Science & Technology

Muons catalyze 'cold' fusion reactions

by Charles B. Stevens

Generating nuclear fusion reactions requires heating hydrogen fuel to tens of millions of degrees Celsius. But by using muons—short-lived, heavy electrons that are produced in charged particle beam accelerators—as a catalyst, "cold" fusion can be produced in molecules at temperatures of less than a few thousand degrees. Scientists from Los Alamos National Lab and EG&G of Idaho Falls, Idaho presented the latest results from experiments with muon-catalyzed fusion at the Washington, D.C. meeting of the American Physical Society April 24-26.

Until a few years ago, it was believed that no more than one fusion reaction could be catalyzed by one muon. But last year, experiments sparked by a new theory developed by Soviet scientists, showed that a single muon would catalyze more than 100 fusion reactions. The latest Los Alamos results have increased this to more than 160, and researchers expect to soon increase this number to more than 300.

More significant, the Los Alamos experimental results are demonstrating new atomic and molecular processes not predicted by currently accepted theory, indicating that the efficiency of muon-catalyzed fusion can be substantially increased above even these levels. Simultaneously, accelerator scientists at Lawrence Livermore National Lab and Los Alamos are developing new technology and techniques that promise to decrease the energy cost of muon generation by as much as a factor of 100. The combined result would produce substantial energy gain for muon-catalyzed fusion.

How the reaction works

When ions are accelerated to extremely high velocities and energies and collide, they disintegrate into a large number of subnuclear entities often misnamed "elementary particles." These collision-generated entities are usually short-lived. Chief among them are mesons, which rapidly decay into muons, which have lifetimes no more than a few millionths of a second. The muon then decays into a stable electron.

Before it decays, however, the muon acts like a heavy electron, weighing about 200 times more. When the muon takes the place of an electron in an atom, its greater mass makes the atomic orbit hundreds of times smaller. If people had muons instead of electrons in their atoms, they would be only about half an inch tall.

In the experiments at the Los Alamos Meson Physics Facility, the accelerator-generated muon beam is injected into a metal chamber containing liquid hydrogen fusion fuel; that is, the heavy isotopes of hydrogen, deuterium, and tritium.

The muon replaces an electron in a tritium atom. This small atom then resonantly penetrates a deuterium-deuterium or deuterium-tritium molecule within five billionths of a second. The smaller orbit of the muon causes the two nuclei of the deuterium and tritium in the molecule to come closer together, producing nuclear fusion within a trillionth of a second. The small orbit of the negatively charged muon "shields" the two positively charged nuclei from their large, mutual electrostatic repulsion.

In determining the efficiency of muon-catalyzed fusion—the number of fusion reactions generated per muon—both the dynamics of the formation of muon atoms and molecules, and the various paths by which the muon can leak out of the reacting chamber must be fully explored. It was initially believed that upwards of 1% of the muons would be carried out of the reaction chamber by fusion reaction products in a loss process called alpha sticking. But the Los Alamos experiments now show that the alpha sticking fraction is less than one-third of 1%.

In terms of atomic and molecular processes, the Los Alamos investigations have confirmed the Soviet theory of rapid, resonant molecular formation. It has been found that the rate of molecular formation continues to increase with increasing fuel temperature and density—and with increasing concentration of tritium.

Most significant, Los Alamos scientists have discovered new, beneficial molecular processes that are not predicted by the Soviet theory. It was previously believed that muonized atoms would have to slow down by colliding with other atoms before they could resonantly penetrate hydrogen molecules. This slowing down took up valuable time in the short life of the muon. But Los Alamos results show that muonized atoms do not have to slow down to penetrate molecules.

Although many practical problems must be overcome to attain economical muon-catalyzed fusion energy generation, the Strategic Defense Initiative is already generating technological spinoffs that are making progress toward this goal. Dr. Steve Jones of EG&G reported on efficient, high-current particle beam accelerators like the Los Alamos RFQ, and there are innovative muon-production techniques being investigated by Lawrence Livermore's Dr. George Chapline, the scientist who received the Lawrence Prize for developing the x-ray laser.

It is likely that economic feasibility will first be demonstrated for using muon-catalyzed fusion as part of a fission fuel breeding facility. Both the muon fusion and the accelerator-generated neutrons would be used to "breed" fuel for existing nuclear fission power reactors.