ISOLDE reveals fundamental property of astatine, the rarest element on Earth

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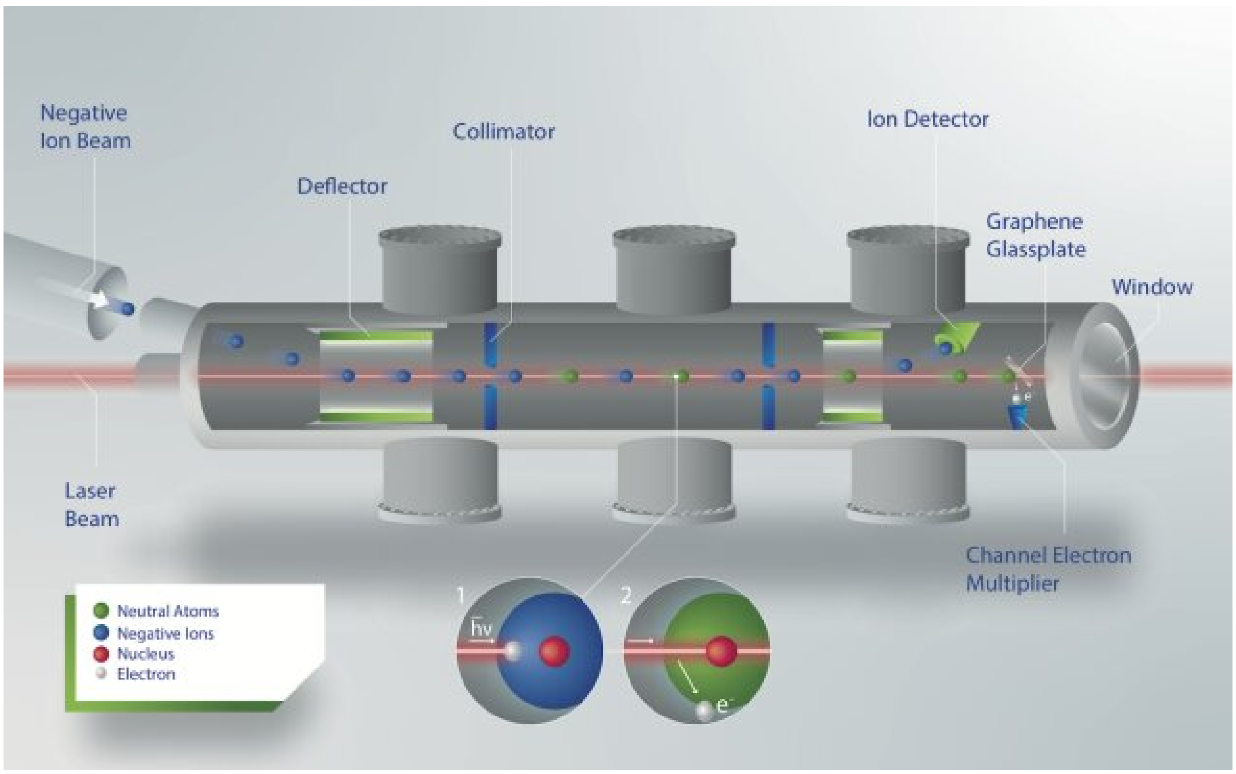

The setup used to measure the electron affinity of astatine. A beam of negative astatine ions is sent to a device comprising several components. Laser light (red) is shone on the ions to measure the energy required to extract the extra electron of the ion (inset 1) and turn the ion into a neutral atom (inset 2). Credit: D. Leimbach et al

A team of researchers using the ISOLDE nuclear-physics facility at

CERN has measured for the first time the so-called electron affinity of the chemical element astatine, the rarest naturally occurring element on Earth. The result, described in a paper just published in *Nature Communications*, is important for both fundamental and applied research. As well as giving access to hitherto unknown properties of this element and allowing theoretical models to be tested, the finding is of practical interest because astatine is a promising candidate for the creation of chemical compounds for cancer treatment by targeted alpha therapy.

The electron affinity is the energy released when an electron is added to a neutral atom in the gas phase to form a negative ion. It is one of the most fundamental properties of a chemical element. Together with the ionization energy, the energy it takes to remove an electron from the atom, it defines several other traits of an element, such as its electronegativity—the ability of the element to attract shared electrons in chemical bonds between atoms.

Although astatine was discovered in the 1940s, knowledge of its properties has mostly been based on theoretical calculations or on extrapolation from the properties of its relatives in the periodic table; astatine is a member of the halogen family, which includes chlorine and iodine. This is because astatine is scarce on Earth, and the tiny amounts of the element that can be produced in the lab prevent the use of traditional techniques to measure its properties. One notable exception was a previous measurement at ISOLDE of the element's ionization energy.

In the new ISOLDE study, astatine atoms were first produced along with other atoms by firing a high-energy beam of protons from the Proton Synchrotron Booster at a thorium target. The astatine atoms were then negatively ionized, and ions of the isotope ^{211}At were extracted and sent to a special measurement device in which laser light of tunable energy was shone on the ions to measure the energy required to extract the extra electron of the ^{211}At ion and turn the ion into a neutral atom.

From this measurement, the ISOLDE researchers obtained a value of 2.415 78 eV for the electron affinity of astatine. This value, which agrees with the value that the authors derived using state-of-the-art theoretical calculations, indicates that the electron affinity of astatine is the lowest of all halogens but is nonetheless greater than that of any other elements outside the halogen family that have been measured so far.

If that wasn't enough the researchers went on to use the derived electron affinity and the previous measurement of the ionization energy to determine several other properties of astatine, such as its electronegativity.

These properties are relevant for studies investigating the possible use of ^{211}At compounds in targeted alpha therapy, a treatment that delivers alpha radiation to cancer cells. Astatine ^{211}At is an ideal source of alpha radiation but most of the ^{211}At compounds under investigation suffer from the rapid release of ^{211}At negative ions, which could damage healthy cells before the compounds reach the cancer cells.

"Our results could be used to improve our knowledge of this release reaction and the stability of the ^{211}At compounds being considered for targeted alpha therapy," says lead author of the study David Leimbach. "In addition, our findings pave the way to measurements of the electron affinity of elements heavier than astatine, potentially of the superheavy elements, which are produced one atom at a time."

"With the present result, we conclude a 10-year research effort at ISOLDE to determine the fundamental properties of astatine, the ionization energy and the electron affinity, which together finally enabled us to derive the electronegativity of astatine," adds Sebastian Rothe, lead author of the earlier ISOLDE study.

More information: David Leimbach et al. The electron affinity of astatine, *Nature Communications* (2020). DOI: 10.1038/s41467-020-17599-2

Provided by CERN

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