On the Road to the Valley of Stability

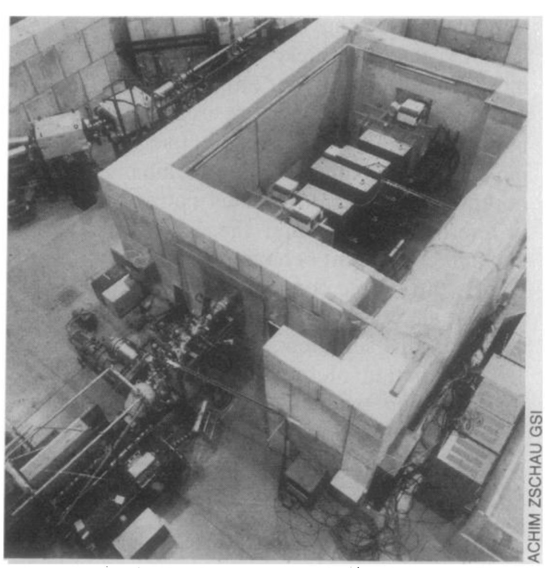
The discovery of element 109 could presage the discovery of the superheavy elements; two groups of researchers are trying right now

In announcing the discovery of element 109 at the end of September, the physicists at the GSI heavy-ion accelerator in Darmstadt, West Germany, have not only given the periodic table its heaviest member yet, but they have also reinforced hopes that similar experiments now under way might produce the long-sought "superheavy elements" around atomic number 114.

Led by Peter Armbruster and Gottfried Müncenberg, the Darmstadt team created 109 last August by firing iron-58 nuclei (26 protons, 32 neutrons) into a thin foil of bismuth-209 (83 protons and 126 neutrons). Their hope was that projectile and target might occasionally fuse into a single nucleus of 26 + 83 = 109. They had chosen iron-58, the rarest of the stable iron isotopes, to complement the bismuth because theory suggested that their best chance of getting element 109 lay in forming a compound nucleus with 32 + 126 = 158 neutrons.

It was crucial that the energy of the iron nuclei be very accurate: 5.15 megaelectron volts per nucleon. Below that point the nuclei would not fuse at all; above it they would shatter. Precisely at the threshold, however, there was a chance that electrostatic repulsion between the nuclei would slow the iron to a stop just as it touched the surface of the bismuth. The two could then flow together gently in what is known as "subcoulomb threshold" fusion.

The chances were slim, however. The heaviest nuclei are very fragile, and until recently there has been theoretical reason to believe they would shatter no matter how gentle the collision. The creation of six atoms of element 107 at Darmstadt last year had suggested that things might not be quite that bad. But even so, the Darmstadt researchers could hope for no more than one atom of 109 in 10 days of accelerator time—and 10 days was all they had.



The reaction product separator at GSI.

Assuming that their hopes were answered, that single nucleus of 109 would come flying out the back of the bismuth foil amidst a spray of nuclear debris. Finding it would require a filter accurate to one part in a trillion—"Like picking out a single grain of sand from a trainload," says GSI director Gisbert zu Putlitz. Furthermore, that filter would have to be fast: the 109 lifetime was predicted to be on the order of milliseconds. Darmstadt's answer was SHIP: the Separator for Heavy Ion reaction Products. Twelve meters long, it used electric and magnetic fields to separate the reaction products by velocity. It was set to take a 109 nucleus, heavier and slower than any of the others, and deflect it into a detector that would monitor its decay. Everything else would be dumped.

Not until 4:10 p.m. on Sunday, 29 August, the last day of the run, did a likely candidate enter the detector. The device was not set to see the nucleus itself. But it did record two alpha particle emissions, a gamma ray and a spontaneous fission. Each event occurred with precisely the energy expected from 109 and its daughters. The sequence and timing were right on the mark. It took a month of analysis to be sure. But on 27 September, at the dedication ceremony for the new superconducting heavy-ion accelerator at Michigan State University, element 109 was announced.

"My first reaction was 'Wow, this is really neat!'," says Al Ghiorso of Lawrence Berkeley Laboratory (LBL), codiscoverer of half a dozen transuranic elements. "I'd say I was about 99% confident that this was really 109."

The good thing about the discovery, he says, is that it convinces people that a fusion approach to element 114 and the other superheavy elements in the "valley of stability" might just barely be feasible.

The existence of the valley was first suggested in 1966 by theorists working with the nuclear shell model. It was known that nuclei are stablest and most tightly bound when both the protons and the neutrons fill up energy levels analogous to the electron shells in atoms. Extrapolating from what was known about existing nuclei, theorists were thus able to predict that nuclei with about 114 protons and 184 neutrons might be far more long-lived than some of the lighter transuranics. In fact, estimates of the half-lives have ranged anywhere from seconds or minutes to billions of years.

Buoyed by GSI's success with elements 107 and 109, Ghiorso and Armbruster have joined forces for a new attempt on element 114. Their teams have just begun their first attempt at the SuperHILAC heavy-ion accelerator at LBL, beaming calcium-48 onto a target of curium-248.

They will be looking for their quarry in three ways. The first is quite similar to the GSI approach on elements 107 and 109, but using a gas-filled separator designed by Ghiorso: SASSY, the Small Angle Separator System. The second is to catch the reaction products in a copper foil, which will then be chemically analyzed for superheavies. (Element 114 should resemble lead.) Finally, a similar copper foil will be exposed for a longer period, then sent to Darmstadt where it will be monitored for slower decays or spontaneous fission. Meanwhile, another calcium/curium experiment is scheduled to begin in Darmstadt in December.

Ghiorso, for one, tends to be a bit of a pessimist. "I long ago bet [Glenn] Seaborg $100 that superheavy elements would never be found," he says. "Of course, we didn't put a time limit on it, so I can never win that bet. I think there's only one chance in a hundred that these current experiments will work. On the other hand, before 107 and 109 I used to think it was only one chance in a million.

"I don't know what it is about the search for superheavies," he adds. "It seems to excite people's imagination. I've been the co-discoverer of half a dozen new elements over the years, and I've never been bored yet."

—M. Mitchell Waldrop