From Dalton's Atom to the Atom Bomb

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During the 19th century the Philosophical Society of Glasgow had as members, or very close associates, a remarkable group of scientists whose work laid the foundation for much of modern science, technology and industry. Many reasons can be advanced for the existence of this group in Glasgow, including the educational system, increasing wealth, the rapid growth of industry and technological innovation in the West of Scotland, but the importance of the idea of matter being composed of atoms, whose relative weights can be found and whose properties have regularities which vary with the weights, cannot be underestimated. It was the good fortune of chemists in Glasgow to be the first in the world to be exposed to this key idea and to have the practical training to play a vital role in working out the consequences.

The Founders: Thomson and Graham

Thomas Thomson was already a distinguished teacher, textbook writer, journal editor and historian when in 1817 he became first lecturer then Regius Professor of Chemistry in the University of Glasgow. More importantly, he had visited Manchester in 1804 where Dalton explained to him his ideas on the atomic composition of matter. Thomson later wrote 'I was enchanted with the new light which immediately burst upon my mind and I saw at a glance the immense importance of such a theory'. He published the first ever account of Dalton's theory in his *System of Chemistry* in 1807. In addition to his advocacy of Dalton's atomic theory Thomson founded in Glasgow the first university school of practical chemistry and after his election as President of the Philosophical Society in 1834 'was largely responsible for changing the moribund Society dominated by artisans into an intellectually competent one'. His work culminated in the start of publication of the *Proceedings* in 1841.

When Thomson was elected President his distinguished pupil Thomas Graham, then Professor of Chemistry at Anderson's University, was elected Vice President. Graham, thoroughly instructed in Dalton's atomic theory and an ingenious and skilled experimenter, took as his main research interest the mobility of atoms in gases and liquids. His interest in this field seems to have been stimulated by Dalton's observation that 'gases of a different nature, when brought into contact, do not arrange themselves according to their density, but spontaneously diffuse mutually and equably through each other, so as to remain in an intimate mixture'.

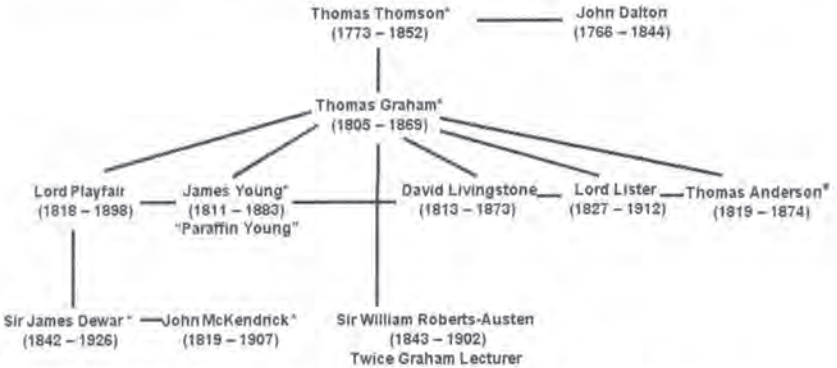
In the course of his researches, Graham invented his diffusion tube – made of glass and closed at one end by a porous plug – which led to Graham's Law: that the rate of diffusion, of a gas varies inversely as the square root of its molecular weight. Graham developed this into the process of atmolysis whereby gases of different molecular weights can be separated by diffusion through porous pipes. This became widely used, and culminated in the huge diffusion plants built to separate uranium isotopes during and after the Second World War.

When Graham extended his studies to diffusion in liquids, the result was Fick's mathematical laws of diffusion, fundamental to all subsequent research in the field, and also to the invention of the process of dialysis (a word coined by Graham) by which solutes can be separated by diffusion through a membrane. This process is, of course, the basis for artificial kidneys.

In 1837 Graham became Professor of Chemistry in University College, London, and in 1855 Master of the Mint. His assistant there, who later succeeded him as Chemist to the Mint, Sir William Roberts-Austen, was twice Graham Lecturer to the Society. In 1879 he gave the first Graham Lecture and in 1900 summarised his own life's work on diffusion in metals and the influence Graham had on him, ending 'I doubt whether he would have wished any other recognition than that universally accorded to him of being the leading atomist of his age'.

Graham's Followers

The figure below shows some of Graham's students and research assistants. The first group (Playfair, Young and Livingstone) attended Graham's lectures on medical chemistry at Anderson's University. They formed a very disparate group but remained close friends and in contact all their lives. Lyon Playfair came from a wealthy and politically powerful background. His grandfa-



Thomas Graham, his predecessors and pupils. Vertical / sloping linkage indicates pupils and research assistants. Horizontal linkage indicates collaboration or close relationships. An asterisk indicates membership of the Society.

ther was Principal of St Andrews University and his father, Inspector General of Hospitals in India. Young, on the other hand, was poor – his father a carpenter – but of great ability: he was Graham's personal assistant. Livingstone was, of course, a weaver studying medicine to become a missionary. All were attracted to Anderson's University because of Graham's high reputation; in Playfair's case instead of some more socially prestigious establishment. One point which turned out to be crucial was that Playfair lodged with a family by the name of Ramsay whose mother had been recently widowed.

Playfair, well launched on a career in chemistry due to Graham, became Professor at Edinburgh and acquired such great scientific and political influence that he could facilitate Graham's appointment to the Mint. However, he was essentially a political animal, becoming MP for the Scottish Universities before being raised to the peerage by the patronage of Gladstone.

It is often said that Playfair's greatest scientific discovery was James Dewar, who became his research assistant at Edinburgh. Dewar, who came from Kincardine, was one of the most skilled experimenters of his age. He became a member of the Society in 1883, while Jacksonian Professor at Cambridge, as a result of his collaboration with John McKendrick, Professor of Physiology at Glasgow and Secretary to the Society. They worked together on the physiology of vision. Dewar, however, is even better known for his work in low temperature physics, a subject he founded; he was the first to make and store liquid oxygen in bulk and also the first to liquefy hydrogen, making use of his invention of the dewar (thermos) flask. He also developed the use of charcoal to absorb gases at low temperatures, a device widely used to improve vacua in many fields of research. With these innovations Dewar not only laid the foundations of the liquid gas industry but even those of space travel.

In 1847 Playfair drew his friend Young's attention to a natural oil well on an estate in Derbyshire. Young followed up this hint, profitably exploited the well, making many important innovations in processing the oil. These included 'cracking' it (a word he coined) to obtain more useful by-products. He later moved back to Scotland seeking new sources of oil and founded a shale oil industry which became the world's largest. He used his wealth to support Livingstone's later expeditions and subscribed largely for the erection of statues of Graham, in Glasgow's George Square, and of Livingstone, near the city's Royal Infirmary. As a distinguished member of the Society he financed the collection and publication of Graham's collected papers.

While he was at University College, Graham had Joseph Lister as one of his students, and there is a story, probably apocryphal, that it was on his advice that the latter undertook further study at Edinburgh, which led eventually to his appointment as Professor of Surgery at Glasgow in 1860. Lister was studying the inflammatory process in wounds – a cause of great mortality – which he believed was due to exposure to air, when Thomas Anderson, President of the Society in 1865, drew his attention to work by Pasteur which showed that putrefaction was due to the presence of minute living particles in the air. Antiseptic and eventually aseptic surgery was the result.

Sir William Roberts-Austen, Graham's last research assistant has already been mentioned. In addition to making the first diffusion measurements in metals – 'My long connection with Graham's researches made it almost a duty to attempt to extend his work on liquid diffusion to metals' – his duties at the Mint led him to study the steels used in making dies, and hence to the properties of steels in general. This in turn led to the chairmanship of a series of influential committees on the properties of alloys, with particular focus on naval armour and shells. The increasing threat of German militarism in the late 19th century had caused a great increase of government concern in this field. By this work Roberts-Austen became a founding father of modern metallurgy. His pioneering work on solid state diffusion led directly to the diffusion technology which is basic to the modern microelectronic industry.

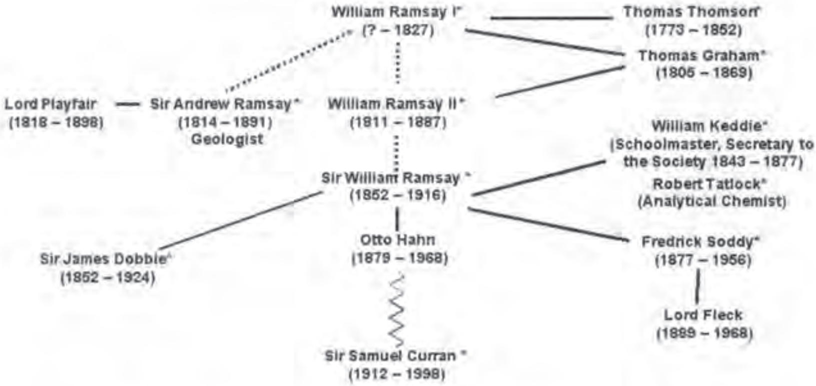
The Ramsay Family

The years around the 1800s were a time of intellectual ferment and numerous societies were founded to promote the spreading of new ideas and useful arts. Typical was the Chemical Society of Glasgow, founded in 1798 by William Ramsay I, an industrial chemist from Haddington. In 1802, when the Philosophical Society with its broader interests was founded, the Chemical Society was dissolved, and William Ramsay joined the new organisation becoming a friend of Thomas Thomson. His grandson, Sir William Ramsay, gave a record book of the Chemical Society to its Philosophical successor.

When William Ramsay I died, his widow took in boarders to assist finances and Lyon Playfair became part of the family circle. He became particularly friendly with Andrew (later Sir Andrew) Ramsay, an amateur geologist, who with Playfair's advice and help became a professional, and eventually Director-General of the Geological Survey.

Sir Andrew's brother William Ramsay II studied briefly under Graham, who was a family friend; he was then apprenticed to Robert Napier, the celebrated shipbuilder, and qualified as an engineer specialising in insurance. He had a great interest in scientific matters and was an early subscriber to *Nature*, which was founded in 1869 by Lochyer.

The figure opposite shows details of these relationships. William Ramsay III (later Sir William) was born at 2 Queens Crescent and later lived at 11 Ashton Terrace. He attended Glasgow Academy, where he was taught science by William Keddie, Secretary to the Society from 1843 until 1877. Later, as a student at Glasgow University, he became a pupil of Sir William Thomson. Because of his interest in chemistry he was apprenticed to Robert Tatlock, the City Analyst and later founder of the famous firm of chemical suppliers; here he started to acquire the manipulative skills which gave his career such distinction. He obtained his PhD at Tubingen where he became fluent in German, and though impressed by the national university and



Sir William Ramsay, his family and research assistants Vertical / sloping linkage indicates pupils and research assistants. Horizontal linkage indicates collaboration or close relationships. An asterisk indicates membership of the Society.

research system, he developed strongly anti-militaristic views, having seen at first hand the triumphalism that followed the Franco-Prussian war. On his return to Glasgow he became an active member of the Society, Secretary of the Chemical Section, and lectured at Glasgow and Anderson's Universities where one of his pupils was James (later Sir James) Dobbie, with whom he later collaborated on chemical research. Indeed Dobbie succeeded him as Chemical Section Secretary, before later becoming Director of the Royal Scottish Museum.

In 1880 Ramsay became Professor of Chemistry at University College, Bristol, and later its Principal, and in 1887 moved on to be Professor of Chemistry at University College, London, where both Graham and his uncle, Sir Andrew, had held chairs. He became deeply interested in teaching and, assisted by Playfair, succeeded in securing funding to match German levels of research and university provision. He maintained his close contacts with Glasgow and the Society through his father and because he inherited a Clyde coast house, Belmont, where he spent his summers sailing and swimming.

Sir William Ramsay

In 1894 Ramsay's career was radically altered by Lord Rayleigh's announcement that there was a small density difference between nitrogen prepared from air and nitrogen produced from ammonia. An example of looking for the next decimal place! Ramsay believed that nitrogen from air might contain a heavier gas and pointed out that in 1783 Cavendish had done experiments that supported this view. With Rayleigh's permission, Ramsay attempted to produce a large volume of this gas chemically. He succeeded, and they jointly announced the discovery at the 1894 British Association meeting. The meeting adopted a suggestion that the gas be called argon, after the Greek for 'idle'.

Ramsay investigated the properties of the new gas and showed it to be completely inert and, from its specific heats, monatomic. This suggested a radical extension of the periodic table which included spaces for a number of inert gases, so far unknown. Ramsay promptly verified this conjecture by obtaining a new inert gas from the mineral cleavite. Spectroscopic studies by Sir William Crookes promptly showed that this gas was the helium which had been suggested as an element by Lockyer on the basis solar spectra observations.

He now started a systematic search for other inert gases which he had provisionally called anglium, scotium and hibernium following the contemporary nationalistic fashion for naming new elements (for example, germanium). He duly found the elements using fractional distillation of liquid air but sensibly turned to Greek for their names: neon, krypton and xenon ('new', 'hidden' and 'strange' respectively).

It is impossible to overestimate the significance of Ramsay's discoveries. They added a new column to the periodic table, created a completely new field within chemistry, and even a new industry, while a detailed study of the helium spectrum now made it possible to obtain clinching evidence for Bohr's atomic theory. Ramsay was awarded the Nobel Prize for Chemistry in 1904, the first Briton to be so honoured.

Thereafter, Ramsay pioneered the subject of radiochemistry, a natural step since he had discovered helium in a radioactive mineral. In 1903 he was joined in this work by Frederick Soddy whom he had examined for his Oxford degree. Together they verified that radium continuously produces helium, strongly suggesting that alpha particles were in fact ions of that gas. Influenced by Ramsay, Soddy joined the chemistry department at Glasgow University where for the next decade he clarified the role of the radioelements in the periodic table and (at a dinner party) coined the word 'isotope' for atoms having identical chemical properties but differing atomic weights. In his experimental work, Soddy was assisted by a technician, Alexander Fleck, whose interest in chemistry he encouraged. Fleck graduated from the University and pursued a career in industrial chemistry, becoming Chairman of ICI and later Lord Fleck. Soddy joined the Society and gave the Graham lecture in 1909. For his work in showing the existence of isotopes and so completing the periodic table as we know it, Soddy was awarded the Nobel Prize in 1921.

Another of Ramsay's research assistants was Otto Hahn who was attracted to work with him by his reputation and German contacts. Ramsay taught him the basics of radiochemistry and gave him an sample of a thorium-bearing mineral from Ceylon, a study of which had suggested that it might contain a new radioactive element. Hahn separated out the element – radiothorium – and Ramsay unselfishly encouraged him to publish the discovery under his name only, allowing him to establish his independent reputation in radiochemical research. Hahn, unfortunately, was less generous in later years. When he published his discovery of nuclear fission in 1938, he excluded Lise Meitner from co-authorship, in spite of their 30 years' collaboration. Indeed Meitner was given no share when Hahn was awarded the Nobel Prize in 1944, an oversight which launched a controversy which is still alive today, almost 50 years later.

The discovery of uranium fission led directly to the atom bomb, in whose development a long-time active member and President of the Society played an active part. Samuel Curran (later Sir Samuel) worked on isotope separation in the USA between 1943 and 1945, during which he invented the scintillation counter, which has become a vital tool in modern science. After that he headed the British fusion bomb project before becoming the first Principal of the University of Strathclyde, the very institution in which, under its earlier name of Anderson's University, Graham himself had taught and researched one hundred and fifty years earlier.