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Studying negative ions in an MR-ToF device

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Negative ions lack a long-range Coulomb force. Instead, the long-range attraction is governed by an induced dipole potential which arises from the polarization of the atomic core by the additional electron. This leads to an enhanced importance of electron-electron correlation. The electron affinity (EA), which is the energy gained by attaching an electron to a neutral atom, is a quantity that gives information about the electron-electron correlation. It can be experimentally determined using the photodetachment process, where a photon with sufficient energy is used to detach an electron from a negative ion.

An accurate description of electron correlation is important for improving theoretical calculations such as for the specific mass shift which is required for extracting nuclear charge radii from experiments. We are now interested in measuring the isotope shift in the EA's of 35Cl and 37Cl. This was first experimentally measured and calculated by Berzinsh et al., where the results obtained agreed in magnitude but not in sign [1]. Following this, Carette and Godefroid were able to improve the computational method to result in a value that not only agreed with experiment but also achieved a higher precision than in the experiment [2].

Since this improved calculation, the isotope shift of 35Cl and 37Cl has not been remeasured, therefore we propose to experimentally determine this to a higher precision. To achieve this, we have coupled a negative ion source to the MR-ToF of the MIRACLS proof of principle experiment [3–5]. With MIRACLS, we can achieve a higher sensitivity by a factor of 40-700 for collinear laser spectroscopy by reflecting ion bunches in the MR-ToF which allows for increased observation time. Due to this method, the efficiency of photodetachment will increase allowing us to use continuous wave lasers which will provide us with higher precision due to the narrowband. Following the measurement with 35Cl and 37Cl, we will extend this to 36Cl which is a long-lived radionuclide. We have already artificially produced 36Cl, but studying it requires the MR-ToF technique due to low availability and to limit contamination.

After this proof-of-principle study has been complete, we can use MIRACLS to make EA measurements on short-lived radioactive isotopes that require online production. This will be especially useful to apply to elements that have lower production yields such as polonium and the actinides.

Here, we present recent developments and milestones with the negative ion collaboration at MIRACLS including the detection method via neutral particles.

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