Occultism and the atom: the curious story of isotopes

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When Francis Aston discovered a new type of neon in 1913, he initially linked it with an atom that had been predicted by two "occult chemists" through a strange form of clairvoyance. But why was this episode later rewritten in the history books?

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THE ROUTES to scientific discovery are sometimes strange. We are all familiar with the story of Newton and the falling apple, or with Friedrich Kekulé's dream of a snake biting its own tail that led to the discovery of benzene's ring-like structure. But such stories – engaging though they might be – are often mythical. They serve a function in science, emphasizing individual psychology and the flash of inspiration from a heroic scientific genius, over the more routine and collective aspects of scientific work.

Romanticism aside, however, the history of science – like Orwell's Big Brother state – usually writes and rewrites history to remove inconvenient facts, mistakes and idiosyncrasies, leaving only a rationalized path to our present knowledge, or what historians sometimes call "whig" history. In so doing, it not only distorts the actual course of historical events but also gives a misleadingly simplistic picture of the richness of scientific activity and the interactions between science and broader culture.

CAVENDISH LABORATORY, CAMBRIDGE UNIVERSITY

Clairvoyant connection – Francis Aston trying to separate neon and "meta-neon" in about 1913.

In the history of physics, for example, the discovery of isotopes by Frederick Soddy and Francis Aston is usually cast as part of a linear sequence of discoveries in atomic and nuclear physics. The story, we are told, began with the discovery of radioactivity in the 1890s, continued with the discovery of the nucleus (1911), isotopes (1913), wave mechanics (1920s) and the neutron (1932), before leading to nuclear fission (1938) and, ultimately, the atomic bomb (1945).

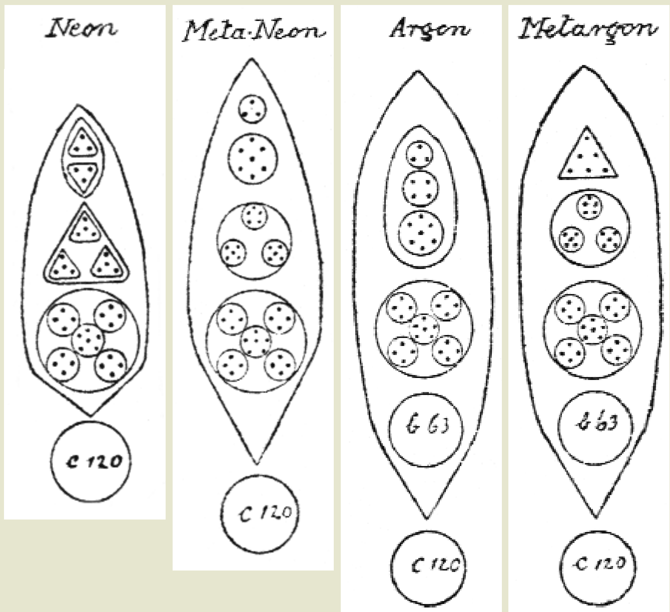
This bomb-directed story naturally emphasizes the key scientific elements of atomic weapons. But in doing so, it over-rationalizes the way in which these discoveries were achieved, and gives a deceptive picture of the process of scientific discovery and of the reasons why science develops as it does. If we look at the actual course of events without the benefit of hindsight, we learn that fact can, indeed, sometimes be stranger than fiction.

J J Thomson and the 'positive rays'

The 1890s were convulsive years for the physical sciences. The discoveries of the rare gases, X-rays, radioactivity and the Zeeman effect – as well as the elaboration of ionic theory and the electrical theory of matter – radically changed our understanding of the physical world. At the Cavendish Laboratory in Cambridge, J J Thomson's 1897 discovery of the "corpuscles" that made up cathode rays – the particles that would later be known as electrons – opened up the microphysics of the atom. But while public audiences marvelled at the spooky new X-ray photography, Thomson and his students, as well as physicists elsewhere, took up the challenge of finding out more about atoms and radiation.

Thomson spent several years trying to work out a scheme of atomic structure based on his corpuscles. He tried various arrangements of corpuscles revolving inside each atom, hoping to find a way of explaining its physical and chemical properties. But although he understood the nature of negative electricity fairly well in terms of rotating rings of corpuscles, he was mystified by the counterbalancing "positive electricity" that must exist in a neutral atom. Thomson thought of it more or less as a massless cement holding the corpuscles – and hence the atom – together. At first, he believed that the number of corpuscles in an atom had to be about the same as the atomic-mass number. Scattering and other experiments soon led him to reduce the number of corpuscles in his model, but this made it radiatively unstable. Thomson concluded that positive electricity must have mass – and that it must, indeed, contain most of the mass of the atom.

In 1906 Thomson therefore began a new research project on "positive rays" – the ions that stream through a hole in the cathode of a gas-discharge tube – in an attempt to understand positive electricity and its role in atomic structure. Working



Strange visions – these structural diagrams for neon, meta-neon and other rare gases were obtained through clairvoyance by the British theosophists Annie Besant and Charles Leadbeater. The illustrations appear in their 1907 book *Occult Chemistry*.

mainly through his assistant Ebenezer Everett and his student George Kaye – who later co-wrote Kaye and Laby's famous *Tables of Physical and Chemical Constants* – Thomson modified the technique that he had used in his successful cathode-ray experiments a decade earlier. By arranging electric and magnetic fields round the discharge tube, he was able to direct the positive rays onto a small fluorescent screen. Theory indicated that the rays should form a series of parabolas on the screen, with each parabola created by rays that have the same charge-to-mass ratio (e/m) but different speeds.

In practice, however, the experiments were deeply troublesome. The results were highly sensitive to changes in pressure, and achieving low pressures was particularly difficult. The maximum value of e/m was always found to be that for the hydrogen ion, H^+, regardless of the gas in the tube. On this basis, Thomson concluded that H^+ was a basic constituent of all atoms. Other than this, however, it was hard to make consistent sense of the experiments, which by 1909 had reached an impasse. To make matters worse, Kaye left the Cavendish for the National Physical Laboratory the following year. Thomson was stuck.

He began to cast around for a new assistant. Fortuitously, he took the advice of his friend John Henry Poynting from Birmingham University and offered the post to one of Poynting's former students – Francis William Aston. A lover of fireworks and mechanical things from an early age, Aston had studied chemistry and physics at Mason College – the forerunner of Birmingham University – in the mid-1890s. He had become extremely skilled in glass-blowing and the use of tools, and set up his own workshop and lab in a loft at home. The sensational discovery of X-rays fascinated him, and he spent much of his spare time outside of his day job in a Wolverhampton brewery designing and building his own gas-discharge apparatus and pumps. In 1903 Poynting offered Aston a scholarship to return to Birmingham University, where he pursued this gas-discharge work in a leisurely fashion for the next few years.

Grotesque monsters

Aston's arrival at the Cavendish in 1910 significantly changed Thomson's experimental approach. An expert in coaxing the best from a piece of apparatus by systematic, incremental tinkering, Aston found ways of achieving and working at much lower pressures than Thomson had ever achieved before. Characteristic atomic and molecular parabolas for different gases now became visible for the first time, and Aston introduced photographic methods to detect and record them. Thomson now began to realize that the positive-ray apparatus could be used to identify gases and their constituents, and by 1912 he and Aston were promoting the "positive-ray spectrograph" as a form of chemical analysis.

While he continued modifying and refining the technique, Aston also embarked on a systematic survey of gases using the new method. Like Thomson, he also saw the rarefied conditions of the gas discharge as a productive source of unusual phenomena for further investigation. "We need not", he wrote, "be surprised at finding upon the [photographic] plates lines corresponding to molecules found neither in the heavens above nor in the earth beneath; nor need those of us who are chemists hold up our head in horror at such unnatural and grotesque monsters of the world of molecules as H_3, CH, CH_2, CH_3, N_3 etc. etc. Rather we should look forward to this line of investigation as an extremely hopeful field in which to study the actual mechanism of dissociation, ionisation and chemical interaction."

This was a significant change in the *meaning* of the positive-ray experiments. They were no longer just a physical way of investigating positive electricity, but also a means of eliciting novel chemical phenomena – and perhaps a way of understanding physics and chemistry in common terms. The new direction of the research bore fruit in 1911 when Thomson noticed a line corresponding to atomic mass 3, which appeared sporadically and which he described as "about as elusive a thing as the sea serpent". Designating it "X_3", he spent much of his time over the next few years chasing this monster.

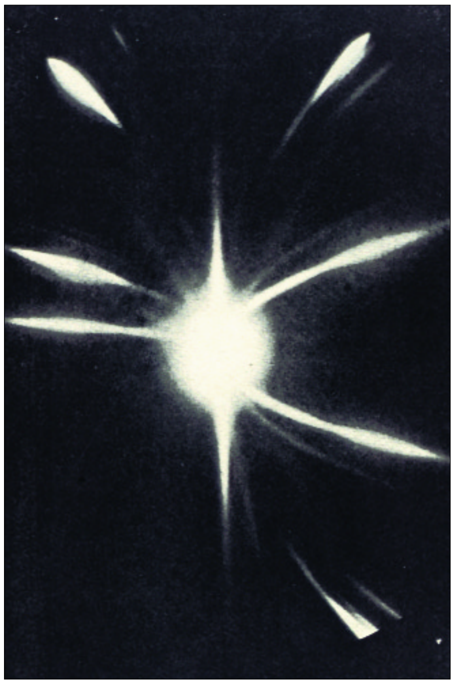
In 1912 Aston found a monster of his own when he introduced neon into the tube. Rare gases like neon were still relatively novel, difficult to obtain and poorly understood. Although neon's atomic weight had then recently been determined to be 20.2, its properties were still a puzzle. When Aston analysed neon in the positive-ray spectrograph, he saw not only the expected parabola corresponding to an atomic mass of about 20 but also a persistent "shadow" parabola corresponding to an atomic mass of 22.

Aston thought that he had discovered a new element closely associated with neon – perhaps a new rare gas or a new feature of the rare gases. He named this new element "meta-neon". It is here that Aston's links with the occult first surface. In a footnote to the paper announcing his discovery to the annual meeting of the British Association (BA) in 1913 in Birmingham, Aston referred to a 1908 publication by Annie Besant and Charles Leadbeater called *Occult Chemistry: A Series of Clairvoyant Observations on the Chemical Elements*.

"By theosophic methods entirely unintelligible to the mere student of physics," noted Aston, "[the authors] claimed to have determined the atomic weights of all the elements known, and several unknown at the time. Among the latter occurs one to which they ascribe an atomic weight of 22.33 (H = 1) and which they call 'Meta Neon'. As this name seems to suit as well as any other, what little we know of the properties of the new gas, I have used it in this paper."

Astral visions

Theosophy – meaning "divine wisdom" – was a centuries-old system of philosophical and religious belief concerning the nature and processes of the divine and their relationship with the phenomenal universe. In its modern form, organized theosophy was a social and intellectual movement founded in the US in the 1870s, and popular in Britain and Europe from the 1880s. One of a number of systems of belief that came to prominence in this period as alternatives to organized religion and scientific rationalism, theosophy drew on ideas from Eastern philosophy, mysticism and ancient occult traditions dating back to Pythagoras. Its blend of esoteric wisdom and spiritual philosophy (including a belief in reincarnation) appealed to Victorian audiences disenchanted by the materialism of much modern science and by a Christianity that they saw as having become compromised by science. In particular, theosophy's emphasis on esoteric wisdom gave it a strong appeal to intellectuals. They saw in it a way of exploring and expressing hidden realities in an increasingly materialistic world without moral or spiritual values.



Ghostly shadow? – Aston's positive-ray spectrograph of neon and meta-neon (top right).

It is well known, of course, that several notable British physicists of this period – including Lord Rayleigh, Oliver Lodge and Thomson himself – were members of the Society for Psychical Research and were interested in what we might now call paranormal phenomena. Although their positions varied from complete belief to cautious scepticism, they all hoped that physics might be able to shed light on phenomena outside the range of normal experience. Like psychical research and spiritualism, theosophy was intellectually both controversial and fashionable in the early years of the 20th century.

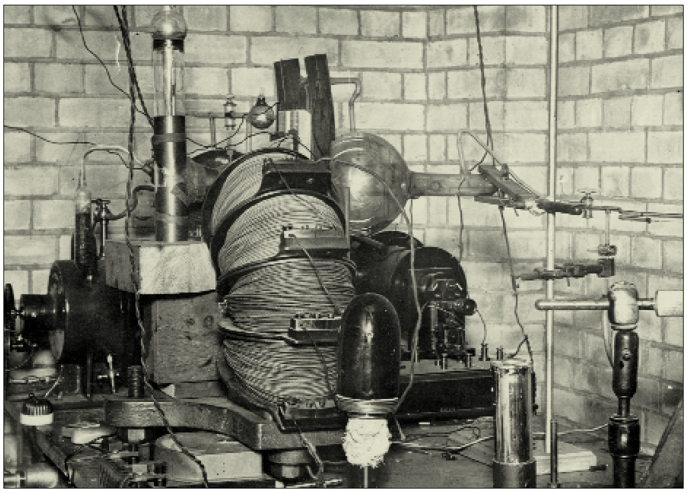
Besant and Leadbeater, to whom Aston referred at the 1913 BA meeting, were two of the leading British theosophists. They had made significant contributions to its philosophy and to the public visibility of the theosophical movement. Their 1905 book *Thought Forms* – a vividly illustrated study of the "astral" auras associated with different moods and emotions – was widely read and had a profound effect on a number of artists and musicians, including Mondrian, Kandinsky and Schoenberg. Besant and Leadbeater saw theosophy as a higher form of science – a means by which natural phenomena and insights unavailable to (or ignored by) the physical sciences could be revealed and tested, and through which deeper universal truths might be attained. In this sense, they saw theosophy and science as complementary.

In the summer of 1895 Leadbeater had first used a form of clairvoyance that he called "astral vision" to "see" inside the atoms of hydrogen, nitrogen and oxygen. His descriptions of the inner architecture of atoms of the various elements were transcribed and first published in the theosophical magazine *Lucifer* in November 1895 under the title "Occult chemistry". Leadbeater described various atomic structures in different degrees of reduction across "etheric sub-planes" down to a fundamental unit. He referred to this as the "ultimate physical atom" – a heart-shaped flow of the theosophical "life force" from which all matter was supposed to be composed. Leadbeater and Besant linked their discoveries to the recent claims of the scientist William Crookes that all atoms might consist of the "protyle" – the elementary unit of matter that had been suggested by the chemist William Prout a century earlier. (Prout had assumed that the protyle was the hydrogen atom, although Crookes suggested that it might be Thomson's electron.)

Besant and Leadbeater's book *Occult Chemistry* expanded on their earlier research by systematically describing the decomposition of all the elements into their "inconceivably beautiful and brilliant" ultimate structures. Again they produced a series of increasingly complex diagrams of atomic structures of all the known elements, correlating their weights and properties to those known from chemistry. But they also had a few surprises. They reported seeing elements that were "not yet discovered" by conventional science, including one that they called "Occultum", which they claimed had an atomic mass of 3. The pair also reported finding a new series of elements closely associated with the rare gases – "meta-neon", "metargon", "meta-krypton" and "meta-xenon" – as well as an entirely new pair of rare gases, dubbed "kalon" and "meta-kalon".

It is telling that Aston was familiar with Besant and Leadbeater's book, and even more so that he chose to adopt their name "meta-neon" for his new gas. After all, naming is important in science, in reflecting credit attribution and intellectual networks. It may even be that Besant and Leadbeater's claims provided Aston and Thomson with a valuable resource in grounding the experimental discovery of a new element: it gave them a peg, as it were, on which to hang and make sense of the neon-22 anomaly. It thus seems highly likely that theosophy had a small, but significant, impact in physics, as well as in other areas such as art, music and philosophy.

Having decided in the summer of 1913 that meta-neon was "a new elementary constituent of the atmosphere", Aston set about separating and isolating it so that he could determine its properties. He designed a quartz micro-balance that was accurate to 10^{-9} g to measure the density of tiny quantities of the novel gas, and deployed his formidable experimental technique to try to obtain a sample of it. The first method he used – fractional distillation – was a failure. The second, which involved repeated diffusion through pipeclay, produced better results. Starting from 100 cm^3 of neon provided by a French colleague, he obtained – after thousands of tedious operations – two extreme weight fractions of only 2–3 cm^3. At the 1913 BA meeting Aston reported that neon and meta-neon had atomic weights of 19.9 and 22.1, respectively, and concluded that atmospheric neon contained 10–15% of the new gas.



Cavendish Laboratory, Cambridge University

Making monsters – the positive-ray apparatus developed by Thomson and Aston.

Occult science: the inside story

Historians, like scientists, sometimes make serendipitous discoveries that open up new areas of study, *writes Jeff Hughes*. The story of Aston, the meta-elements and theosophy came to light when I was going through a large grey box of Aston's papers in Cambridge University Library as part of my research on the history of nuclear physics between the wars (*Physics World* July 2000 pp43–48). The papers were uncatalogued, and consisted mainly of offprints of Aston's many published papers, together with some interesting letters from scientific colleagues and a couple of his lab notebooks. Buried among this material was a yellowed, 15-page typed manuscript entitled "On the homogeneity of atmospheric neon".

The document, scarred with what looked like burn marks from pipe ash on the first couple of pages, was undated, and did not correspond to any of Aston's published papers. But from its description of his work on the positive-ray analysis of neon and meta-neon, and from the internal evidence of the other papers he cited, it quickly became clear that it had been written in the second half of 1913. It seemed likely to be a version of the paper that Aston delivered at the British Association's meeting in Birmingham in September 1913, where I knew he had spoken on his neon discovery.

As well as revealing significant new details of Aston's attempts to separate the two forms of neon, the document showed that he had been in touch with Bohr, who had told him about the new nuclear theory of the atom and its implications for the interpretation of neon and meta-neon. But the last page of the paper – after the usual acknowledgments and so on – contained a curious "Note on the name 'Meta Neon'", in which Aston admitted his source for the name.

Initially amazed that he would even be familiar with Besant and Leadbeater's *Occult Chemistry*, I became interested and decided to follow up the theosophical connection. The story that began to emerge about the culture in which Aston worked and the way he produced his results was very different to the one in the historical books and articles I had read. It was obvious that the history had been rewritten from a later perspective. Rising to this challenge, I decided to write a book on the *real* history of Aston, isotopes and the mass-spectrograph. This article is just one small part of that story.

Radioactivity and isotopes

As Aston continued his patient work on the new gas at the Cavendish, two interventions led to a reinterpretation of the meaning and significance of meta-neon. The first came from Frederick Soddy, a lecturer in radioactivity at Glasgow University (who had previously co-discovered with Ernest Rutherford the disintegration theory of radioactivity). As a radio-chemist, Soddy had recently developed the theory of "isotopic elements" or "isotopes" – atoms of different masses that occupy the same place in the periodic table and are chemically inseparable. The theory was heavily criticized, however, and Soddy needed all the supporting evidence he could find. He seized on Aston's results and claimed that neon and meta-neon were examples of "isotopes" among the lighter elements – so extending and, he hoped, embedding his concept outside the narrow field of radioactivity.

At the same moment, Niels Bohr, who was then working with Rutherford at Manchester, suggested that isotopes could be understood in terms of his colleague's new and still-speculative nuclear theory of the atom. Bohr also explicitly included neon and meta-neon as examples of "isotopes" among the light elements. He argued that, according to Rutherford's theory, such species should have identical nuclear charge and electronic configurations but different masses and different internal nuclear structures. This was a powerful line of argument, and Rutherford himself soon adopted it to promote his nuclear theory. Yet it was far from self-evident to many scientists – not least because of its double-edged nature. As Bohr put it, isotopes were paradoxically a "necessary consequence and simultaneously 'proof' of Rutherford's theory". Belief was important here, too.

By the summer of 1914 a new matrix of mutually supporting evidence was beginning to coalesce linking Rutherford's nuclear theory and Soddy's isotopes. Aston's neon and meta-neon were important elements in establishing the generality of the isotope concept to all elements, not just the radioactive ones. Although the outbreak of the First World War drastically curtailed research as scientists were mobilized, scientific discussions continued whenever possible. Aston, who was seconded to the Royal Aircraft Establishment at Farnborough, discussed meta-neon and the isotope hypothesis with, among others, Frederick Lindemann, who later (as Lord Cherwell) became Churchill's scientific advisor. Rutherford and Bohr continued to promote the nuclear theory, while Soddy widened his argument for isotopes to include the explanation of phenomena such as non-integral atomic weights.

Rutherford's disintegration of nitrogen nuclei using alpha particles in 1917 was a powerful experimental statement in favour of the nuclear hypothesis, and its publication in 1919 did much to persuade those who had previously doubted or been indifferent to the question of atomic structure. By this time, Rutherford had just succeeded Thomson as head of the Cavendish. When Aston returned to Cambridge, he began developing a new form of the positive-ray spectrograph to explore the neon question from a different angle. He called it a "mass spectrograph" to distinguish it from Thomson's apparatus. To his huge surprise, the device produced "isotopic" forms for chlorine and many other elements. With Rutherford and the nuclear theory in the ascendant, Aston now found a new patron for his work, and a ready vehicle for the interpretation of the "isotopes galore" that tumbled out of his machine as he again worked his way through the periodic table.

The mutually reinforcing evidence from radioactivity and from positive rays – united by the nuclear atom in a carefully constructed (and often contested) argument – now seemed natural and inevitable. The award of the 1921 and 1922

Nobel Prizes for Chemistry to Soddy and Aston, respectively, confirmed the new orthodoxy of the nuclear interpretation of isotopes. Only Thomson, now a marginal figure, continued to doubt.

History rewritten

It is here that the Orwellian rewriting of history begins. In his Nobel lecture and in his influential 1922 textbook *Isotopes*, Aston reconstructed the history of his own work to make the link between neon-22 and isotopes seem straightforward. The language of "meta-elements" was (correctly) attributed to Crookes, but dismissed as a false path on the now artificially straightened road to the nuclear interpretation of isotopes. All reference to occult chemistry was eliminated. This reconstructed history quickly became accepted as the conventional account. By the time he addressed the BA again in 1935 in Norwich, Aston's subject – "The story of isotopes" – had become a familiar parable in the history of nuclear physics. But it covered up the complexity of the intellectual work that had gone into the reinterpretation of meta-neon and how isotopes and the nuclear atom had been brought together.

Soddy might well have been thinking of Aston when he complained to a colleague in 1936 about "the sort of legend that grows up in connection with the history of discoveries in our own time…So easy is it to fall into the error of thinking that things which look obvious after a discovery were just as obvious before". Yet Aston's rewriting of scientific history served a purpose. It disconnected isotopes and the nuclear theory from a set of ideas that he and his new mentors would have found embarrassing. It made the nuclear theory seem always to have been the obvious and plausible account of atomic structure, and effaced one of the sources of his own earlier work. And perhaps, too, it was typical of a certain scientific approach to history!

Aston died in Cambridge in November 1945, three months after the nuclear bombings of Hiroshima and Nagasaki that his beloved isotopes helped bring about. Despite his rewriting of history, interest in the theosophical interpretation of the atom has not died out entirely. In the 1980s the British theoretical physicist Stephen Phillips resurrected Besant and Leadbeater's *Occult Chemistry*. His book *Extra-sensory Perception of Quarks* points to remarkable similarities between Besant and Leadbeater's atomic structures and results from elementary particle physics. It sustains the connections between science and theosophy made by Aston 90 years ago, and shows that the margins of scientific culture are as rich and varied now as they were in Aston's day. The wellsprings of creativity in science do indeed run deep, and sometimes strange. But that is what makes science interesting.

Further reading

I Falconer 1988 J J Thomson's work on positive rays, 1906–1914 *Historical Studies in the Physical Sciences* **18** 265–310

J Oppenheim 1985 *The Other World. Spiritualism and Psychic Research in England, 1850–1914* (Cambridge University Press)

S M Phillips 1980 *Extra-Sensory Perception of Quarks* (The Theosophical Publishing House, Madras and London)

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