Four new synthetic elements approved

[By Ulrika Forsberg, Claes Fahlander, Dirk Rudolph, Division of Nuclear Physics, Department of Physics, Lund University, and Lars Öhrström, Division of Chemistry and Biochemistry, Department of Chemistry and Chemical Engineering, Chalmers University of Technology]

Recently, chemists and physicists in the Joint Working Party (JWP) have approved the new elements, but what is the significance and how can we make use of elements that exist so fleetingly?

To the annoyance of those scientific journalists who had already penned their chronicles for 2015, the approval of four new elements was announced shortly before the end of the year by the International Union of Pure and Applied Chemistry (IUPAC). [1] The elements with atomic numbers 113, 115, 117, and 118 were approved by the Joint Working Party (JMP) of IUPAC and the International Union of Pure and Applied Physics (IUPAP).

In two reports, detailing the literature and the evidence, the JWP states that a group of researchers at the RIKEN institute in Japan will suggest a name for 113, whilst 115 and 117 will be named by scientists from the Joint Institute for Nuclear Research (JINR) in Dubna, Russia, and the Oak Ridge and Livermore laboratories in the US. Element 118 will be named jointly by JINR and Livermore. [2] The very few identified atoms of these four new elements have been produced by the bombardment of medium heavy atoms, e.g. zinc or calcium, onto a target of heavy atoms, e.g. bismuth or berkelium. Berkelium explains the participation of the Oak Ridge laboratory, the only one in the world that is able to produce viable amounts, tens of milligrams, of berkelium and californium.

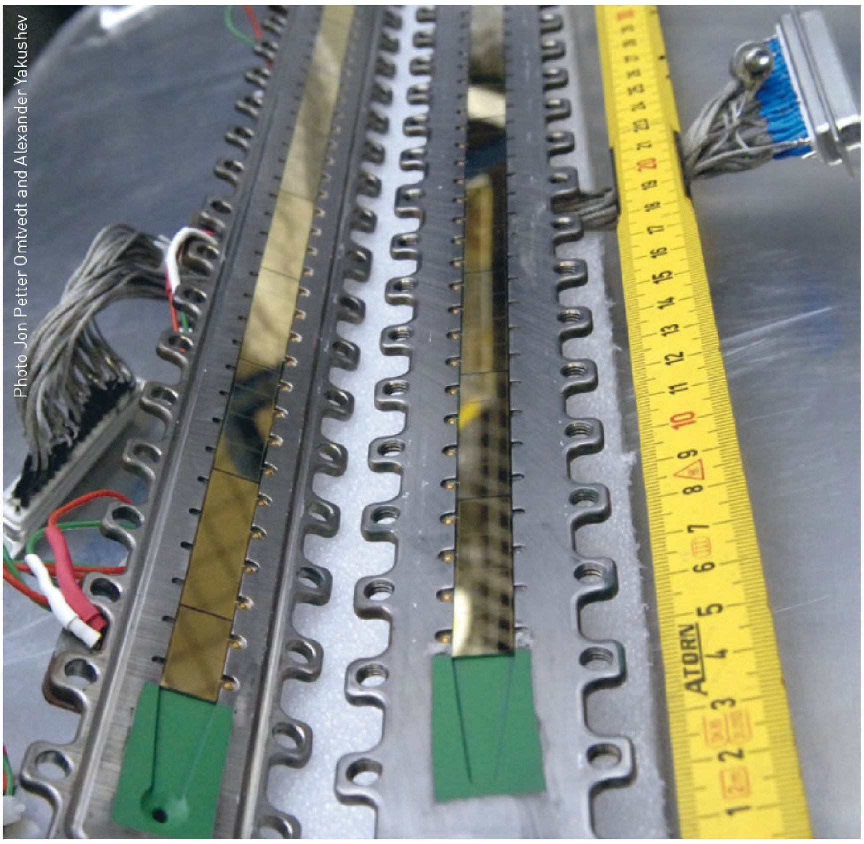
Photo Jon Petter Omtvedt and Alexander Yakushev

This is the detector used to study the chemical properties of the element with Z = 114. Atoms are passed through the gold plated tunnel formed when the two halves of the detector are screwed together. The atoms are adsorbed on to the walls of the tunnel, and when they subsequently decay, the emitted alpha particle is detected, indicating the position. One or two atoms can be produced and detected per working week.

So, what practical significance is there? Or, is it just about prestige?

Well, even though the isotopes produced so far of these new and super heavy elements have a short life (milliseconds to fractions of a second), and the number of atoms is very low, we can still learn a lot from them. That is because basic theories in both nuclear physics and chemistry are best tested and developed in extreme situations.

How do the attracting nuclear forces in the atomic nucleus balance the repulsion that ensues between the positively charged protons, which will grow stronger with a higher atomic number, Z? How do we take into account that electrons start to move at a speed approaching that of light when Z becomes very high, and we need to use both quantum chemistry and the theory of relativity in order to calculate which atomic orbitals are occupied? For instance, the shiny appearance of well-known substances such as gold is due to relativistic effects.

However, is it possible to find out what properties these new elements/atoms have? Yes, some information can be gleaned because they are short-lived and will decay by emitting an alpha particle (He^{2+} ion). Using a gas flow, the atoms are passed through a tunnel in which the temperature is falling gradually. Detection of the alpha particle reveals the exact location of the atom, and at what temperature it is adsorbed in the tunnel.

Atoms that adhere at room temperature have chemical properties similar to, for instance, lead. Those that do not adhere at →

all would be of a noble gas. Volatile metals, such as mercury, will adhere somewhere between these two extremes, and the likely properties of the new atoms can be obtained through comparative calculations.

However, there are two limiting factors: firstly, this method requires that the atoms have a sufficiently long life in order to have time to be transported to and through the detection tunnel (about 1 sec), and secondly, it must be possible to produce a sufficient number of atoms.

From a chemist's point of view, there are many exciting questions: Is element 118 really a noble gas or do the relativistic effects result in 114, livermorium, being the noble gas of the 7th period? Some experimental results suggest that the latter is true! Will the yet to be discovered 119 and 120 end up in group 1 and 2 with 8s electrons? And what about after 120, will that be when we enter into the completely unknown territory of g electrons?

The alpha decay plays another important role, as it represents the traditional way of identifying new, heavy elements. An element decays after a time t1 by emitting an alpha particle with an energy E1 resulting in a known isotope with the atomic number Z-2. This in turn decays after a typical time t2 and a characteristic energy E2 into an isotope Z-4, and so on. The life-time and energy can be matched to the data of already known isotopes, and with a sufficiently long chain of decay it is possible to accurately pinpoint Z by reverse calculation.

The issue with the recently approved elements with Z≥114 has been that they decay into new chains where there are no known data for t and E to compare with. Hence, apart from the new elements, the experiments gave a number of previously unknown isotopes, Z-2, Z-4, Z-6 and so on, in order to prove the existence of the new elements. This has been a taxing job involving attempts to chemically study the previously unknown isotopes Db-268 and Db-270 (dubnium) with half-lives of over 24 hours, four times the half-life of the isotope Tc-99m[1] (technetium), which is so important for medical diagnostics.

The problem with unknown decay chains leads us to both the centenary of the tragic death of the young scientist Henry Moseley, and to the current work by scientists from Lund University carried out

Photo N Lalović

The scientists Claes Fahlander, Luis Sarmiento, Ulrika Forsberg, and Dirk Rudolph at Lund University are trying to measure the atomic number, Z, for new elements using x-ray technique. In the background can be seen a chart of nuclides from 2012 covering all known isotopes reported at the time. The fire alarm Ulrika is holding contains americium, Z = 95.

at the GSI Helmholtzzentrum für Schwerionenforschung in Darmstadt.

In 1915, at the age of just 27, Moseley was nominated for the Nobel Prize in both chemistry and physics, but he died as a British Army volunteer during the catastrophic invasion of Turkey at the Dardanelles, the so called Gallipoli campaign. Moseley arranged the atoms of the periodic table according to their atomic number, which he determined through x-ray spectroscopy. According to Moseley's Law, the square root of the frequency of the short-wave x-rays emitted from a sample exposed to x-rays is directly proportional to the atomic number Z.

A similar technology, being developed in Lund for the identification of Z in super heavy elements, is based on the observation of the x-rays that are sometimes emitted in conjunction with their nuclear alpha decay.

What about the applications for the new elements? It might be possible to produce isotopes that are more stable than those made so far, but it would be very difficult and would require liberal amounts of extra neutrons in the nucleus. Hence, it is unlikely that the newest elements will be used within the near future, but who knows: 90 years ago or so, elements with atomic numbers higher than uranium (Z = 92) were unthinkable, but then around 70 years ago americium (Z = 95) was discovered, which today is used in fire alarms!

The question everyone will be asking now is of course what names these new elements will be given, when IUPAC's temporary names are replaced by permanent names and symbols. The scientists who discovered them have been given six months to propose names, which then have to be ratified by IUPAC. According to the recommendations and "in keeping with tradition", elements should be named after mythological concepts, minerals, places, properties, or a scientist.[3]

The Swedish names will be established by the Swedish Chemical Society's nomenclature committee, but these names will probably not differ from IUPAC's, other than possibly in their spelling.

The public has shown great enthusiasm for the naming of the elements. A petition to name ununpentium lemmium after the recently diseased heavy metal rocker Ian "Lemmy" Kilmister has had 150,000 signatures, and soon after the death of David Bowie a similar petition was set up for bowium. A superstitious mind might draw the conclusion that yet another two rock icons will kick the bucket before the time allocated for name suggestions runs out, so that the 7th row of the periodic table is completed by a quartet, the classic size of rock bands. KB

References

1. *IUPAC's press release dated 2015-12-30 at www.iupac.org. The next day, the Swedish National Committee for Chemistry posted a similar press release at www.natkomkemi.se/*

2. *Four elements earn permanent seats on the periodic table - U.S., Russian and Japanese scientists credited with official discoveries, Andrew Grant, December 31, 2015. www.sciencenews.org/*

3. *How to Name New Chemical Elements, W.H. Koppenol, Pure and Applied Chemistry, 74, 787-791 (2002), revised in 2015: http://iupac.org/*

1. Where m indicates a metastable nuclear isomer.