The great physicist Ernest Rutherford is famously reported to have said, “All science is either physics or stamp collecting”, to the irritation of subsequent generations of scientists who were not physicists. Yet when Rutherford was awarded a Nobel prize in 1908 for a physics experiment, the prize was given for chemistry. Rutherford took it with good humour, referring to his “instant transmutation from physicist to chemist”.

Rutherford played a key part in developing a periodic law governing the chemical elements in the 20th Century, and our understanding of elements today is down to both chemistry and physics.

The law was discovered 145 years ago this month, in February 1869, by Dmitri Mendeleev and other chemists. Although he’s regarded as a chemist, Mendeleev spent almost no time searching for the elements in his laboratory. What constitutes a chemical element has long been debated, and is still unresolved to some extent.

The concept of an element goes back to the ancient Greek philosophers. They recognised just four terrestrial elements: earth, water, air and fire. These corresponded with the shapes of the four Platonic solids known to mathematicians: the cube, the icosahedron, the octahedron and the tetrahedron. Thus, the liquidity of water was thought to parallel the relatively smooth shape of the 20-faced icosahedron, while the pain caused by touching fire was explained by the sharp corners of the tetrahedron. When a fifth Platonic solid, the 12-faced dodecahedron, was later discovered, Aristotle proposed the existence of a fifth element. It was ‘quintessence’, the celestial aether.

Of course, some of the 90 or so naturally occurring substances we recognise today as elements have been known since antiquity or even earlier – for example, carbon, copper, gold, iron, lead, mercury, silver, tin and sulphur. These substances were found in an uncombined form or were easily separable from the minerals in which they occurred. For many centuries, alchemists occupied themselves in attempting to transform the naturally occurring ‘base’ metals, such as iron and lead, into the ‘noble’ metals, gold and silver, without success. In the scornful words of the influential natural philosopher Francis Bacon, writing in the 1620s: “All the philosophy of nature which is now received is either the philosophy of the Grecians, or the other of the alchemists. The one never faileth to multiply words, and the other ever faileth to multiply gold.”

MODERN MATTER

The modern concept of the chemical element began to emerge only in the late 18th Century with the work of the French chemist, Antoine-Laurent de Lavoisier. He is generally regarded as the founder of modern chemistry from the 1770s until his death under the guillotine in 1794. Using quantitative experiments, Lavoisier defined an element empirically as a material substance that was yet to be decomposed into any other elements. Two millennia after the Ancient Greeks wrongly classified the four elements as fire, water, wind and earth, Dmitri Mendeleev uncovered underlying patterns in nature – leading to one of the most powerful tools in science.

> In a Nutshell

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How do we know?

How do we know? more fundamental substances. In 1789, the year of the French Revolution, Lavoisier ... the table in 1879

Dmitri Mendeleev may have arranged the elements like a game of solitaire to create his famous table

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(patience) with 'element' cards. Virtually may have played a form of solitaire ing the elements, 1869, (1 March in the format and deadline. He wrote out the elements simultaneously. He wrote out the elements... by increasing atomic weight, thereby spotting periodic repetitions of chemical properties. And he listed several ‘natural groups’, like alkali metals and halogens, in columns, thereby spotting patterns of increasing atomic weight. This generated what he called his first try (see below). The missing element was Sc, scandium – unknown in 1869 but discovered in 1874, with an atomic weight of 45.

Dr Dmitri Mendeleev may have arranged the elements in a game of solitaire to create his famous table in 1869.

THE PERIODIC TABLE

It was the genius of Dmitri Mendeleev that placed the elements in a logical, periodic table, arranging them by atomic weight and subsequently spotting similar chemical properties. He compiled his famous table in 1869, (1 March in the Gregorian calendar), directed the Cavendish laboratory. He carried out most of his research in Britain, at Manchester and Cambridge, where he directed the Cavendish Laboratory. This work included revealing the structure of the atomic nucleus, which led to the concept of atomic number.

Ernest Rutherford (1871–1937) was the youngest of 14 children. He lost both parents when he was young but managed to obtain some scientific training in St Petersburg and then went to Germany, before returning to Russia. By analysing atomic weights and chemical properties, he devised his periodic table in 1869.

John Dalton (1766–1844), the son of a poor country weaver and the father of the modern atomic theory, was a schoolmaster in Manchester, later controversially maintained that the chemical elements were composed of atoms, and in 1803 compiled a list of relative atomic weights for some of the most important known elements.

Henry Moseley (1887–1915) was an English physicist. After training under Rutherford at Manchester, he returned to Oxford University in 1913 for research work. He discovered and the key relationship between an element’s atomic number and its chemical behaviour. He was killed by a sniper’s bullet at Gfts, during the First World War.

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How do we know? How do we know?

of predictions of the existence of unknown elements. He labelled them with the Sanskrit word, ela, meaning ‘one’. They included eka-aluminium, eka-boron and eka-silicon, which he predicted would have the atomic weights 68, 44 and 72, respectively. The first of them was discovered in 1875 and named gallium (atomic weight 69.7). The second in 1879 and named scandium (atomic weight 45.0), the third in 1886 and named germanium (atomic weight 72.6). Moreover, Mendeleev predicted almost all of the chemical properties of the new elements correctly.

Not all his predictions were so successful. Well before his death in 1907, new discoveries challenged his theory. In fact, current versions of the periodic table ignore three cardinal principles dear to Mendeleev: the valency, the indivisibility, and the immutability of the atom.

The valency is the number of chemical bonds an atom can form with other atoms. The noble (inert) gases helium, neon, argon, krypton, xenon and carbon were discovered in the 1890s by the chemist William Ramsay and the physicist Lord Rayleigh – appeared totally unreactive, with a ‘forbidden’ valency of zero. Today, we know some do form a few chemical compounds.

The discovery of the electron in 1897 by the physicist J.J. Thomson disproved indivisibility – the atom plainly had an inner structure. And radioactivity, discovered by the physicist Henri Becquerel in 1896 and named by the physicists-cum-chemists Marie and Pierre Curie in 1898, showed that transmutation of elements does occur. Elements like uranium, polonium and radium all undergo radioactive decay.

By the Numbers

Most of the objections, though, was Mendeleev’s unyielding reliance on increasing atomic weight as the chief ordering principle of his periodic table. The higher the atomic weight of an element, the later should be its position in the periodic table, he maintained. Mendeleev himself was aware of this difficulty, because he allowed one or two exceptions to this rule – notably for tellurium, which he placed earlier than iodine despite its atomic weight of 127.6 for tellurium versus 126.9 for iodine. He justified this reversal on the grounds that the atomic weights for one or both of these elements had been incorrectly determined. But his reasoning turned out to be the wrong way. While tellurium, polonium and radium all undergo radioactive decay.

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