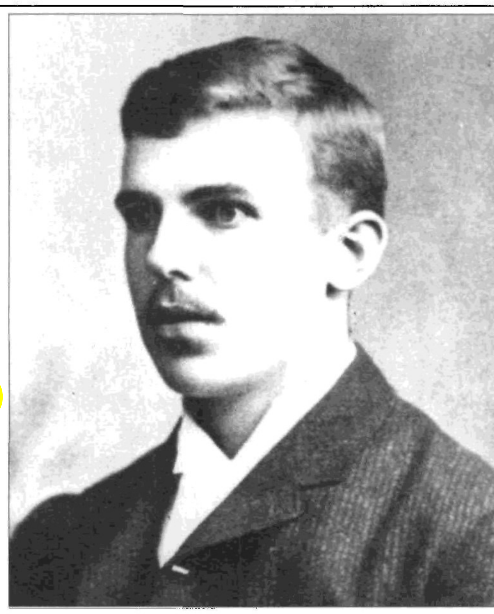
Ernest Rutherford: scientist supreme

John Campbell

ERNEST Rutherford is one of the most illustrious scientists that the world has ever seen. He achieved enduring international fame because of an incredibly productive life, during which he altered our view of nature on three separate occasions. Combining brilliantly conceived experiments with much hard work and special insight, he explained the perplexing problem of naturally occurring radioactivity, determined the structure of the atom, and was the world's first successful alchemist, changing nitrogen into oxygen.

Rutherford received a Nobel prize for the first discovery, but the other two would have been equally worthy candidates, had they been discovered by someone else. Indeed, any one of his other secondary achievements – many of which are now almost forgotten – would have been enough to bring fame to a lesser scientist. For example, he invented an electrical method for detecting individual ionizing radiations, he dated the age of the Earth, and briefly held the world record for the distance over which wireless waves could be detected. He predicted the existence of neutrons, he oversaw the development of large-scale particle accelerators, and, during the First World War, he led the allied research into the detection of submarines.

A New Zealander born and bred, Rutherford left his homeland in 1895 at the age of 23 for Cambridge, where he was to become one of the university's first research students. After three years there he moved again, this time to McGill University in Canada, which was the scene of some of his most famous early work. He came back to Britain in 1908, first spending 11 years at Manchester, before finally returning to Cambridge shortly after the First World War. When he died in 1937 – by then very much an elder statesman of science – the *New York Times* was moved to write the following: "It is given to but few men to achieve immortality, still less to achieve Olympian rank, during their own lifetime. Lord Rutherford achieved both. In a generation that witnessed one of the greatest revolutions in the entire history of science, he was universally acknowledged as the leading explorer of the vast, infinitely complex universe within the atom, a universe that he was first to penetrate."



CAVENDISH LABORATORY

Rutherford as a student in New Zealand in about 1892. Tall and lean, he was a useful rugby player and led an active student life. He soon obtained the standard BA degree from Canterbury College as well as masters degrees in both mathematics and physical sciences. Awarded a research scholarship in 1895, he left to seek his fortune in Europe.

New Zealand – a lucky start

Earnest (sic) Rutherford was born lucky. Although he made his own luck once he began his scientific research, many things fell fortuitously into place for him before that. He was lucky that he was born neither a girl nor the eldest son. He was lucky to have been brought up surrounded by hardworking, practical people. He was lucky to have obtained three separate scholarships, each on the second attempt. But most of all, he was lucky to have been born to James and Martha Rutherford. They were a couple who valued education: Martha because she had been educated and James because he had not.

His father's family had emigrated from Scotland to New Zealand in 1842, while his mother's had come from England in 1855. Both arrived as children, aged three and twelve, respectively, and the story of how they met is an interesting one (see *Rutherford's Ancestors* in further reading). His parents married in 1866, and on 30 August 1871 their fourth child (of 12) and second son was born in rural Nelson on New Zealand's South Island. Two months later, the child was mistakenly registered as "Earnest".

The family moved regularly, as James' work dictated. They

1 Rutherford's first great discovery – atoms are not always stable

Sweden issued this SKr 35 stamp in 1968 to commemorate Rutherford's 1908 Nobel prize for his work on radioactivity

After two years of research in New Zealand, Ernest Rutherford obtained a scholarship that he eventually chose to take up in Cambridge. Such was his skill in experimental work, that within months of his arrival in 1895 at the age of 24, he was invited to assist the head of the Cavendish Laboratory, J J Thomson, who was trying to understand how gases could be made to conduct electricity. When Thomson announced the discovery of the electron in 1897, Rutherford was an immediate convert to the idea of objects smaller than atoms. He began to use the newly discovered X-rays and the rays from radioactive materials to help with Thomson's work on conduction in gases.

When he moved to McGill University in Canada in 1898, Rutherford tried to understand radioactivity. He and his assistants found that thorium gave off an "emanation" that was radioactive; essentially, Rutherford had discovered radon gas. In 1901 he invited a young chemist, Frederick Soddy, who was initially committed to the chemists' view that atoms were stable, to do some of the chemical work. Within three months, they were confidently talking about atoms transmuting into other elements. For this work on radioactivity, Rutherford was awarded the 1908 Nobel Prize for Chemistry.

went to nearby Foxhill for railway construction and farming, to Havelock for flax- and saw-milling, and finally to Taranaki on the North Island for flax-milling. Ernest – known to his family as Ern – led the life of a rural New Zealand child. As a young boy at Foxhill, he milked the family cows, went birds-nesting, got birched for transgressions, splashed around in the creek and experimented with different fertilisers on pumpkin plants. His first science lessons were at Foxhill School, where he obtained his first science book as a prize. One experiment in the book explained how to measure the speed of sound by timing the interval between a cannon's flash and boom, and Ern improvized a miniature cannon that used gunpowder and a marble. Unfortunately, it blew up when he first tried to fire it, although luckily no-one was hurt.

As a young teenager in the tiny village of Havelock, Ern was lucky to avoid being drowned to death, a fate that his two younger brothers suffered. He was also lucky to have a teacher whose standard of education was well above his lowly post – a drunkard who could teach him the Latin that was needed to enter senior secondary school. Between the ages of 15 and 18, Ern was a boarder at Nelson College, where his best subject was mathematics. He also took mechanics, sound and light – although he avoided chemistry, as he knew that the teacher was only one step ahead of the class. Out of school, he rose to sergeant in the cadet corps and learnt self-defence in affrays in the college hostel.

In 1890 Ern moved to Canterbury College in Christchurch. The amazing thing about New Zealand at the time was that within 50 years of the crudest European settlement, the country already boasted a flourishing university system. The progress was largely due to the Canterbury Association – a group of people in Britain who began colonizing New Zealand in 1850. The association wanted to found a Canterbury university that would attract students from as far away as India and Australia. When Canterbury College was formally established in 1873 in the town of Christchurch – itself named after the Oxford college – the population of the whole province was a mere 55 000.

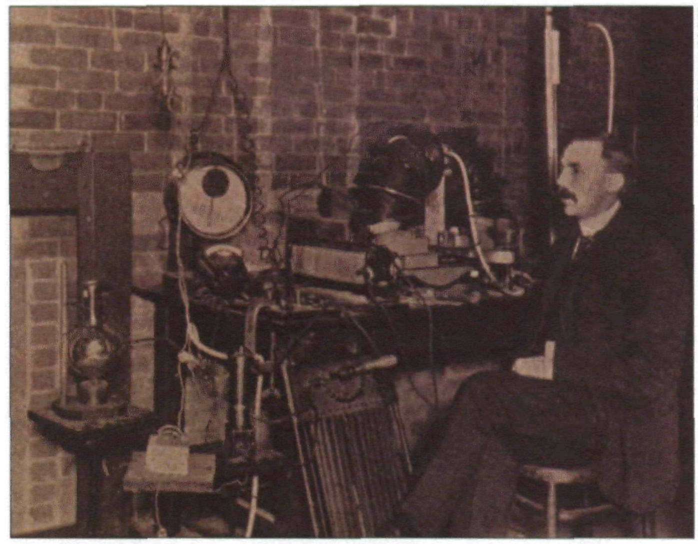
At Canterbury, Ern entered the full life of an undergraduate. Tall and lean, he played rugby as a useful forward. On alternative Saturday nights he debated at the Dialectic Society, on one occasion supporting the motion "that the influence of the modern newspaper press is excessive and dangerous". He also attended the science society, which he once addressed on electrical waves and oscillations. Ern lodged in the house of Mary Newton, who had been a staunch member of the Women's Christian Temperance Union ever since her husband had drunk himself to death. The group knew that if women were to have some control over liquor they needed to be enfranchised, and in 1893 – the first year in which Ern was old enough to appear on the electoral roll – New Zealand became the first country in the world to allow women the vote. But he gained something else from the Newton household: he later married the young daughter, Mary (May) Newton.

On passing the standard BA degree, Rutherford obtained the one scholarship in New Zealand for a masters degree in mathematics. Such was his ability that he ended up taking a double masters degree, also obtaining first-class honours in physical science. Although both subjects included exams, the latter course also required candidates to carry out an original investigation. What was he to do? He turned down one suggestion to look for the molecular building blocks of life by following electrical discharges in gases, as he felt he did not know enough chemistry. Instead, he decided to extend his undergraduate research project on the magnetization of iron by examining its behaviour at high frequencies. In doing so, he developed a device for mechanically switching two electrical circuits within a controlled time interval down to 10 μs of each other.

At this stage, Rutherford's options were very limited. He briefly contemplated a career in medicine, and missed out on schoolteaching jobs on several occasions. He even worked as a rather unsuccessful replacement teacher. In 1894 he decided to return to Canterbury and extend his research on iron to even higher frequencies. His aim was to gain one of the new scholarships funded by the impressive profits from London's Great Exhibition of 1851, which enabled students from the British Empire to study in a country of their choice. During this work, he invented a magnetic detector that could measure current pulses as short as 2 ns. This was to become known as the Rutherford detector – the first of many devices named after him. He developed it into a frequency meter and used it to study the dielectric properties of materials at high frequencies.

However, there was only one 1851 scholarship for graduates from New Zealand, and Rutherford lost out to a rival candidate – a chemist who had developed methods for extracting gold from ores using the cyanide process. Once again, luck was to play a part in Rutherford's life, for the chemist withdrew as he could not afford to take up the scholarship because it paid less than his job as a government analyst. It was awarded instead to Rutherford, who departed for Europe in 1895 at the age of 23.

People who are not from New Zealand tend to forget – or are never told – that Rutherford was born, raised, moulded and educated in New Zealand. He left as a highly trained young man with three degrees from the University of New Zealand, having had two years of independent research working at the forefront of the advanced electrical technology of the day. His brilliance at experimental science was evident before he left.



1906 NATURE 74 273

After finishing his PhD at Cambridge in 1898, Rutherford moved to McGill University in Montreal, Canada, where he inherited one of the best-equipped physics labs in the world. He was fairly certain that the alpha particle was the nucleus of a helium atom, and it was at McGill that he first observed that a beam of alpha particles was scattered by atoms in the air. He later refined this scattering technique at Manchester to determine the structure of atoms.

From New Zealand to Cambridge

On board the ship to Europe, Rutherford decided to learn German as he was not sure if he would take the scholarship in Britain or in Germany, which was then the centre of science. On arriving in London in 1895, he made various inquiries with a number of scientists, including the head of the Royal Institution in London. He also decided to visit J J Thomson at the Cavendish Laboratory in Cambridge. Thomson was the author of one of the books that Rutherford had studied in New Zealand – and both liked what they saw. Luckily, Cambridge had just lowered its nose to admit graduates other than its own, and Rutherford became Cambridge's first research student. His immediate successes there were trumpeted as Cambridge's wisdom in widening its net, and his presence therefore smoothed the path for future non-Cambridge graduates.

Rutherford began by using his magnetic detector to extend his earlier work on iron to the dielectric properties of glass at high frequencies, a problem that interested Thomson. To compare the sensitivity of his detector with that of the other main detector of current pulses – the coherer – he placed his detector in a receiving loop and used a Hertzian oscillator to generate damped "wireless" waves. On hearing that Rutherford could detect these waves at distances of more than 20 m, Sir Robert Ball – a Cambridge astronomer who had been scientific adviser to the body that maintained lighthouses around Ireland – rushed to see a demonstration. He told Rutherford that if he could increase the range, he would have solved the vexing problem of ships being unable to detect lighthouses in foggy weather. After gleefully reporting to May Newton, who was still in New Zealand, that fame, fortune and marriage awaited, Rutherford pushed the distance out to half a mile (about 800 m) across Jesus Green in Cambridge.

By the time that he had heard that a young Italian, Guglielmo Marconi, was extending the range even further with help from the British Post Office, Rutherford had already switched fields. Thomson had quickly realized that Rutherford was exceptional, and invited him to join in his research into the mechanism whereby gases, which are normally electrical insulators, could conduct electricity. For two years much of Rutherford's inventiveness went into quantifying this field.

Before long, Rutherford was again lucky, as some of the most remarkable discoveries of physics were about to cascade from European laboratories. In November 1895 Wilhelm Röntgen discovered X-rays and a few months later Henri Becquerel stumbled on radioactivity. And in 1897 J J Thomson announced the discovery of the electron, the first sub-atomic particle (see "J J Thomson and the discovery of the electron" by Gordon Squires *Physics World* April 1997 pp33–36). The atom would never be the same again, and Rutherford was lucky to be there at the birth of the new physics. He used these discoveries to help his work on conduction in gases, but soon turned his attention to radioactivity. He discovered that radioactivity seemed to consist of two types of rays, one less penetrating than the other, and named them alpha and beta rays.

Despite these research successes, Rutherford knew he would have trouble being accepted at Cambridge and securing a permanent position there. As he wrote home in a letter to May: "There is one demonstrator on whose chest I would like to dance a Maori war-dance". The only option was to move on.

The move to Canada

Rutherford was soon recruited by McGill University in Montreal, Canada, to "form a research school to knock the shine out of the Yankees", as he wrote in a letter home. He arrived in Canada on 20 September 1898. At McGill he inherited one of the best-equipped physics labs in the world. He also gained Sir William McDonald, who had amassed a fortune from tobacco, as a patron and John Cox as a fellow professor. Cox shouldered the administration and teaching to allow Rutherford to concentrate on research. The staff at McGill were also well trained in precision experiments on heat. Although one piece of anonymous student doggerel showed that Rutherford was not a good teacher of lowly undergraduates –

Ernie R-th-rf-rd, though he's no fool,
In his lectures can never keep cool,...

– he could nevertheless inspire people when talking about his research.

RUTHERFORD MUSEUM, MCGILL UNIVERSITY

Rutherford (front row, right) was a hugely talented research physicist and an inspiring leader, although teaching undergraduates was not his favourite task. Fortunately his colleague at McGill University, John Cox (front row, centre) shouldered much of the department's teaching load. Harriet Brooks (back row) was Rutherford's first female research student.

His first task was to use the knowledge that he had gained at Canterbury to improve the sensitivity of devices that measured physical vibrations. These measurements were needed to provide evidence to support a street-railway company that was being sued because of the vibrations that its trains induced in nearby buildings. Rutherford, of course, succeeded in the task, since he had the ability to develop apparatus that was suitable for any job in hand. Indeed, when McGill started a school of railway engineering, Rutherford helped them and became the first person to send a wireless signal from a train to a station.

Rutherford also trained the demonstrators and students at McGill in radioactive measurements. In particular, he taught them the quantitative electrical detection methods that were based on the rate at which a radioactive source discharged an electroscope. He was able to merge this with one demonstrator's skill in careful heat measurements to determine that the large energies involved in radioactivity did not arise from the chemical regrouping of atoms. However, he soon realized that he would need many skilled collaborators to carry out his work, and convinced the new professor of electrical engineering – a young American called R Owens – that he should extend Rutherford's study of the radiation from uranium to thorium. This led to the discovery that thorium was emitting a radioactive gas – a new element, radon gas.

But Rutherford needed someone who was good at chemical analysis, and he tried to recruit another friend – this time the new professor of chemistry at McGill, James Walker. However, Walker declined on the grounds that he was an organic chemist. The claims for the existence of sub-atomic particles – electrons – grated with many chemists, who felt that the indivisibility of the atom was the cornerstone of their patch of science. On 28 March 1901 the McGill Physical Society called a meeting to debate the issue – or, as Rutherford saw it, to demolish the chemists. John Cox and Rutherford spoke for the sub-atomic view, while the counterargument was put forward by Frederick Soddy, a young inorganic chemist from Oxford, who was lucky to still be in Canada, having failed to obtain a job in Toronto.

In his address, *Chemical Evidence for the Indivisibility of the Atom*, Soddy called for a strong protest against the atomic theory that was being promoted by Thomson and Rutherford. In Soddy's view, the Physical Society had displayed undue levity about chemical matters, and the two sides were unable to resolve their differences. Rutherford invited Soddy to join him, and within three months convinced him to accept that radioactivity was a manifestation of sub-atomic change. Rutherford had revealed that atoms are not necessarily stable entities as had been assumed since the time of the ancient Greeks.

By invoking radioactivity, Rutherford also succeeded in reconciling estimates of the age of the Earth, which geologists and physicists had disagreed over for many decades. The physicist Lord Kelvin had used the rate at which the temperature increases down a deep mine to estimate the rate at which the Earth was cooling. This enabled him to calculate when the surface had been molten rock, from which he predicted that the Earth was just a few tens of millions of years old. Geologists, however, had measured the rate of deposition of sediments and found that the Earth was much older than Lord Kelvin's prediction – more like several hundreds of millions of years. But by adding in the radioactivity and the heat output of radium in the rocks, Rutherford increased Kelvin's estimate to hundreds of million years, just as the geologists had predicted.

However, there was a problem. Lord Kelvin did not believe that the energy of radium was internal to atoms, and he was in the audience when Rutherford addressed the Royal Institution on the subject of radium in 1904. Rutherford saved the situation with sudden inspiration. "To my relief, Kelvin fell fast asleep, but as I came to the important point, I saw the old bird sit up, open an eye and cock a baleful glance at me! Then a sudden inspiration came, and I said, 'Lord Kelvin had limited the age of the Earth provided no new source of heat was discovered. That prophetic utterance refers to what we are now considering tonight, radium!' Behold! the old boy beamed at me." Rutherford clearly had diplomatic skills.

During his experiments at McGill with beams of alpha particles, Rutherford noticed that the beam was wider in air than it was in vacuum. He placed a thin sheet of mica in the way of a beam and concluded that alpha particles were scattered by atoms. Later in Manchester he was to use this technique, now know as Rutherford scattering, to determine the structure of atoms.

Meanwhile, marriage was beckoning, and in 1900 Rutherford returned to New Zealand to marry May Newton. They spent their honeymoon at the country's southern lakes, where their only child, Eileen, was conceived. Rutherford brought his new wife to Canada, and although they returned to New Zealand in 1905 to show Eileen to their families, each of the trips took Rutherford away from his work for several months. Indeed, he only ever made four visits home during his lifetime.

Rutherford also received a string of regular of job offers from America, but he was not tempted. His salary at McGill was high, and he wisely showed each offer to the administration so that it was regularly increased still further. He was establishing an enviable reputation. As John McNauhgton, a classics professor at McGill, said after hearing Rutherford speak about his research: "Here was the rarest and most refreshing spectacle – the pure ardour of the chase, a man quite possessed by nobel work and altogether happy in it".

His reputation soon began to spread beyond McGill, and in February 1907 Cox wrote to the Swedish Academy of Sciences recommending Rutherford for a Nobel prize. "It would indeed be a satisfaction to his friends here," wrote Cox, "if he should receive so great an honour while still a member of the University where during nine years he has completed so many researches." Although German and Swedish scientists also nominated Rutherford for the prize, it was not until the following year that the 37-year-old Rutherford became a Nobel laureate. He received the 1908 Nobel Prize for Chemistry for his work on the radioactive disintegration of elements and the chemistry of radioactive substances (see box 1); the overnight transformation into a chemist amused him immensely. (Curiously, J J Thomson was the only British scientist to ever nominate Rutherford for a Nobel prize – in 1908 – and even then the nomination was made too late for that year's award.)

2 Rutherford's second great discovery – the atomic nucleus unveiled

Rutherford's scattering experiments at Manchester, which showed that most of an atom's mass exists in a tiny nucleus at the centre of the atom, were commemorated by this Soviet stamp from 1971

At McGill University in Canada, Rutherford noticed that a beam of alpha particles became fuzzy when passed through a very thin film of cleaved mica. At Manchester, where he had moved to in 1907 at the age of 35, he asked his assistant Hans Geiger to measure the intensity of alpha particles as a function of the angle at which they were scattered. He also gave a secondary project to a young student, Ernest Marsden, whom Geiger had trained in radioactive measurement techniques.

Marsden was asked to look for alpha particles scattered through large angles. When Marsden reported that he had observed alpha particles scattered backwards from a thin foil of gold, Rutherford was amazed. It was, he said, as if a large naval shell had been fired at a tissue paper and bounced backwards. By 1911 Rutherford had explained this result through a nuclear model of the atom, in which the positive charge and the vast majority of the mass of an atom is concentrated in a nucleus about one thousandth the size of the atom. The volume taken up by the nuclei in all of the atoms in a human body is about the same as a grain of fine sand.

Back in Britain

Rutherford was slowly starting to realize that he needed a larger pool of collaborators than North America could provide. He also felt that Canada was too far from the centre of research, and began to look for another move. Fortunately, Arthur Schuster, the head of physics at Manchester University, specifically resigned to free up a position for Rutherford, and he moved back to Britain in 1907. It was here that he made his second and third great discoveries – that the atom has a nucleus (see box 2) and that atoms can be changed from one form to another (see box 3). He was also responsible for a number of other inventions, such as the Rutherford–Geiger detector, which in improved form is now called the Geiger–Müller tube.

It is strange that although Ernest Rutherford's greatest discoveries were made in Canada and Manchester, these two places are generally overlooked in Britain in favour of his time at Cambridge – where Rutherford spent the final 18 years of his life from 1919 to 1937 as an elder statesman of science. This is perhaps the reason why many people link Rutherford solely with Cambridge, and why they tend to forget about his times in New Zealand, Canada and Manchester. But Rutherford was always proud of being a New Zealander and always referred to himself as such. When he was raised to the peerage in 1931, he chose the territorial designation of Lord Rutherford of Nelson in honour of "my birthplace and home of my grandfather", and his dying words were to remind his wife that he wished to leave a bequest to Nelson College.

However, for many years New Zealand curiously – and to its lasting shame – chose to neglect Ernest Rutherford. Every house he lived in was demolished, which is why overseas visitors on a pilgrimage to his birthplace were, for some decades, driven 200 km south of Nelson to view a rural pigsty. On the 50th anniversary of his death in 1987, the site remained a national disgrace. I went there at dawn and gazed despairingly at the untidy piles of river boulders that had been dumped on the site many years before.

Happily, his rehabilitation in New Zealand is now almost complete. The Rutherford Birthplace was opened in 1991 – an outdoor information centre and a tourist destination of international significance. Totara, oak and maple trees at three corners of the section advertise the countries that gained through his fame. In 1992, when New Zealand replaced Queen Elizabeth on its banknotes with its own citizens, Ernest Rutherford was chosen to grace the $100 banknote. This is the largest denomination, which means that his image regularly appears in advertisements on TV, newspaper and magazines.

Britain, of course, still continues to honour Ernest Rutherford – the new Rutherford Conference Centre at the Institute of Physics in London bears witness to that fact. Only Canada, for whom Rutherford was their first Nobel prize winner, regretfully continues to largely ignore him. Although there is a Rutherford museum at McGill University, which contains the world's finest collection of scientific apparatus that he developed, it has only survived through the enthusiasm of two lone individuals, who served sequentially as honorary curator.

While the world may hold up Einstein as the symbol of scientific intelligence, Rutherford's brilliance was different and, I believe, underrated. Lord Bowden, a former UK science minister, once reminisced to me about his own days as a research student at the Cavendish Laboratory. "There were

3 Rutherford's third great discovery – the world's first successful alchemy

New Zealand, where Rutherford was born, neglected its most famous son for many years, but he now appears on the country's $100 banknote, while his groundbreaking work on the transformation of elements has been commemorated on this 7 cent stamp

In 1913 while Rutherford was at Manchester University he extended his work on the scattering of alpha particles from thin films. He now wanted to find out how they scattered from light atoms. Conservation of momentum predicted that if alpha particles were fired at hydrogen gas, high-speed hydrogen nuclei (protons) would be produced, and that these nuclei would travel four times further than alpha particles. In 1914 Rutherford duly set Ernest Marsden to play marbles with nuclei – and, as expected, Marsden observed the long-range hydrogen nuclei. (Interestingly, Marsden later went to work in New Zealand. He joined the New Zealand army in 1916, and served in France in the same sector as – but on the opposite side to – his colleague Hans Geiger.)

Late in 1917, after completing his own wartime work on the acoustic detection of submarines, Rutherford returned to his work on scattering. He found that higher-energy protons were ejected when nitrogen gas was bombarded with alpha particles through the reaction $^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}H$. In doing so he became the world's first successful alchemist, having turned nitrogen into oxygen.

some very distinguished theoretical physicists in the Cavendish in my time, and I often heard them talking," he recalled. "I always thought that these men were extraordinarily brilliant; I could understand only part of what they were saying and I could never imagine that I could contribute to their ideas in any way at all. But after I heard Rutherford explaining something I thought, 'That is perfectly simple and perfectly obvious; why on Earth didn't I think of it myself?'"

That is testimony to the unique brilliance of Ernest Rutherford, scientist supreme.

Further reading

J Campbell 1996 *Rutherford's Ancestors* (AAS Publications, Christchurch, New Zealand)

J Campbell 1998 *Rutherford: Scientist Supreme* (AAS Publications, Christchurch, New Zealand)

John Campbell teaches physics at the Physics Department, University of Canterbury, Private Bag 4800, Christchurch, New Zealand (e-mail j.campbell@phys.canterbury.ac.nz). He was also convenor of the Rutherford Birthplace Project and was awarded a New Zealand science and technology medal for his work on Rutherford