New type of nuclear fission discovered

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The experimental apparatus with which Otto Hahn and Fritz Strassmann discovered nuclear fission in 1938. Image: Wikipedia.

(PhysOrg.com) -- Nuclear fission, or the splitting of a heavy nucleus, usually results in symmetrical fragments of the same mass. Physicists attribute the few known examples of fission that is asymmetric to the formation in the resultant fragments of "magic" nuclei, which are extremely stable nuclei with all energy levels filled. Now, experiments at the European particle physics laboratory at the Organization for Nuclear Research (CERN) near Geneva in Switzerland have found the isotope mercury-180 splits asymmetrically into ruthenium-100 and krypton-80 rather than the expected zirconium-90.

The nucleus of mercury-180 contains 80 protons and 100 neutrons, and symmetrical fission would result in two nuclei of zirconium-90, which contains 40 protons and 50 neutrons. This result was expected to be dominant especially because 50 and 40 are magic and semi-magic numbers respectively, meaning the levels in the nucleus would be completely filled with protons/neutrons.

Andrei Andreyev, of the University of the West of Scotland in Paisley, and colleagues carried out the experiments at the ISOLDE facilities at CERN. These facilities enable physicists to work with pure beams of highly unstable heavy elements and collect their reaction products and analyze them. They began with a beam of the highly unstable thallium-180, which has 81 protons and 99 neutrons, and which decayed primarily by the capture of an electron to convert one of the protons into a neutron, giving the 80 protons and 100 neutrons of mercury-180. This should then theoretically split symmetrically.

Instead, the mercury isotope split into ruthenium-100, with 44 protons and 56 neutrons, and krypton-80, with 36 protons and 44 neutrons. These are isotopes with incompletely filled energy levels.

Asymmetric splitting has been seen previously in isotopes of uranium, which often split into the isotope tin-132 and a smaller fragment. The tin-132 has all energy levels in the nucleus filled, with 50 protons and 82 neutrons, and is an extremely stable isotope. This asymmetric fission was therefore easy to explain, but the new findings cannot be explained in this way, and this is the first time such unexplainable fission has been observed.

The researchers then analyzed the energy requirements for different types of mercury-180 splitting, and found less energy was required for the asymmetric split found experimentally than for the symmetrical split predicted by the theory. Team member Piet Van Duppen of the Catholic University of Leuven in Belgium, said this may mean other isotopes in the same area of the periodic table may also split into asymmetric daughter fragments. Another isotope of mercury has now been tested, and it also split asymmetrically.

The results of the experiments highlight the gap in the scientific knowledge of nuclear fission, which still cannot be fully described in detail some seven decades after the process was discovered. The gap may be filled in as new radioactive beam facilities become available in the next few years, including the Facility for Antiproton and Ion Research in Germany and the Facility for Rare Isotope Beams in the US.

The experimental results of the experiments are published in *Physical Review Letters*.

More information: New type of asymmetric fission in proton-rich nuclei, *Physical Review Letters*, A. N. Andreyev et al. Accepted for publication.