A New Block on the Periodic Table

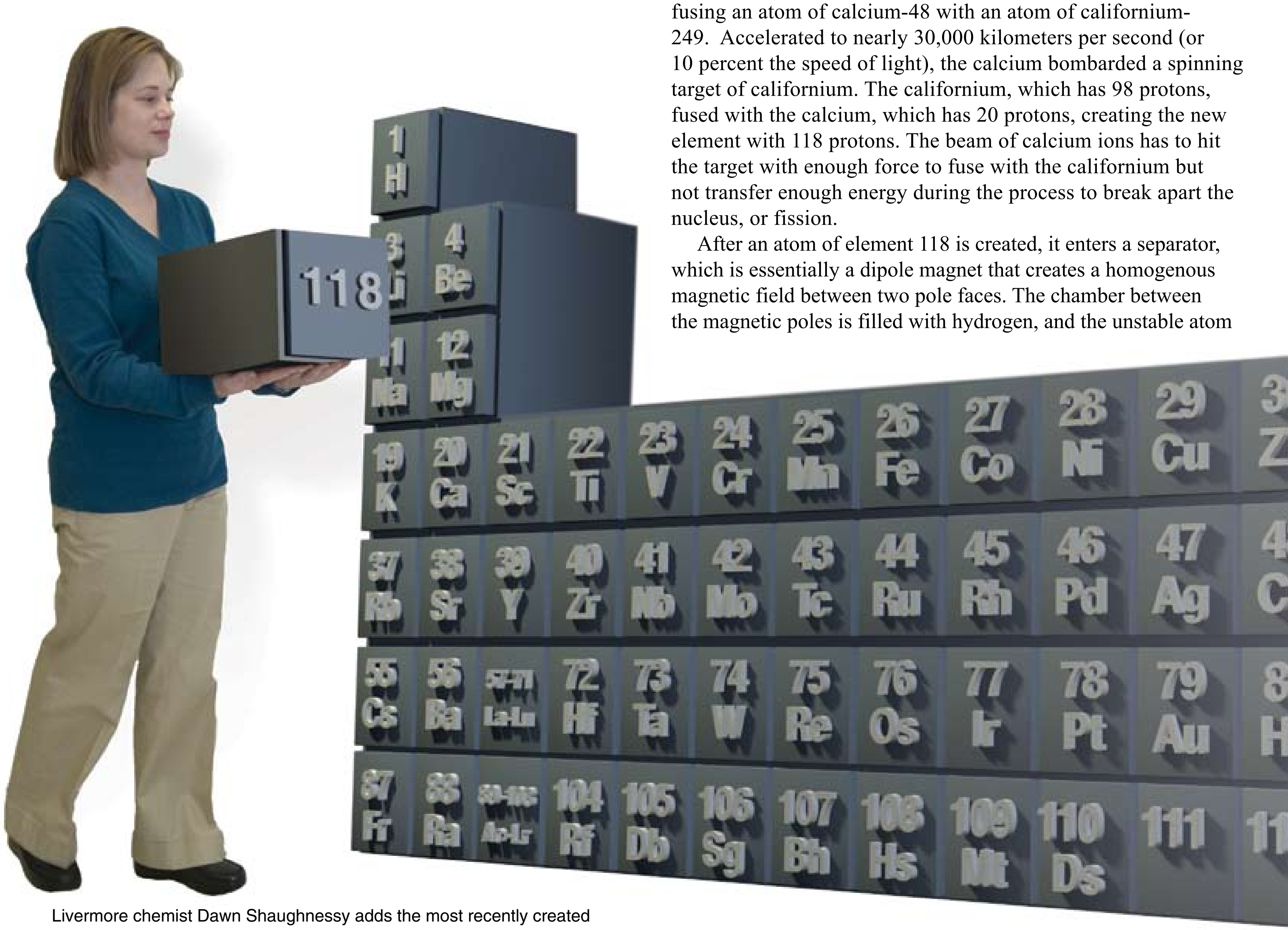
SCIENTISTS from Lawrence Livermore working in collaboration with a team from the Joint Institute for Nuclear Research (JINR) in Dubna, Russia, have discovered element 118, the newest block on the periodic table. Lasting less than a millisecond before decaying and ultimately fissioning, element 118 is the latest element to be synthesized artificially.

Why do scientists work so hard to create new elements that last for such a short time? According to chemist Dawn Shaughnessy from Livermore's Chemistry, Materials, and Life Sciences Directorate, "Each new element we discover provides more knowledge about the forces that bind nuclei and what causes them to split apart. This knowledge, in turn, helps us better understand the limits of nuclear stability and the fission process."

Element 118 under Construction

During experiments conducted in Dubna's U400 cyclotron between February and June 2005, element 118 was created by fusing an atom of calcium-48 with an atom of californium-249. Accelerated to nearly 30,000 kilometers per second (or 10 percent the speed of light), the calcium bombarded a spinning target of californium. The californium, which has 98 protons, fused with the calcium, which has 20 protons, creating the new element with 118 protons. The beam of calcium ions has to hit the target with enough force to fuse with the californium but not transfer enough energy during the process to break apart the nucleus, or fission.

After an atom of element 118 is created, it enters a separator, which is essentially a dipole magnet that creates a homogenous magnetic field between two pole faces. The chamber between the magnetic poles is filled with hydrogen, and the unstable atom



Livermore chemist Dawn Shaughnessy adds the most recently created element to the periodic table.

traveling from the cyclotron into the separator immediately picks up electrons from the hydrogen until it reaches an equilibrium state. The magnetic field is set to recognize this equilibrium state so that, for the most part, only atoms with a matching charge state are passed to a detector. In this way, the few atoms of interest are separated from a flood of interfering particles.

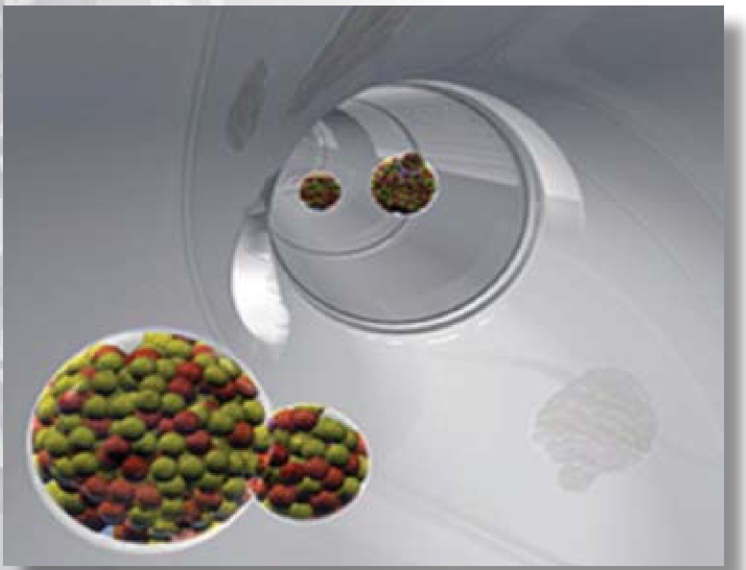
The detector is key to proving the new element's fleeting existence. An atom first passes through a time-of-flight counter, which detects the time the atom enters and its speed. The atom then moves into the detector box and implants itself in one of the silicon walls. The counter sends a signal that helps scientists to identify new and heavier atoms, which travel more slowly, and to ignore unwanted by-products.

The new element undergoes alpha decay almost immediately—that is, it ejects a helium nucleus (two protons and two neutrons) making it element 116. Element 116, in turn, decays to element 114, and then it either undergoes fission or a third alpha decay to element 112. Scientists do not see the element itself—they see only the unique and distinctive alpha decays that prove it existed. Because each of these daughter products is so heavy, they do not travel far between decays, and the signal from the detector shows each one. Only alpha decays within a particular time frame and with certain energy signatures can possibly be emitted from element 118.

Mapping the Island of Stability

Scientists have been creating new elements since 1940, when neptunium and plutonium were created at the University of California at Berkeley. As more elements were created, a pattern emerged: each new element was radioactive, slightly heavier than the one before, and in general, more unstable with an increasingly short half-life. However, in the 1960s, a few scientists theorized that the isotopes of some of the synthesized heavy elements would be more stable, with much longer half-lives. These isotopes would form an "island of stability" in a "sea" of highly unstable isotopes that exist beyond the natural elements. Because those elements would have longer lifetimes, they might be useful for new applications.

Since then, scientists have endeavored to reach this island of stability, constantly pushing the border of what is technologically achievable. To be in the island, the isotopes must have filled or nearly filled nuclear shells. These shells are analogous to the



An artist's conception shows the production of element 118 as it travels through the accelerator to the detector. Three atoms of element 118 are produced when calcium ions bombard a californium target.

Lawrence Livermore scientists (left to right) Jackie Kenneally, Jerry Landrum, Nancy Stoyer, and Ken Moody perform chemical separations on reaction products produced in a cyclotron at the Joint Institute for Nuclear Research in Dubna, Russia. Dubna's U400 cyclotron produces some of the most intense calcium-48 beams in the world and does so for the months required to produce just a few atoms of the superheavy elements.

electron orbitals in atoms. When the shells are filled with the number of protons equal to one of the "magic numbers" of 2, 8, 20, 28, 50, and 82, the nucleons have a greater binding energy and are more stable against nuclear decay. These same numbers and the number 126 are magic numbers for neutrons. The calcium-48 isotope used to create element 118 is "doubly magic" because it has 20 protons (a magic number) and 28 neutrons (also a magic number). Calculations performed in the 1960s indicated that the next magic proton number is 114.

When the Livermore–JINR team earlier created the relatively long-lived elements 114 and 116, they demonstrated that the island of stability exists. (See *S&TR,* January/February 2002, pp. 16–23.) Because element 118 has such a short half-life, it is not likely to have a magic number of protons. Rather, the element's decay properties, and those of its decay daughters, tend to support the view that element 114 contains a magic number of protons. If element 118 were located completely beyond the island of stability, current theory says it would not have lasted as long as it did. The fact that element 118 did not undergo fission immediately was unexpected and suggests that the island of stability is larger than predicted.

Chemist Ken Moody from Livermore's Defense and Nuclear Technologies Directorate says, "Our goal is to create new elements with as many neutrons as possible." However, until technology allows the forcing of more neutrons into the nuclei, no single experiment can prove which is the next magic number. Nonetheless, the discovery of element 118, together with the discovery of elements 113–116, has helped map more of the island of stability and answer some questions.

Applications for element 118 and, indeed, for many other heavy elements, have not yet been pursued. However, several heavy elements do have applications. For example, americium is used in smoke detectors, curium and californium are used for neutron radiography and interrogation, and plutonium is used in nuclear weapons.

Filling in the Periodic Table

Scientists from Livermore and JINR are starting experiments to create element 120. Using a beam of iron-58 to bombard a plutonium-244 target, the team hopes to create element 120 and further map the island of stability. What will be the last block on the periodic table? Although current technology has a limited ability to force more neutrons into the nucleus, future radioactive beam accelerators might produce more intense beams of neutron-rich isotopes. If so, researchers might reach the center of the island. The ultimate goal of the Livermore–JINR team is to fully map the island of stability and develop a comprehensive magic number theory that explains how nuclei bind and how they resist fission.

—Karen Rath

Key Words: element 118, heavy elements, island of stability, Joint Institute for Nuclear Research (JINR).

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