

Rare gases, heavy water and mutton-bird oil

Three tales from the School of Chemistry Collection

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The School of Chemistry Collection was assembled in the 1970s by the late Joan Treasure Radford, a member of the school from 1956 to 1980.¹ It comprises more than 300 items, dating from the 1850s to the 1960s, which interpret the University of Melbourne's first century of chemistry teaching and research.² Recent research has revealed many rich stories behind the objects. These stories illustrate the objects' significance, not only to the history of chemistry at the university, but also to the broader history of this branch of science. In the following pages I discuss three objects and some of the personalities associated with them.

The microbalance, rare gases and the isotopes of neon

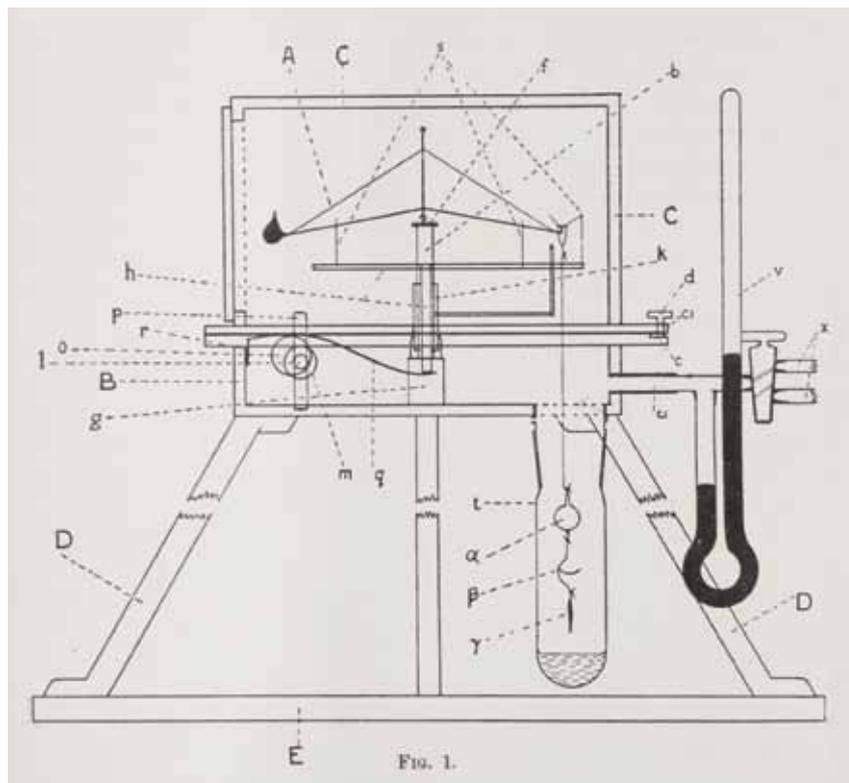
Amongst the collection is an item resembling a small brass box, measuring 12 by 10 by 6 centimetres, with fittings projecting from its sides, and mounted on a base with adjustable feet. This is a microbalance, similar to one designed in 1909 by two University of Melbourne staff, Bertram Dillon Steele³ of the Chemistry Department and Kerr Grant⁴ of the Physics Department.

Most scientific instrument collections will contain one or more analytical beam balances: devices

made of brass and steel and housed in beautiful cases of polished wood and glass. They are familiar even to the unscientific eye, in their similarity to the classical image of the scales of justice displayed on many a court building, or even to vintage kitchen scales, with two pans: one for weights and one for the material to be weighed. Simple forms have been used in local markets for millennia,

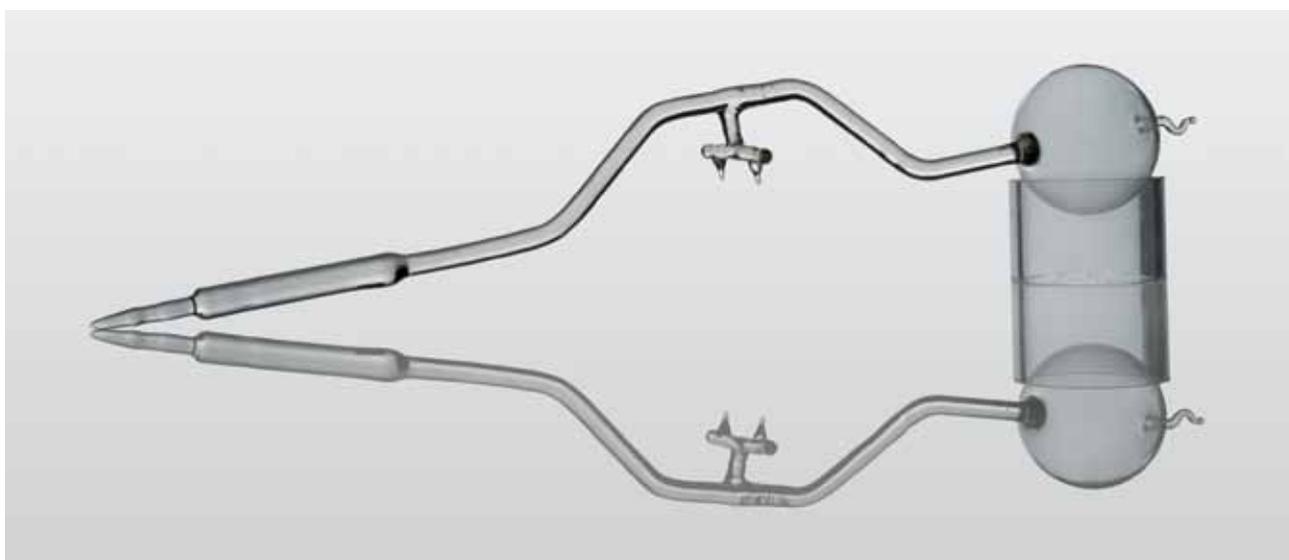
but the first evidence of their use in the laboratory comes from medieval drawings of alchemists' workshops.

Accurate weighing by beam balance was the basis of the chemical revolution attributed to the careful quantitative work of Antoine Lavoisier, known as the 'father of modern chemistry', and others in the late 18th century. By 1900 chemistry had progressed to the point where



Opposite: Diagram of microbalance from Bertram D. Steele and Kerr Grant, 'Sensitive micro-balances and a new method of weighing minute quantities', *Proceedings of the Royal Society of London*, series A, vol. 82, no. 558, 18 September 1909, p. 580

Below: Microbalance quartz beam, made by E.J. Hartung, Melbourne, glass, length: 36.7 cm. Cat. no. 13a, School of Chemistry Collection, University of Melbourne



the investigation of processes at the molecular and atomic level required the measurement of weights of micrograms (one millionth of a gram) to sensitivities of nanograms (one thousandth of a microgram). The problem facing Grant and Steele was to quantify the oxidation of metals in which weight changes of less than a microgram occurred. To obtain accuracy and reproducibility at such small masses, many interfering factors had to be considered and neutralised. The original function of the balance case, with its sliding doors, was to exclude drafts of air and maintain constant temperature. But at the level of precision required by Steele and

Grant, other considerations, such as the buoyancy of the pans at either end of the beam, became important. In consequence, they opted for a balance consisting of a quartz beam swinging on a knife edge in a case which could be pumped out to a sustainable vacuum.

The diagram of Steele and Grant's microbalance, which they published in 1909,⁵ shows the contents of this somewhat mysterious brass case (illustrated opposite). The quartz beam was made by Steele, who was an accomplished glassblower; a later version is shown above. The bulb at one end was filled with gas to a pressure that set the

balance point for the sample on the opposite pan. Changes in the sample weight could then be corrected by admitting gas to the evacuated balance case, thus altering the buoyancy of the bulb. This alteration could then be used, through careful calibration, to measure the change in weight of the sample.

Such was the potential sensitivity of this apparatus that a similar microbalance was made almost immediately by William Ramsay of University College London, who had communicated the original Steele and Grant paper to the Royal Society.⁶ Ramsay's instrument was used to determine the atomic weight

Kerr Grant-style microbalance, modified by E.J. Hartung for use in the study of the photodecomposition of silver salts, c. 1924, metal, marble, mixed media, height: 40.0 cm. Cat. no. 9, School of Chemistry Collection, University of Melbourne

of the gas produced in the radioactive disintegration of radium. The gas was called 'radium emanation' but was subsequently named radon, the heaviest element in the group of 'rare' or 'noble' gases that had long been the subject of the research for which Ramsay was awarded the Nobel Prize in chemistry in 1904. Ramsay and his colleague Robert Whytlaw Gray found by means of the microbalance that the atomic weight of 'radium emanation' was 223, close to the value of 222.4 estimated by Marie Curie in her Nobel Prize-winning research on radium, undertaken in Paris in the late 1890s and early 1900s.⁷ A further application of Steele and Grant's invention was employed in 1914 by the English chemist and physicist Francis William Aston, to estimate the atomic weight of neon, for which he obtained a value of 20.19.⁸ Aston was to invent the mass spectrometer and show that neon, the second-lightest gas in Ramsay's 'rare gas' group, was composed of two isotopes, of atomic weights 20 and 22.⁹

Both Steele and Grant moved on from the University of Melbourne shortly after the invention of the microbalance: Steele became professor of chemistry at the University of Queensland and Grant became professor of physics at the University of Adelaide.



Tintometer used by William Davies in his research into fish oil and mutton-bird oil, c. 1935, mixed media, 14.0 x 58.0 x 36.0 cm. Cat. no. 30, School of Chemistry Collection, University of Melbourne



The microbalance illustrated opposite is a later version used by Ernst Johannes Hartung, professor of chemistry at the University of Melbourne from 1928 to 1953, in his research into the photodecomposition of silver salts.¹⁰ The painstaking work required in those days to determine weight changes at the microscopic level in order to determine atomic weights has long been superseded by instrumental methods, of which Aston's mass spectrometer was one of the first.

William Davies and the tintometer

William Davies was born in Lancashire and studied chemistry at Manchester University, graduating in 1917. He was appointed senior lecturer in organic chemistry at the University of Melbourne in 1924. Davies' career was crowned by his appointment in 1953 as the university's first professor of organic chemistry. In his earlier career at Melbourne, he conducted research into vitamins, in particular vitamin A and its occurrence in fish caught in Australian waters. An important instrument used in such work was the Lovibond tintometer,¹¹ one of which resides in the collection. The tintometer enabled the experimenter

to determine the concentration of oil by comparing the colours of a test solution with a set of standard colours. In this instance, a blue test colour of a test solution of vitamin A was created by adding the chemical compound antimony trichloride.

The Lovibond tintometer was first developed in the 1880s by an English brewer, Joseph William Lovibond, to test the quality of beer. Based on the premise that the flavour of beer was closely associated with its colour, Lovibond hit upon the idea that the quality of the beer could be measured against a standard scale of colour. 'Colorimetry', as Lovibond called this method, soon found application beyond brewing, with the sugar, oil and tanning industries taking a keen interest. In 1895 Lovibond retired from the active management of his brewery business to concentrate on further developing the tintometer, and in 1896 established the Tintometer Ltd Company. In the 1920s many new applications for the tintometer were developed, including its use for measuring vitamin A by Sigmund Otto Rosenheim and Edgar Schuster of the Medical Research Council in Hampstead.¹² It was on this application that Davies was to rely in his own work.

One minor application of this technique for measuring vitamin A is recounted by Davies, who in the late 1930s disproved the claim that mutton-bird oil sold in Melbourne had beneficially high vitamin A content.¹³ The mutton-birds used in the experiment were caught on Babel Island by a senior constable of the Tasmanian police. In order to extract their stomach oil they were, to quote the paper Davies later published, 'killed and squeezed'. This was long before animal ethics committees were set up to monitor research practices!

Heavy water

Of the many liquid and solid chemical samples in the collection, some of which are over 100 years old, one simple phial of colourless liquid labelled 'deuterium oxide' and manufactured by the Norwegian company Norsk Hydro is the most intriguing (illustrated on page 42). Commonly referred to as heavy water, deuterium oxide is water highly enriched in the hydrogen isotope deuterium. We have no information at present about the provenance of this sample. Possibly it was acquired in the 1930s, when heavy water became a curiosity following the discovery in 1932 of the neutron by English physicist James

Sample tube containing deuterium oxide (heavy water), manufactured by Norsk Hydro, Norway, c. 1935. Cat. no. 160, School of Chemistry Collection, University of Melbourne



Chadwick and the isolation of heavy hydrogen (deuterium) in 1931 by the American physical chemist Harold Clayton Urey.¹⁴ Just as the gas neon, mentioned earlier, has isotopes with atomic weights of 20 and 22, differing by two neutrons, so does hydrogen, the lightest element, have isotopes of atomic weights 1 and 2, differing by one neutron.

Deuterium is a minor proportion of ordinary hydrogen (about 0.002 per cent). The only source of heavy water in the 1930s was from

the Norsk Hydro power plant in Vemork, southern Norway, where hydrogen was generated from the electrolysis of water, using Norway's abundant and cheap hydro-electric power. This hydrogen was piped to a nearby fertiliser factory at Rjukan to be used as feedstock in the synthesis of ammonia. In 1934 it was discovered that hydrogen produced by electrolysis of water is depleted in deuterium, whereas the remaining water is enriched in deuterium, so that repeated recycling of the water

to the electrolysis cell eventually produces heavy water. The Norsk Hydro plant was taken over by the Germans in April 1940 after their invasion of Norway. The German atomic research effort focused on the use of heavy water as a moderator in their proposed fission reactor, in which slow neutrons reacted with the U^{235} isotope to produce nuclear fission. The allies succeeded in interrupting the heavy water supply from Norway in 1943 by staging several commando attacks on the

plant and on the ferry taking the stocks of heavy water to Germany. In 1965 these events were dramatised in the film *The heroes of Telemark*, starring Kirk Douglas.

The Germans never did succeed in building a working fission reactor, the first requirement of an atomic weapons program. In the USA, the Manhattan Project employed graphite as the moderator in the first successful reactor in Chicago in 1942, and went on to make the first atomic bombs in 1945. The Norsk Hydro heavy water plant ceased operating in 1971. Currently, the largest producer of heavy water is India.¹⁵

As demonstrated by the three items explored here, each object in the Chemistry Collection has its own fascinating story to tell about the history of the field of chemistry and the individuals associated with it, both at the University of Melbourne and beyond.

Dr Trevor McAllister was born in Belfast, Northern Ireland, where he gained his degrees in chemistry in the 1960s. After a 35-year career in research laboratories in Canada (NRC) and Australia (CSIRO), he is now retired and is a tour guide at the Melbourne Museum and the State Library of Victoria. He has enjoyed the past two years in the 'time warp' of the Chemistry Collection, on which this article is based.

The School of Chemistry Collection is currently in storage, although a small display can be visited on the ground floor of the Chemistry Building. The University Library has provided a Scholarly Information Innovation Grant to the School of Chemistry to establish a fully searchable online database of the collection. This will be launched in late 2012.

- 1 Valda M. McRae, *Chemistry @ Melbourne 1960–2000*, School of Chemistry, University of Melbourne, 2007, p. 166.
- 2 The collection has been the subject of several articles by Dr Petronella Nell: 'Rediscovered: An introduction to the School of Chemistry Collection', *University of Melbourne Collections*, issue 4, June 2009, pp. 28–33; 'Our chemical cultural heritage: The University of Melbourne Chemistry Collection', *Chemistry in Australia*, November 2009, pp. 20–3; 'Our chemical cultural heritage: Macadam and Kirkland (1862–85)', *Chemistry in Australia*, December 2009, pp. 28–9; 'Our chemical cultural heritage: Masson and Rivett (1858–1961)', *Chemistry in Australia*, May 2010, pp. 27–8; 'Our chemical cultural heritage: Hartung (1893–1979)', *Chemistry in Australia*, September 2010, pp. 30–2.
- 3 Bertram Dillon Steele was appointed lecturer and acting professor in chemistry at the University of Melbourne in 1906. See Barry Chiswell, 'Steele, Bertram Dillon (1870–1934)', *Australian dictionary of biography*, vol. 12, Melbourne University Press, 1990, <http://adb.anu.edu.au>.
- 4 Kerr Grant joined the University of Melbourne's Natural Philosophy Department in 1905. See S.G. Tomlin, 'Grant, Sir Kerr (1878–1967)', *Australian dictionary of biography*, vol. 9, Melbourne University Press, 1983, <http://adb.anu.edu.au>.
- 5 Bertram D. Steele and Kerr Grant, 'Sensitive micro-balances and a new method of weighing minute quantities', *Proceedings of the Royal Society of London*, series A, vol. 82, no. 558, 18 September 1909, pp. 580–94.
- 6 R. Whytlaw Gray and William Ramsay, 'The density of niton (radium emanation) and the disintegration theory', *Proceedings of the Royal Society of London*, series A, vol. 84, no. 573, 26 January 1911, pp. 536–50.
- 7 Curie won the Nobel Prize in chemistry in 1911 for the discovery of radium and polonium, and for the isolation of radium and the study of its nature and compounds.
- 8 F.W. Aston, 'A simple form of micro-balance for determining the densities of small quantities of gases', *Proceedings of the Royal Society of London*, series A, vol. 89, no. 612, 1 January 1914, p. 439.
- 9 F.W. Aston, *Isotopes*, London: Edward Arnold, 1922, p. 64.
- 10 Joan Radford, *The Chemistry Department of the University of Melbourne: Its contribution to Australian science 1854–1959*, Melbourne: Hawthorn Press, 1978.
- 11 J.W. Lovibond, *Light and colour theories and their relation to light and colour standardisation*, London: E. and F.N. Spon, 1921.
- 12 G.S. Fawcett, 'Sixty years of colorimetry', *Proceedings of the Physical Society*, vol. 56, issue 1, 1 January 1944, pp. 8–21.
- 13 William Davies, 'The vitamin A and vitamin D contents of mutton bird oil', *Australian Journal of Experimental Biology and Medical Science*, vol. 17, 1939, pp. 81–4.
- 14 Harold C. Urey, F.G. Brickwedde and G.M. Murphy, 'A hydrogen isotope of mass 2', *Physical Review*, vol. 39, issue 1, January 1932, pp. 164–5.
- 15 For a popular account of the early atomic researchers see Diana Preston, *Before the fallout: From Marie Curie to Hiroshima*, New York: Walker and Co., 2005.