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Status of the heaviest elements as of January 2013

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Superheavy elements 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 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, Darmstadt, Berkeley, and RIKEN Nashina Center.

Fusion cross sections steadily decrease with increasing Z, and are in the picobarn range for the heaviest elements. The cross section can be optimized for a given target isotope by careful choice of beam and target. Typically, one superheavy atom is produced for $\mathcal{O}(10^{19})$ heavy ions on target.

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, or the decay chain might be via previously unknown isotopes of the daughters. Gold-plated examples are rare, one of these being the recent observation of $^{278}113 \to {}^{274}\mathrm{Rg} \to {}^{270}\mathrm{Mt} \to {}^{266}\mathrm{Bh} \to {}^{262}\mathrm{Db} \to {}^{258}\mathrm{Lw}$ at RIKEN [1].

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 laboratory which discovers it, which then has naming rights. On 30 May 2012 IUPAC recognized the names flerovium (Fl)and livermorium (Lv) for elements 114 and 116, respectively, even though these elements had been observed only at Dubna by Oganessian et al. [2]. (Copernicium (Cn) was recognized in 2010.)

Several dozen isotopes with $112 \le Z \le 118$ have been reported with various degrees of confidence [3,4], but elements 113, 115, 117, and 118 are not yet recognized by IUPAC. The recent convincing observation of ^{278}113 by the Japanese group may earn the recognition of element 113.

Mostly because of important relativistic corrections to the inner electronic energy levels, the chemistry of a new superheavy element may not be 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 onto a gold surface [5].

Sample references:

1. K. Morita, et al., J. Phys. Soc. Japan **81**, 103201 (2012).

2. R.C. Barber, et al., "Discovery of the elements with atomic numbers greater than or equal to 113 (IUPAC Technical Report), Pure Appl. Chem. **83,** 1485–1498 (2011).

3. Yu. Ts. Oganessian, J. Phys. G **34**, R165 (2007).

4. Yu. Ts. Oganessian, et al., Phys. Rev. C **83**, 054315 (2011).

5. R. Eichler, et al., Nature **447**, 72–75 (2007).