The New York Times
nytimes.com

February 1, 2004

Uut and Uup Add Their Atomic Mass to Periodic Table

By JAMES GLANZ

A team of Russian and American scientists are reporting today that they have created two new chemical elements, called superheavies because of their enormous atomic mass. The discoveries fill a gap at the furthest edge of the periodic table and hint strongly at a weird landscape of undiscovered elements beyond.

The team, made up of scientists from Lawrence Livermore National Laboratory in California and the Joint Institute for Nuclear Research in Dubna, Russia, is disclosing its findings in a paper being published today in Physical Review C, a leading chemistry journal. The paper was reviewed by scientific peers outside the research group before publication.

"Two new elements have been produced," said Dr. Walt Loveland, a nuclear chemist at Oregon State University who is familiar with the research. "It's just incredibly exciting. It seems to open up the possibility of synthesizing more elements beyond this."

The periodic table is the oddly shaped checkerboard — with an H for hydrogen, the lightest element, in the upper-left-hand corner — that hangs in chemistry classrooms the world over. Each element has a different number of protons, particles with a positive electrical charge, in the dense central kernel called the nucleus.

The number of protons, beginning with one for hydrogen, fixes an element's place in the periodic table and does much to determine an element's chemical properties: ductile and metallic at room temperature for gold (No. 79), gaseous and largely inert for neon (10), liquid and toxic for mercury (80).

Elements as heavy as uranium, No. 92 on the list, are found in nature, and others have been created artificially. But much heavier elements have been difficult to make, partly because they became increasingly unstable and short-lived.

Still, for roughly half a century, nuclear scientists have been searching for an elusive "island of stability," somewhere among the superheavies, in which long-lived elements with new chemical properties might exist. Dr. Loveland said that the new results indicated that scientists might be closing in on that island.

"We're sort of in the shoals of the island of stability," said Dr. Kenton J. Moody, a Livermore nuclear physicist who was one of the experimenters in the work.

"It's an amazing effect," he added. "We're really just chipping away at the edges of it."

The experiments took place at a cyclotron, a circular particle accelerator, in Dubna, where the scientists fired a rare isotope of calcium at americium, an element used in applications as varied as nuclear weapons research and household smoke detectors. Four times during a month of 24-hour-a-day bombardment in July and August, scientists on the experiment said, a calcium nucleus fused with an americium nucleus and created a new element.

Each calcium nucleus contains 20 protons and americium 95. Since the number of protons determines where an element goes in the periodic table, simple addition shows the new element to bear the atomic number 115, which had never been seen before. Within a fraction of a second, the four atoms of Element 115 decayed radioactively to an element with 113 protons. That element had never been seen, either. The atoms of 113 lasted for as long as 1.2 seconds before decaying radioactively to known elements.

Scientists generally do not give permanent names to elements and write them into textbooks until the discoveries have been confirmed by another laboratory. By an international convention based on the numbers, element 113 will be given the temporary name Ununtrium (abbreviated Uut for the periodic table) and element 115 will be designated Ununpentium (Uup).

Dr. Loveland said he agreed that the new elements would require independent confirmation before they could receive final acceptance. And he conceded that the Dubna find was likely to receive more than the usual amount of scrutiny: two years ago, the reported discovery of Element 118 was retracted after a scientist at Lawrence Berkeley National Laboratory was found to have fabricated evidence.

The only other truly simultaneous discovery of two elements in recent times came in 1952, when einsteinium (99) and fermium (100) were discovered in the fallout from the hydrogen bomb explosion at Eniwetok Atoll in the Pacific Ocean. The most recent successful discovery of an element — one that has received a name — came in 1994. That element, No. 110, is called Darmstadtium for the city in Germany where it was discovered.

But as scientists wait for confirmation on elements 115 and 113, the data presented by the Dubna and Livermore groups appear solid, said Dr. Sigurd Hofmann, a nuclear physicist at the Institute for Heavy Ion Research in Darmstadt, the laboratory where Darmstadtium was found.

"These Dubna data look quite convincing," Dr. Hofmann said. "And I'm sure with some more experiments, it will finally be accepted."

Dr. Joshua B. Patin, a 28-year-old nuclear chemist who is the lead American author on the paper, said he had found it deeply moving to add two more entries to a scientific icon that dates to the 1860's. That was when the Russian chemist Dmitri Ivanovich Mendeleyev noted clear patterns in the chemical properties of the known elements and arranged them into the periodic table, leaving gaps for other elements that he correctly predicted would someday turn up.

"This is a working piece of art," Dr. Patin said. "We're not done yet. Nothing's been finished. What it could really mean down the road, nobody can tell. And that's the part that's exciting to me."

The lead authorship on the work went to Dr. Yuri Oganessian, scientific director of the Flerov Laboratory of Nuclear Reactions at the Joint Institute for Nuclear Research in Dubna, whose theoretical research in the 1970's revealed the path that eventually led to the most recent discoveries.

The experimental group that Dr. Oganessian leads is especially skilled at using extremely small amounts of the rare calcium isotope in the bombardment and at filtering out signals from just a handful of new atoms among the debris spewing from the collisions.

"These elemental discoveries underscore both the value of federally supported basic research and the benefit of unfettered international scientific collaboration," said Energy Secretary Spencer Abraham, whose agency helped finance the work.

In a written response to questions, Dr. Oganessian said the results "favor the conclusion about the formation of a new element and refute any other interpretation." He added that confirmation of the work was necessary, but that everything had been done to ensure that the analysis was correct.

"In order to exclude the human factor," Dr. Oganessian said, "the analysis of the data is carried out in parallel and independently by the two groups in Dubna and in Livermore."

Physicists long ago discovered that atomic nuclei have what came to be known as "magic numbers." Nuclei that contain just those numbers of protons and their electrically neutral cousins, neutrons, are especially stable. The numbers 2, 8, 20, 28, 50, 82 are magic for both protons and neutrons.

Theoretically, those numbers come about because nuclei have a shell-like structure, said Dr. Witold Nazarewicz, a nuclear theorist at the University of Tennessee and Oak Ridge National Laboratory. Each shell can hold particular numbers of protons and neutrons, and a nucleus is most stable when its shells are precisely filled up, leading to the magic numbers.

The highest known magic number for neutrons is 126, meaning that common lead, with 82 protons and 126 neutrons in its nucleus is the heaviest known "doubly magic," or extremely stable, isotope in the periodic table.

"The question is, what is the next doubly magic nucleus beyond lead?" Dr. Nazarewicz said.

Those numbers should help map out what Dr. Nazarewicz prefers to call generically a "region of stability" among the superheavies. (Because, he says, it could resemble a peninsula more than an island.) Various theories have suggested that the next magic proton number is 114, 120 or 126, he said. There is general agreement that the next magic neutron number is 184, he said.

The new experiments by the Livermore and Dubna scientists created forms of element 115, for example, with at most 173 neutrons, suggesting that they are still short of what could be a land of strange new forms of matter.

Rather than being round, nuclei in that region and beyond could contain bubbles and have strange doughnut-like shapes, Dr. Nazarewicz said.

They could also have unpredictable chemical properties.

The new work should shed light on whether theories of those undiscovered bits of matter are correct or not, he said.

"Those discoveries tell us a great deal about the underlying nuclear structure," Dr. Nazarewicz said. "About how the very heaviest systems are built — how they tick."

Dr. Darleane C. Hoffman, a nuclear chemist at the University of California, Berkeley, also cautioned that the new findings would have to be checked out by other laboratories. But she said the value of the work was unquestioned.

"Scientifically, just for the pure science of it, wouldn't you like to know just how many chemical elements there are?" Dr. Hoffman said. "And until you actually have a measurement that you believe and you can confirm, you don't have any idea whether the various models the theorists propose have any meaning at all."

