Radioactive negative ions at ISOLDE

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Negative ions are unique quantum systems to probe electron correlation effects: since the Coulomb potential of the nucleus is almost entirely screened, the binding of the additional electron is primarily due to many body interactions between electrons. Consequently, negative ions are sensitive probes for electron correlation theories that go beyond the independent particle approximation, which is of crucial importance for the understanding of atomic and molecular structure. However, due to the weak binding potential, the energy gained by attaching an electron to a neutral atom, referred to as electron affinity (EA), is typically only of the order of one eV. For the same reason, negative ions typically lack bound excited states with opposite parity, with the noticeable exceptions being lanthanum, cerium, osmium and thorium [1-4]. Consequently, the EA is the only parameter which can be probed with high precision, typically via laser photodetachment threshold spectroscopy. Furthermore, the determination of isotope shift in the EA is an excellent benchmark to probe the accuracy of theoretical calculations of the specific mass shift, which is required when e.g. extracting nuclear charge radii from spectroscopic data.

In order to study radiogenic elements, in particular those with short half-lifes, an on-line facility such as CERN-ISOLDE needs to be utilized, where elements with half-lifes of >30ms can be produced and delivered to experimental setups. A program to study EAs and isotope shifts utilizing radiogenic negative ions at ISOLDE was established by the GANDALPH collaboration a few years ago, reaching a major milestone with the determination of the electron affinity of astatine utilizing the GANDALPH detector in 2018 [5]. Following the long shutdown of the CERN accelerator complex, experiments determining the isotope shift in the EA of chlorine as well as the determination of the EA of polonium are being prepared and are expected to take place in 2023.

Furthermore, efforts to convert positive ions delivered by ISOLDE to negative ions using the charge-exchange process were initiated, broadening the range and accessibility of negative ion experiments at ISOLDE. Initial yields of the production of uranium from charge exchange reactions by injecting a 40keV ion beam into a sodium filled charge exchange cell were performed in 2022.

Here, we will present the status and developments of the negative ion program at ISOLDE including the measurements of the EA of ^{128}I and ^{211}At, charge exchange production yields as well as future activities including the isotope shift in the EA of chlorine, the EAs of Po, Fr and the actinide elements.

References

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