Explosive Expansion of Atomic Nuclei

In its normal state, an atomic nucleus behaves much like a drop of water. Its neutrons and protons hang together as if they were components of a liquid.

Now, researchers have confirmed experimentally that heating up an atomic nucleus to temperatures far hotter than the sun's interior causes the nucleus to expand by nearly 50 percent in diameter. Only then does the nucleus disintegrate into many pieces.

"This is the first direct evidence for the expansion of nuclear matter," says nuclear chemist Victor E. Viola of Indiana University at Bloomington.

Knowledge of how nuclei expand and contract under different conditions furnishes insights into such astrophysical processes as the collapse of ordinary stellar material into a neutron star — a giant nucleus, in effect, with a mass comparable to that of the sun but a diameter of only 10 kilometers.

Viola reported these findings last week at an American Chemical Society meeting in Anaheim, Calif. The results also will be published in an upcoming issue of PHYSICAL REVIEW LETTERS.

Theorists have long found it useful to model an atomic nucleus as a drop of liquid. On this basis, they have suggested that a nucleus could, under certain circumstances, change from a liquid to a more loosely bound gaseous state. Some theorists have also predicted that intense heating could cause a nucleus to expand considerably.

"The model that I have been developing and working with suggests that the expansion happens first, and then at low density the nucleus tends to break apart," says physicist William A. Friedman of the University of Wisconsin–Madison, who consulted with Viola's team.

As a complement to the theoretical work, experimentalists have typically studied the characteristics of nuclear matter by smashing together large, heavy nuclei and sifting through the debris for clues. To make it somewhat easier to analyze the results, Viola, Indiana's Kris Kwiatkowski, and their collaborators focused on high-energy collisions between speeding helium-3 particles and targets containing silver or gold nuclei.

"We're trying to pump a lot of energy into a nucleus," Viola says. "We use very simple, light projectiles to do this."

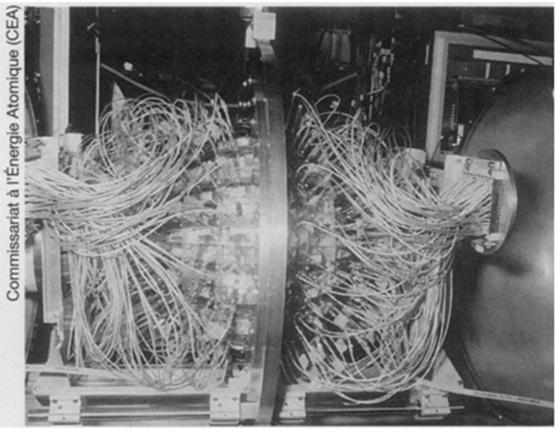
To identify the type, energy, and propagation direction of all the pieces, the researchers built a special apparatus, called the Indiana Silicon Sphere detector array, that completely surrounds the target (see photo). Performing the experiment at the Saclay Center for Nuclear Studies near Paris, Viola and his team collected enough data to deduce the size and other characteristics of the source of the fragments.

"It's like reconstructing an explosion," Viola remarks. "We believe our data now give us concrete evidence that expansion [of the nucleus] is occurring."

In a collision, a helium-3 nucleus penetrates to the center of its target silver or gold nucleus, generating subatomic particles called pi mesons. These pi mesons interact with the neutrons and protons to heat the nucleus rapidly from the inside, pushing temperatures as high as 20 billion kelvins. This heating causes the nucleus to expand, then fragment.

"We certainly see the nucleus disassembled into many, many pieces," Viola says. For example, a gold nucleus containing 197 particles may break up into 40 or more pieces, mainly small clusters and individual neutrons and protons.

"So far, model and experiment have been fairly consistent," Friedman notes.


Commissariat à l'Énergie Atomique (CEA)

Indiana Silicon Sphere charged-particle detector array.

The researchers are planning to extend their studies, this time using antiprotons as the bombarding particles. "Antiprotons are an ideal way of getting a great deal of energy into a nucleus very rapidly," Viola says. *— I. Peterson*

Scientists 'grow' replacement heart valves

Using a patient's own heart muscle cells as seeds for new tissue, researchers are testing a novel technique to "grow" replacement heart valves for persons with cardiac disease.

Christopher K. Breuer, a physician at Children's Hospital in Boston, says the new method for engineering heart valve tissue could offer an alternative to animal-derived or mechanical devices.

"Tissue-engineered heart valves do not have many of the problems associated with today's replacement valves and may some day offer an improvement over today's state-of-the-art therapy," Breuer said last week at a meeting of the American Chemical Society in Anaheim, Calif.

In the United States, physicians replace approximately 60,000 heart valves each year, mostly with plastic prostheses or valves fashioned from the vascular tissue of pigs. Such valves cannot develop, grow, or repair themselves, and both kinds sometimes trigger immune responses leading to blood clots, infections, or rejection, Breuer says.

Artificial valves last only 10 to 20 years, creating problems not only for children who have heart operations, but also for adults who need new heart valves at age 40 and may have to face a second operation at age 50 or 60.

"These are difficult operations and you don't want to put someone through one more than once," Breuer says. In theory, the new living valve should integrate fully into the patient's heart tissue, growing and developing along with the person receiving it.

To engineer the valve, a physician removes a small piece of tissue from a patient's heart, then cultures the cells in a laboratory, separating them into the three cell types found in valves: smooth muscle, endothelial, and fibroblast.

Those cells are then implanted into a biodegradable material, polyglycolic acid, which surgeons already use in dissolvable sutures, Breuer says. The material serves as a scaffold, enabling the cells to form living valve tissue. After 6 weeks, the foreign material dissolves completely, leaving in its place a biological valve that resembles natural heart tissue.

Breuer says that he and his colleagues are "evaluating the biomechanical properties of these structures and comparing them to native heart valve tissue."

The research team estimates that many of the 2,300 patients who receive heart transplants every year could potentially benefit from this research, as could the 40,000 patients who need, but cannot get, replacement hearts, owing to a limited supply of donor organs.

So far, the researchers have tested the procedure in lambs, with good results, Breuer reports. However, the valves will require more research and development before any testing can begin in humans. *— R. Lipkin*