Status of the heaviest elements as of June 2016

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Superheavy elements (SHE) are normally synthesized by exposing a high-Z target to a 2.5–7.5 MeV/u ion beam such as ^{48}Ca or ^{70}Zn. The target can be a stable isotope such as ^{208}Pb or ^{209}Bi; in this case the process is called cold fusion. If the target is radioactive (an actinide), it is a "hot fusion" reaction. Targets as heavy as ^{249}Bk and ^{249}Cf have been used. Since fusion is followed by neutron loss (e.g. ^{248}Cf(^{48}Ca,4n)^{292}Lv), the atomic numbers of the beam and target nuclei determine whether the fusion products have even or odd Z. The main laboratories involved are at Dubna (JINR), Darmstadt (GSI), Berkeley (LBNL), and Saitama, Japan (RIKEN) [1].

Fusion cross sections steadily decrease with increasing Z, and are in the picobarn range for the heaviest elements. This means that 1–10 SHE/week can be produced for $\mathcal{O}(10^{18})$ heavy ions on target [1].

In the best of worlds, a superheavy isotope decays via a long chain of α emissions, the last few between well-studied isotopes of known elements. But often the evidence from a given event is unconvincing: Spontaneous fission may truncate the chain too early, an α might escape the detector before depositing all of its energy, or the decay chain might proceed via previously unknown daughter isotopes. Gold-plated examples are rare, one of these being the observation of $^{278}113 \to {}^{274}\text{Rg} \to {}^{270}\text{Mt} \to {}^{266}\text{Bh} \to {}^{262}\text{Db} \to {}^{258}\text{Lw}$ at RIKEN [2].

The International Union of Pure and Applied Chemistry (IUPAC) gives its blessing to a new element only after its experimental demonstration "beyond reasonable doubt." This usually means convincing reproduction of the result at a second laboratory, preferably by a different technique. This criterion is not applied with complete rigidity; sometimes the evidence from one laboratory becomes overwhelming. IUPAC recognition includes recognition of the discovery laboratory, that then has naming rights. Typically, strong evidence has come from several laboratories years in advance of IUPAC recognition.

Elements 114 and 116 were recognized by IUPAC in May 2009 on the basis of work at Dubna. Key to the discoveries was decay through ^{283}112, an isotope confirmed at GSI and LBNL [3]. (An independent LBNL discovery of a different 114 isotope, ^{285}114, had also been reported [4]. On 30 May 2012 IUPAC recognized the names flerovium (Fl) and livermorium (Lv) for elements 114 and 116. Copernicium (Cn, $Z = 112$) had been recognized on 15 December 2010.

IUPAC announced verification of the discoveries of elements 113, 115, 117, and 118 on 30 December 2015 [7]. Tentative names were proposed in June 2016 [8]. The 7th period of the periodic table is now complete!

Mostly because of important relativistic corrections to the inner electronic energy levels, the chemistry of a new superheavy element is not a given. Remarkable chemical studies have been made using just a few atoms with short lifetimes. Traditional ion-exchange column methods have been miniaturized, but even they find their limits. Evidence that Cn is a homolog of Hg, and is probably quite volatile, was based on the adsorption of just two atoms from the gas phase onto a cold gold surface [9].

Sample references:

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