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News

Atomic nucleus takes two shapes

The squashed heart of a sulphur isotope fluctuates between different states.

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Contrary to some expectations in the world of nuclear physics, researchers have found that a radioactive nucleus of sulphur oscillates between two different shapes, sometimes appearing like a sphere and other times like an American football. The result, reported this month by researchers in France, is causing nuclear physicists to rethink prevailing theories about what makes some nuclei stable and others prone to splitting apart.

According to standard nuclear physics, the nuclei at the heart of atoms are made up of neutrons and protons that settle into neatly defined energy shells. When the neutron or proton shells are full, which happens at 'magic numbers' including 2, 8, 20, 28, and more, nuclei are more stable and less likely to undergo radioactive decay. The idea of magic numbers is also sometimes extended to 'magic islands' of nuclei, for which only the number of protons or neutrons is magic or nearly magic.

The concept of magic islands has encouraged the search for superheavy elements that would not otherwise be stable. The heaviest elements found to date, numbers 116 and 118, are thought to be close to a magic number.

"The question is whether the influence of the magic numbers stretches across the nuclear chart," says Paul Mantica, a nuclear chemist at Michigan State University in East Lansing.

Make it magic

One example is sulphur-43, a radioactive isotope of sulphur that lasts 280 milliseconds before decaying. Whereas the most stable nuclei contain similar numbers of protons and neutrons, sulphur-43 is lopsided, with 27 neutrons and 16 protons. Past experiments had prompted some uncertainty over the stability of numbers close to the magic number of 28, so Laurent Gaudefroy at the French Atomic Energy Commission's research centre in Arpajon, Ile de France, and his colleagues, decided to measure the properties of the sulphur-43 nucleus precisely. They did this by detecting gamma rays emitted when the nucleus moved between different energy states[1]. In addition, "we measured the [magnetic] spin of the nucleus, which is a very difficult experiment," Gaudefroy says.

Together, this information revealed the shape of the sulphur-43 nucleus. Whereas a magic or nearly magic nucleus is expected to take the shape of a sphere, the measurements showed that the sulphur-43 nucleus oscillates from a higher-energy spherical state to a lower-energy one that is prolate — that is, shaped like an American football.

It seems that the 27 neutrons, which are near a magic number and 'want' to settle into a spherical shape, may be experiencing interference from the 16 protons, which are not, says Mantica. But the nature of the interaction between the protons and neutrons is still up for debate. Unlike the gravitational force, the strong nuclear force that holds the nucleus together isn't captured by an exact mathematical expression, and theorists rely on empirical data when they try to model the behaviour of nuclei. "This is certainly an important experimental result," says theorist Peter Möller of the Los Alamos National Laboratory in New Mexico.

The new result is likely to have implications far beyond the lab. Astrophysicists rely on predictions of the stability of nuclei near higher magic numbers, including 50 and 82, to understand the nuclei produced by supernovae and the merging of neutron stars. So far physicists have not been able to make many of the larger exotic nuclei on Earth — but Gaudefroy says the next step for his group will be to study nickel-78, which contains 28 protons and 50 neutrons.

References

1. Gaudefroy, L. *et al. Phys. Rev. Lett.* 102, 092501 (2009).

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