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Marie Curie, Radioactivity, the Atom, the Neutron, and the Positron

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The *Australian Journal of Chemistry* is pleased to publish a collection of papers commemorating the 100th anniversary of the Nobel Prize in chemistry awarded to Marie Curie (née Marya (Maria) Skłodowska) for the discovery of two new radioactive elements, polonium and radium.[1] Her first Nobel Prize, in physics in 1903,[2] was shared with Henri Bequerel and her husband Pierre Curie for their work on the radiation phenomena discovered by Becquerel – the so-called Becquerel rays, which were later determined by Rutherford and Royds in 1907 to be α-particles (He^{2+} nuclei). It was Marie Curie who in 1898 coined the term radioactivity for this new property of matter.

Although Marie and Pierre had discovered and isolated two new highly radioactive elements, Po and Ra from the uranium mineral pitchblende in 1898, the Nobel physics committee appeared to have reservations about this and made no mention of it, thereby making it possible for the chemistry Nobel committee to award her the second prize in 1911. The Curie story is reviewed herein by Clarence Hardy.[3]

It is important to realize that these discoveries were made before the structure of the atom was understood. Neither the proton nor the neutron nor indeed the atomic nucleus were known, and the electron had only just been discovered by J. J. Thomson in 1897. The best model of the day was J. J. Thomson's 'plum pudding model', in which the corpuscular electrons were sitting like the plums in an ill-defined nuclear fluid. Rutherford's 'solar system' model came in 1911, and Bohr's now familiar quantum model of the atom in 1913. The Becquerel rays were at first thought to be similar to Röntgen's X-rays, i.e. electromagnetic in nature. The α-particles emitted by polonium became crucially important in the discovery of the neutron, which earned Chadwick the Nobel Prize in Physics in 1935, and Irène Curie and her husband Frédéric Joliot the Chemistry Nobel, also in 1935, for the discovery of the transmutation of elements by α-particle bombardment of lighter elements, e.g. $^{27}Al + \alpha(^{4}He) \rightarrow {}^{30}P + {}^{1}n$. The Joliot-Curies first thought the neutron rays emanating from light elements such as beryllium and aluminium on α-bombardment were a powerful variant of γ-rays (high energy electromagnetic radiation), but Chadwick realized their particulate nature. The ^{30}P isotope formed in the Joliot-Curie experiment is radioactive, emitting positrons with a half-life of 3 min. Thus, they discovered artificial radioactivity.[4] Similarly, radioactive isotopes of nitrogen and silicon were produced by α-bombardment of boron and magnesium, respectively. Positrons are nowadays immensely important in positron emission tomography (see paper by Greguric et al.[5] below). The fascinating story of the neutron – the Curie family's legacy – is reviewed expertly by John and Alsia White.[6]

The discoveries of Po, Ra, radioactivity, the atomic nucleus, and the neutron paved the way to our current understanding of the atom and the associated advances in chemistry, physics, and medicine. The development of radiation chemistry since the Curies and till the present day is reviewed briefly by Ronald Cooper.[7]

Alison Edwards[8] highlights modern uses of neutron diffraction in structure determination in cases where X-ray diffraction is unable to provide definitive answers. This takes advantage of the different scattering properties of X-rays and neutrons: because the neutrons are electrically neutral, they are diffracted more readily by the nuclei rather than the electrons in a molecule, thereby enabling them to reveal the precise locations of the nuclei of hydrogen and other light elements or to ascertain their absence. While neutron diffraction used to be a technique firmly in the realm of physics because forbiddingly large crystals were needed in order to obtain chemical structures, technical advances using Laue neutron diffractometers have made it possible to undertake such studies on crystals of manageable sizes (fractions of mm^3).

Radioactive elements and isotope labelling are of practical importance in several areas of medicine. Radium and other radionuclides were introduced very early by Marie Curie herself and are still used in radiotherapy to combat malignant tumours. More recently, γ-rays from e.g. ^{60}Co, electron (β-rays), and proton beams from particle accelerators have come into use. The synthesis of radioactively labelled drugs (radiosynthesis) is interesting because it permits the location of the molecule on the target and elsewhere by means of 3D positron emission tomography. Ivan Greguric and coworkers describe a synthesis of positron-emitting ^{18}F-labelled nicotinamide (half-life of ^{18}F 110 min) designed to target random metastasis of melanoma tumours.[5]

Because the ingestion of radionuclides is harmful and potentially lethal, it is of crucial importance to be able to determine their presence in drinking water – not least in Australia with its large deposits of uranium ore. Megan Cook and Ross Kleinsmith describe a method for the simultaneous determination of α-emitting Ra-226 and β-emitting Ra-228 in water by liquid scintillation spectrometry.[9]

 10.1071/CH11235 0004-9425/11/070847

References

[1] The Official Web Site of the Nobel Prize. The Nobel Prize in Chemistry 1911: Marie Curie. Available online at: http://nobelprize.org/nobel_prizes/chemistry/laureates/1911/index.html (accessed 8 June 2011).
[2] The Official Web Site of the Nobel Prize. The Nobel Prize in Physics 1903: Henri Becquerel, Pierre Curie, Marie Curie. Available online at: http://nobelprize.org/nobel_prizes/physics/laureates/1903/index.html (accessed 8 June 2011).
[3] C. Hardy, *Aust. J. Chem.* **2011**, *64*, 849. doi:10.1071/CH11118
[4] The Official Web Site of the Nobel Prize. The Nobel Prize in Chemistry 1935: Frédéric Joliot, Irène Joliot-Curie. Available online at: http://nobelprize.org/nobel_prizes/chemistry/laureates/1935/joliot-curie-lecture.html (accessed 8 June 2011).
[5] I. Greguric, S. Taylor, T. Pham, N. Wyatt, C. D. Jiang, T. Bourdier, C Loc'h, P. Roselt, O. C. Neels, A. Katsifis, *Aust. J. Chem.* **2011**, *64*, 873. doi:10.1071/CH11048
[6] J. W. White, A. B. White, *Aust. J. Chem.* **2011**, *64*, 855. doi:10.1071/CH11214
[7] R. Cooper, *Aust. J. Chem.* **2011**, *64*, 864. doi:10.1071/CH11142
[8] A. J. Edwards, *Aust. J. Chem.* **2011**, *64*, 869. doi:10.1071/CH11234
[9] M. Cook, R. Kleinsmith, *Aust. J. Chem.* **2011**, *64*, 880. doi:10.1071/CH11120