

## Flag the Periodic Table

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I was searching the web for a plain unadorned Periodic Table and came across this representation created by Jamie Gallagher at Glasgow University. The source is: <http://www.smithsonianmag.com/smart-news/the-periodic-table-of-elemental-discoveries-1773011/> or just google “periodic table flags”. It is anything but plain and unadorned and gives an intriguing perspective on the elements. It provides another opportunity to discuss the human dimension of the Periodic Table. Since locating this I have found there are other slightly different versions depending on how the discovery is interpreted, but I’ll stay with this version as it is the one Jamie has given me permission to use.

The first thing that surprised me was that Sweden came in at number two for the number of elements discovered. My immediate justification was the Ytterby elements and Carl Wilhelm Scheele. But no. Scheele is only directly credited with two: chlorine in 1774, but not recognised as an element until Humphry Davy isolated it in 1808, and molybdenum, discovered as a new entity by Scheele in 1778 and first isolated by his countryman Peter Jacob Hjelm in 1781. The selection is based on the country in which the element was isolated, not where the source sample came from so only four of the seven elements identified in the tailings of the Ytterby mine are credited to Sweden (terbium, holmium, erbium and thulium). Of the others yttrium is credited to Finland (at an institution which was part of Sweden at the time of discovery), and gadolinium and ytterbium to Switzerland.

Sweden and France are distinct from the other major players in element discovery in that their elements are spread throughout the Periodic Table, whereas the UK, Germany and USA discoveries tend to be grouped.

In the 18<sup>th</sup> and 19<sup>th</sup> centuries, chemistry was a young science with limited techniques and although it might be apparent that a new substance had been found, identifying it as a new element was a different matter. Part of the problem was the definition of an element as *a substance that cannot be broken down into anything simpler*. This is a negative definition and it is interesting to discuss the implications of negative definitions with students. In this case the question is: “Have you tried hard enough?” Lime (CaO) and magnesia (MgO) were originally classified as elements because neither strong heating nor chemical reducing agents such as carbon would break them down into anything simpler. The later (positive) definition that an element was a substance that contained only one type of atom could not be implemented until atomic structure discoveries of the early 1900s made it clear what “type of atom” meant.

Scheele had produced chlorine by the action of HCl on the ore pyrolusite (MnO<sub>2</sub>):



This is still a standard method for preparing chlorine in the laboratory. Scheele was aware that pyrolusite contained a new element but was unable to isolate it. This was achieved by fellow Swede, Johan Gottlieb Gahn, in the same year (1774) when he reduced the MnO<sub>2</sub> with carbon to obtain manganese.

The discovery of oxygen is clouded by the phlogiston theory and the tardiness of publishers. The phlogiston theory was essentially an “anti-oxygen” theory. In attempting to explain burning, it proposed that combustible substances contained *the* component of fire naming it phlogiston. When these substances burned they lost phlogiston which was why carbon lost weight when it burned. Breathing was thought to remove phlogiston from the body. When ignited in a closed container the substance stopped burning because the air became saturated with phlogiston. A mouse in this container died because it could not get rid of its phlogiston (since the air was already saturated with it).

In 1772 Scheele discovered oxygen by heating mercury(II) oxide and “various nitrates”, presumably KNO<sub>3</sub> and NaNO<sub>3</sub>. The account of his studies was not published until 1777. In the meantime Joseph Priestley in England had done much the same experiment and called the gas “dephlogisted air” because candles burned much longer in it than in ordinary air. Antoine Lavoisier in France was instrumental in unravelling the confusion, recognising that the phlogiston theory was unsatisfactory in many instances and firmly denouncing it. He named the gas “oxygène”, meaning acid generator, believing it to be a component of all acids, so there was still a way to go in understanding. Scheele, Priestley and Lavoisier all effectively discovered oxygen hence the three flags in the oxygen space.

Vanadium was first discovered by a Spanish-Mexican mineralogist, Andrés Manuel del Rio, in 1801, but other chemists convinced him that all he had was impure chromium and he retracted his claim. It was subsequently isolated in 1831 by Nils Gabriel Sefström in Sweden. Later Frederich Wöhler confirmed del Rio’s work.

Jon Jacob Berzelius, Georg Brandt, Carl Mossander, Per Theodore Cleve and their co-workers account for many of the other discoveries attributed to Sweden.

The clusters of elements with the same flag can generally be traced to the development of particular techniques. The earliest example of such a cluster is the Group 1 and 2 metals. Chemists had been aware of the elements but it wasn’t until Humphry Davy got his hands on a voltaic pile (electrochemical cell) and electrolysed the molten salts that the metals themselves were isolated. In a two year burst in 1807-08 he produced samples of the metals sodium, potassium, magnesium, calcium, strontium and barium.

Almost a century later, English physicist Lord Raleigh and Scottish chemist William Ramsay confirmed the existence of a whole new group of elements – the noble gases. They were investigating discrepancies between the density of nitrogen gas obtained from air and nitrogen obtained from chemical reactions. They suspected that atmospheric nitrogen contained another gas.

Careful fractional distillation of air yielded not one but several gases that they named krypton, neon and xenon as Group 18 elements in addition to helium and argon that had been isolated earlier. In 1868, previously unseen spectral lines were detected in the analysis of light from the sun during an eclipse and indicated the presence of a new element. It was named helium (after *helios*, Latin for sun). Various studies showed evidence of helium on earth but it was not finally confirmed until William Ramsay isolated it in 1895.

USA, “the new world”, didn’t feature on the Periodic Table until 1940 when astatine was discovered. They made up for lost time by harnessing the cyclotron particle accelerator at the University of Berkeley, California, to bombard atoms and under Glen Seaborg generated synthetic elements 93 to 103 with the exception of nobelium, element 102, which was created at the Flerov Laboratory of Nuclear Reactions in Dubna, Soviet Union. A group at

the Society for Heavy Ion Research in Darmstadt, Hesse, Germany were responsible for elements 107–112 and Russian/US laboratories have collaborated to produce elements 113–118.

It is a rule that elements are not named after living people. This rule has been broken once when element 106 was named Seaborgium in 1997, having been created in 1994. The naming honoured Glen Seaborg’s life-long contribution to science including leading the team at Berkeley that produced so many transuranium elements. The naming caused heated debate among chemical societies. Seaborg died in 1999. A similar rule applies to people’s images on banknotes. New Zealand broke this rule when Sir Edmond Hillary featured on the \$5 note in 1992. He died in 2008.

This article merely scratches the surface of a few of the many fascinating stories around the discovery of the elements, particularly those discovered pre-1900. The Wikipedia entries for each element and the chemists and physicists involved are good starts for information. *The Disappearing Spoon (and other true tales of madness, love and the history of the world from The Periodic Table of the Elements)* by Sam Kean is another good source, although some of his chemical statements are what you might expect from a physics major – which he is.

