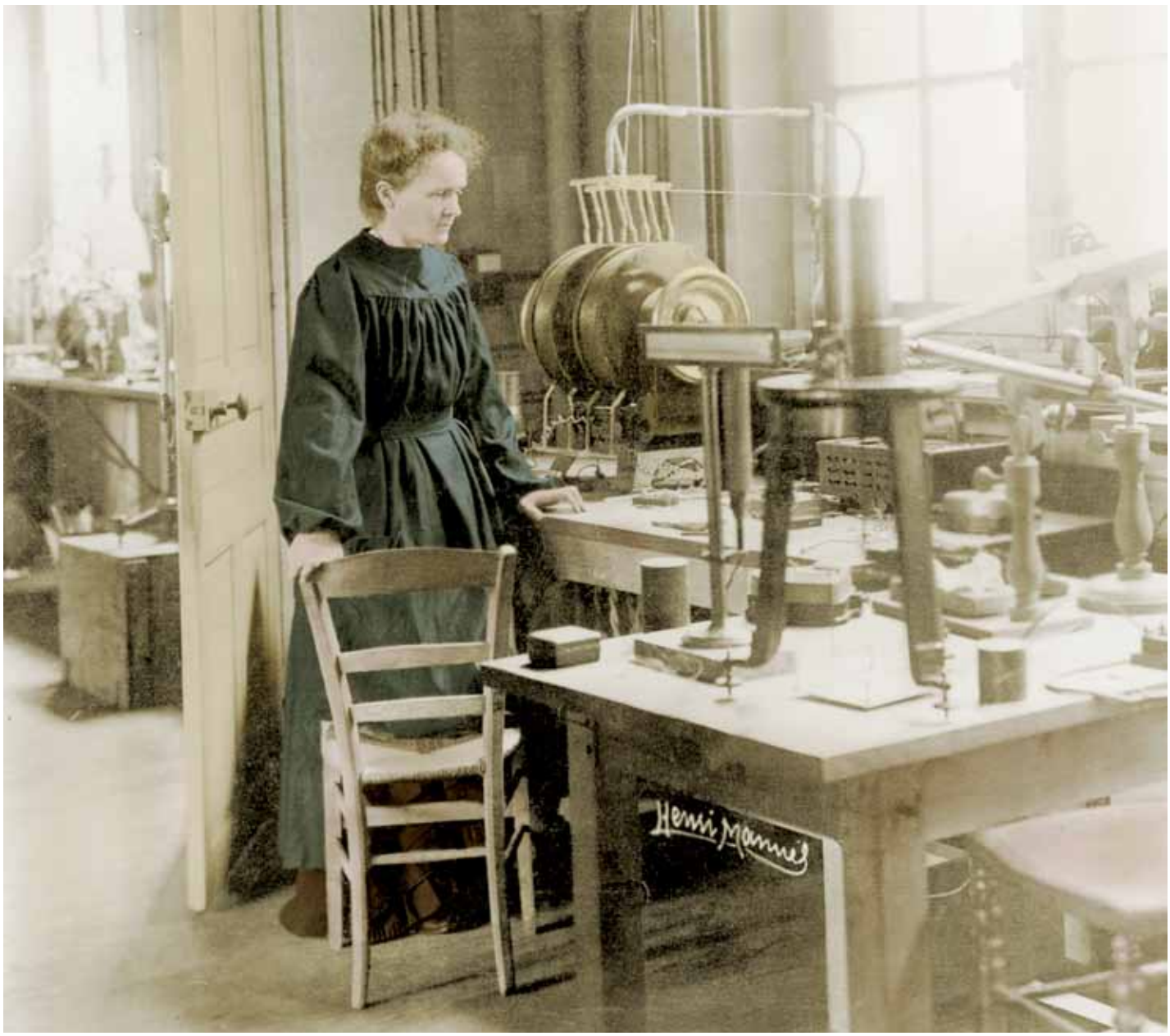
Elements of inspiration

International Year of CHEMISTRY 2011

Unerring in her scientific enquiry and not afraid of hard work, Marie Curie set a shining example for generations of scientists. Bill Griffiths explores the life of a chemical heroine



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On 10 December 1911, Marie Curie was awarded the Nobel prize in chemistry for 'services to the advancement of chemistry by the discovery of the elements radium and polonium'. She was the first female recipient of any Nobel prize and the first person ever to be awarded two (she, Pierre Curie and Henri Becquerel had shared the 1903 physics prize for their work on radiation). Such was Marie's impact on the scientific world – and the role of women within it – that one of the four stated goals of the 2011 international year of chemistry is to celebrate the centenary of her prize.

Early years

She was born Maria Salomea Sklodowska on 7 November 1867 in central Warsaw, Poland. Both her parents were teachers (her mother died when Maria was 10) and she was highly motivated and well educated. Poland was then a subject state of Russia and women were excluded from advanced study, so in 1891 she joined her sister Bronia in Paris, enrolling at the Paris Sorbonne University and taking her physics and mathematics degrees with outstanding grades in 1893–4. She met Pierre Curie in the spring of 1894, and they married in 1895 at a civil ceremony in Sceaux in the Parisian suburbs. They were both rather shy and unworldly, caring little for material things; their chief recreation was cycling, but they shared too a deep appreciation of science and an obsessive dedication to it. Their first daughter Irène was born in 1897.

Pierre's work on piezoelectricity, crystal symmetry and magnetism at the Municipal School of Industrial Physics and Chemistry (EPCI) in Paris is still fundamentally important, especially the concepts of the Curie temperature (above which magnets lose their magnetism) and the Curie law relating magnetism and temperature. Marie published her first paper in 1897 on the magnetisation of steels but looked for a new research topic, which she found in radioactivity. A year after Wilhelm Röntgen's observation of x-rays in 1895, Henri Becquerel discovered radioactivity of uranium from photographic plates which, when wrapped in black paper close to uranium or its salts, showed images when developed.

Marie was allocated a damp room of the EPCI for her doctoral research, and showed that among a wide variety of inorganic materials, uranium and thorium were the only elements then known to exhibit radioactivity. Her samples were placed on a condenser plate charged to 100 Volts and attached to one of Pierre's electrometers, and thereby she measured quantitatively their radioactivity. She found the minerals pitchblende (UO_2) and chalcolite ($Cu(UO_2)_2(PO_4)_2.12H_2O$) to be more radioactive than pure uranium, so reasoned that they must contain other, stronger radioactive constituents. On 12 April 1898 she presented her findings, writing that 'these minerals may contain an element which is much more active than uranium'.[1] She and Pierre decided that she would concentrate on the chemical aspects of element separation, while he would study their radiation properties.

Polonium and radium

In April 1898, Marie dissolved pitchblende in HCl and treated the solution with H_2S; uranium and thorium remained in solution, but the precipitated sulfides remained highly radioactive. After further manipulation this radioactive material was found to co-precipitate with bismuth. In July she and Pierre published a paper (coining the word 'radio-active' in its title), presented by Becquerel to the Academy of Sciences – founded in 1666, this institution was as prestigious in France as the Royal Society in Britain. They suggested, for the first time, that radioactivity was a phenomenon associated with the atom, and proposed that the new element, once its existence was confirmed, should be called polonium.[2]

They realised that pitchblende must contain yet another highly radioactive material, not precipitated from its solutions by H_2S, $(NH_4)_2S$ or ammonia, having a water-insoluble carbonate akin to $BaCO_3$ and a chloride slightly less soluble than $BaCl_2$ which acted as a carrier for it. This they named radium, publishing their results on Boxing day 1898;[2] French spectroscopist Eugène-Anatole Demarçay found a new atomic spectral line from the element, helping to confirm its status. Since it was much more radioactive than polonium the Curies concentrated their efforts on it. It was clear that much more pitchblende was needed to obtain significant quantities of radium, and they eventually obtained some 8000kg of waste ore from Austria. They worked for the next four years under appalling conditions in a leaking unventilated shed, freezing in the winter and dreadfully hot by summer. Marie wrote: 'I had to spend a whole day mixing a boiling mass with a heavy iron rod nearly as large as myself. I would be broken with fatigue at the day's end'. Nevertheless she described life in 'this miserable shed' as 'the best and happiest years of our life', and was much honoured when Lord Kelvin and other famous scientists visited her there.

They worked with 20kg batches of pitchblende: grinding, dissolving and refining them to small quantities of solutions. In 1902 they isolated 0.1g. of anhydrous $RaCl_2$ after thousands of recrystallisations from the more-soluble $BaCl_2$ in HCl, measuring the atomic weight of radium as 225.

In 1901 Pierre and Becquerel published a paper on the physiological effects of radioactivity, and Pierre showed, with medical collaborators, that radiation from radium (and subsequently from radon gas which it and other radioactive elements emit) could destroy cancerous cells.

The physics Nobel prize

In June 1903 Pierre came to the UK to give a discourse at London's Royal Institution. Many eminent scientists were present including Sir William Crookes, Sir Oliver Lodge, Lord Kelvin and the physicist William Ayrton. Ayrton's wife Hilda, a remarkable scientist in her own right, and Marie became firm friends.

Marie completed her doctoral thesis in June 1903. Later the same day Ernest Rutherford (himself to become a chemistry Nobel laureate in 1908) met the Curies for dinner; Marie trusted him and they formed a lasting friendship. That evening, when Pierre showed him some radium glowing blue in the dark,

In short

- **It is 100 years since Marie Curie became the first person ever to win two Nobel prizes**
- **Marie and her husband Pierre pioneered the study of radiactivity and discovered two new elements, radium and polonium**
- **The pair had to process tonnes of minerals under horrific conditions to extract tiny amounts of radium**
- **Their daughter, Irène, also won a Nobel prize in chemistry, and Marie is remembered in the names of universities, institutes, charities and the element curium**

The Curies isolated traces of radium and polonium from tonnes of pitchblende uranium ore

THEODORE GRAY

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Rutherford noted that Pierre's fingertips were raw and inflamed, as indeed were Marie's. Others had observed that both Curies had burns, which must have arisen from their handling of radium. This and inhaling radon formed from radium's decay almost certainly adversely affected their general health. After the first world war in particular there were increasing reports of illness and sometimes deaths amongst those who had worked with radium salts for cancer therapy, as paints for luminous watches, and in quack 'cures' for a host of ailments.

In November 1903 the Curies and Becquerel were awarded the physics Nobel prize for their work on radioactivity. Becquerel attended the Stockholm ceremony, but neither of the Curies went: Pierre was ill and overwhelmed with teaching duties and Marie was recovering from a miscarriage. It was a mixed blessing – financially helpful (70 000 francs), but it exposed them to international acclaim and scrutiny. Marie later wrote that 'the overturn of our voluntary isolation was a cause of real suffering for us'.

A professorship was created for Pierre at the Sorbonne with an accompanying post for Marie; that year Pierre was elected to the Academy of Sciences and in June he gave his Nobel lecture in Stockholm. In December 1905 their second daughter, Eve Denise, was born.

Troubled times

On 19 April 1906, Marie left the Sorbonne to give the children their lunch; Pierre walked in the rain to meet his publishers. When crossing the cobbled Rue Dauphine he was run over by a horse dray and instantly killed. Marie was devastated. He was buried in Sceaux and later Marie and her children moved there.

Outside of the laboratory, Pierre and Marie were keen cyclists

Marie's mobile x-ray vans brought radiology to the front lines in the first world war

ALAMY

Marie was given Pierre's Sorbonne chair, thereby becoming the first female professor in France. That year Lord Kelvin wrote to *The Times* newspaper suggesting that radium was a compound of lead containing five helium atoms, but Rutherford robustly disagreed, saying that radium fulfilled every test required of an element. Marie resolved to prove that this was so. In 1907 she made 0.4g of $RaCl_2$ and re-determined the atomic weight as 226.45. In 1910 she isolated radium as a shiny-white metal by electrolysing $RaCl_2$ in mercury and distilling off the latter from the amalgam.[3]

Paul Langevin, a pioneer in magnetochemistry, one-time student of Pierre and long a friend of the Curies, succeeded Pierre as professor of physics and chemistry at the EPCI. Although married with four children he was separated and had a small apartment near Marie's laboratory where they sometimes met. In 1911 his study was burgled, letters from Marie stolen and published. They were mainly domestic in nature, Marie advising him about how to deal with his marital problems,

BILL CLARKE / LEWES THEATRE CLUB PRODUCTION 'ACTIVE ELEMENTS' BY JOHN FISHER

but the press made much of them. Opinions differ as to whether they were lovers in this brief affair, but there is no evidence whatsoever that she had enticed him from his wife. Langevin challenged the publisher of the letters to a duel; pistols were drawn but neither duellist fired, and with this farce public interest waned and the affair ended. Much later Marie's granddaughter Hélène married Langevin's grandson.

The chemistry Nobel prize

In 1910 Marie was proposed for election to the Academy of Sciences. Had she been elected she would have been its first female member, but in 1911 she lost by one vote to the inventor Edouard Branly. She was deeply upset and never applied again; for years she stopped publishing in the society's journals.

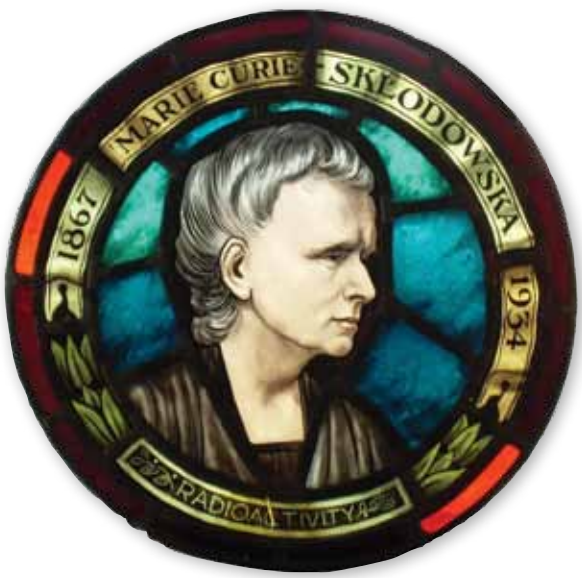
On 8 November 1911 she was awarded the Nobel prize in chemistry for discovering polonium and radium. This time she went to Stockholm to receive it, taking her sister Bronia and elder daughter Irène, and in her acceptance speech mentioned that she alone had coined the term radioactivity but that polonium and radium were joint discoveries with Pierre.

In 1912 the Pasteur Institute and the Sorbonne decided that an 'Institut du Radium' be established in the newly-named Rue Pierre Curie, and Marie became director of its Curie laboratory. At the outbreak of the first world war, using her knowledge of x-rays, she set up a Red Cross radiology unit. Her daughter Irène, now aged 17, helped her and nursed on the front lines. In 1920 she met the influential American journalist Marie Meloney who persuaded her to visit the USA in 1921 to raise money for radium research. There she met the president Warren Harding, and returned to France with a gram of radium and a generous research grant.

Her eyesight now deteriorated badly from cataracts, and her general health, never very good, worsened. In March 1925 Irène presented her doctoral thesis on α-radiation at the Sorbonne, and in 1926 married Frédéric Joliot, a physicist at the Radium Institute. From 1932 Marie's health declined further – though she continued working – and she died on 4 July 1934 from leukaemia (Irène was to die later from the same disease, aged 59). Marie was buried at Sceaux with Pierre, and Polish soil was scattered over her coffin. Her remains and those of Pierre were later re-interred in the Panthéon in Paris, France's national burial place for the famous, as was Langevin.

Marie toiling to extract radium from pitchblende in her 'hut' – as portrayed in a modern theatre production

Marie Curie was a truly remarkable woman. Despite the exhausting labour of her early work with pitchblende and bringing up two children, she was physically quite frail and became more so, probably due to radiation exposure. In Pierre she found a partner who shared her obsessive love for science and aversion to publicity. She was never a feminist, though she believed strongly that men and women should have equal opportunities in education and work. Albert Einstein, who knew her well, wrote: 'Marie Curie is the only one whom fame has not corrupted'.



Marie has been commemorated in stamps, banknotes and in this stained glass medallion by Polish artist Jozef Mazur

The Curie legacy

The extended Curie family won no less than six Nobel prizes – in addition to Marie and Pierre's three, Irène and Frédéric Joliot-Curie won the chemistry prize in 1935 'in recognition of their synthesis of new radioactive elements', and Eve Curie's husband, Henry Labouisse, received the 1965 peace prize on behalf of Unicef. The Joliot-Curies worked at Marie's Radium Institute from 1934 on α-particle bombardment of elements, transmuting these to radioactive products (for example converting aluminium to radioactive phosphorus). Although Rutherford and others had earlier transmuted stable light elements, these were the first transformations to produce radioactive isotopes. In 1939, Marguerite Perey, a student of Marie's at the Radium Institute, discovered francium as a radioactive decay product of actinium, and in 1962 she was elected as the first female member of the Academy of Sciences, the honour so shamefully denied to Marie in 1911.

The Curie name lives on in many ways, including the Pierre and Marie Curie University in Paris; the Maria Curie-Sklodowska University in Lublin, Poland; the Curie Institute (from the earlier Radium Institute) in Paris, and the Marie Curie charities. Also named after the Curies were the element curium, the Curie (Ci) unit of radioactivity and the minerals curite, sklodowskite, and cuprosklodowskite. But perhaps Marie's most lasting legacy is the inspirational example set to generations of scientists – both male and female – that rigorous and determined investigation can lead to remarkable discoveries.

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References and Further reading

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