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Nations Work Together to Discover New Element

The discovery of element 117 increases evidence for the "island of stability" in super-heavy nuclei, opening new frontiers of chemistry.

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A new element took its position on the Periodic Table in 2010 after a long research effort that included the Joint Institute of Nuclear Research (JINR), Dubna, Russia; the Research Institute for Advanced Reactors, Dimitrovgrad; Oak Ridge National Laboratory; Lawrence Livermore National Laboratory; Vanderbilt University; and the University of Nevada Las Vegas.

Enlarge Photo

Photo courtesy of Oak Ridge National Laboratory

Berkelium-249, contained in the greenish fluid in the tip of the vial, was crucial to the experiment that discovered element 117. It was made in the High Flux Isotope Reactor at DOE's Oak Ridge National Laboratory.

The team identified six atoms of the new element, atomic number Z=117, or ununseptium.

ORNL Associate Laboratory Director Jim Roberto said the experiment, in addition to discovering a new chemical element, has pushed the Periodic Table further into the neutron-rich regime for heaviest elements.

"New isotopes observed in these experiments continue a trend toward higher lifetimes for increased neutron numbers, providing evidence for the proposed 'island of stability' for super-heavy nuclei," he said.

The theorized island of stability is of great interest to researchers who study the forces and physics of the atomic nucleus. Atoms are made up of a nucleus surrounded by a cloud of electrons; that nucleus is composed of neutrons and protons in shell-like arrangements.

When those shells of protons or neutrons are completely occupied (closed) and there is a substantial energy gap between the last filled shell and next one available for nucleons, these nuclei are referred to as "magic"; when the shells of both protons and neutrons are closed, the nuclei are "doubly magic."

Doubly magic nuclei are especially stable against decay. For example, Lead-208, with 82 protons and 126 neutrons, is the heaviest stable isotope within doubly magic nuclei. Experiments such as the one that created element 117 enter the realm where the next theorized stable nuclei may occur, which is believed to be a nucleus with 184 neutrons that help hold together 114, 120 up to 126 protons.

> **"When the californium-252 radioisotope was discovered, there were no known practical uses for it, but now it is widely used in industry and medicine."**

The experiment, in fact, produced 11 new "neutron-rich" isotopes that edged scientists closer to the island of stability. In fact, although the element 117 atoms existed for only a fraction of a second, they endured longer than many isotopes of lighter elements.

"Because the half-lives are getting longer, there is potential to study the chemistry of these nuclei. These experiments and discoveries essentially open new frontiers of chemistry," Roberto said.

The practical possibilities of such a discovery are unknown, but tantalizing. "When the californium-252 radioisotope was discovered, there were no known practical uses for it, but now it is widely used in industry and medicine," Roberto said.

Under the leadership of JINR's Yuri Oganessian, five months of the Dubna JINR U400 accelerator's calcium-48 beam—one of the world's most powerful—was dedicated to the project. The massive effort identified a total of six atoms of element 117 and the critical reams of data that substantiate their existence.

The two-year experimental campaign began with a 250-day irradiation of curium in ORNL's High Flux Isotope Reactor (HFIR), producing 22 milligrams of berkelium-249, which has a 320-day half-life. The irradiation was followed by 90 days of processing at ORNL's Radiochemical Engineering Center to separate and purify the berkelium.

The berkelium-249, with the clock ticking away on its 320-day half life, was sent to the Russian Research Institute of Atomic Reactors in Dimitrovgrad, where a target was fabricated with the Bk-249 radioisotope applied to a thin film of titanium. That target was sent to JINR at Dubna.

What followed was 150 days of bombardment with an intense beam of 7 trillion calcium-48 ions per second at one of the world's most powerful heavy ion accelerators. Detectors collected atoms diverted by a gas-separation chamber from the beam's fantastically energetic collisions with the target.

Eventually, the detectors turned up six short-lived but history-making atoms of element 117, which then decayed into elements 115, 113, 111, 109, 107 and 105, which had been seen before, although some of the isotopes were more neutron rich.

Those neutron-rich isotopes fit heavy-element theoretical models of an extra-stable, but so far unknown, element glued together with 184 neutrons.

Atoms have a particular signature, which researchers sought through detectors aided by the storied nuclear data analysis capabilities at Lawrence Livermore National Laboratory.

Researchers at Lawrence Livermore, which has been involved in the discovery of six elements with Dubna (113, 114, 115, 116, 117, and 118) analyzed data from the calcium-48 beam collisions—comprising billions upon billions of events—duplicating and confirming the Dubna team's search for the new element.

The berkelium—the critical target material—was produced at the High Flux Isotope Reactor and processed at the adjoining Radiochemical Engineering & Development Laboratory.

Enlarge Photo

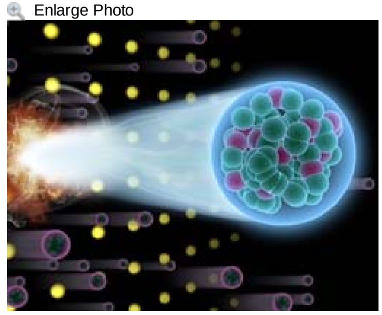

Image courtesy of Oak Ridge National Laboratory

For a fleet instant, an atom of element 117 exists before decaying the Russian accelerator. Six such atoms were detected.

"Without the berkelium target, there could have been no experiment," said Roberto, who is a principal author on the *Physical Review Letters* paper announcing the discovery and who helped initiate the experiment.

ORNL also has a history of new element discoveries. Shortly following World War II's end, the laboratory announced that promethium had been discovered during the Manhattan Project work at the lab's Graphite Reactor. By way of its production of radioisotopes for research, ORNL has contributed to the discovery of a total of seven new elements.

Roberto said the success of the element-117 campaign underscores the value of international collaborations in science.

The experiment came together largely owing to the international science community of nuclear physics. Vanderbilt University's Joseph Hamilton, who was familiar with Oganessian and his work, also had close relations with ORNL, where he helped put together the laboratory's Joint Institute for Heavy Ion Research, a collaboration among ORNL, Vanderbilt, and the University of Tennessee, in the 1980s.

By way of those connections, Hamilton knew Roberto and also knew about ORNL's capabilities with producing exotic radioisotopes at HFIR and REDC. Add to that mix some good fortune in the arrival of funding for a new campaign to produce californium-252, which enabled the production of the berkelium-249.

"This use of ORNL isotopes and Russian accelerators is a tremendous example of the value of working together," Roberto said. "The 117 experiment paired one of the world's leading research reactors — capable of producing the berkelium target material — with the exceptional heavy ion accelerator and detection capabilities at Dubna."

—Bill Cabage, Oak Ridge National Laboratory, cabagewh@ornl.gov

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Publication

Y. T. Oganessian et al. "Synthesis of a new element with atomic number Z=117," *Physical Review Letters* **104,** 142502 (2010)

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The *Physical Review Letters* article can be accessed at http://physics.aps.org/articles/v3/31.

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