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Excited States in Negative Ions

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Abstract

This thesis covers experimental studies of atomic negative ions with the main goal of increasing our fundamental understanding of these fragile quantum systems. Comparisons of measurements and calculations have been used to increase our understanding of these highly correlated, yet simple, systems. All the described studies in this thesis have investigated the photodetachment process, i.e. when a photon removes an electron from a negative ion. The measurements were mainly performed using a collinear laser-ion beam setup at the Gothenburg University Negative Ion Laser LAboratory (GUNILLA).

Novel threshold behavior was observed in studies of photodetachment of K^-, Cs^- and Na^- to highly excited states of the residual atom that has a large and negative polarizability. The cross section of this process was seen to be greatly suppressed just above threshold. In contrast, if the residual atom is left in a state with a large and positive polarizability a rapidly rising onset in the cross section was observed. The two behaviours are attributed to the fact that the detached electron either travels in a strongly repulsive or strongly attractive potential. These potentials are similar to those found in β-decay and are an excellent example of the generality of physics. A semi-classical model was developed in order to explain the novel threshold behavior.

In the studies on K^- and Cs^-, resonances due to doubly excited states were observed to modulate the cross sections in several photodetachment channels. In the case of K^- three known and two unknown resonances were observed below the $7\,^2P$ threshold. For Cs^-, a rich spectrum of overlapping resonances was observed below the $10\,^2P$ threshold. A new resonance parametrization was developed in order to handle the overlapping resonances.

A new field ionization setup has been developed in order to investigate the photodetachment process in greater detail. This apparatus will enable three new types of measurements: partial cross sections to very highly excited states approaching the double detachment limit; branching ratios to Rydberg states in the same energy range; and near threshold cross sections for the fundamentally interesting double photodetachment process. Initial experiments on the photodetachment of Cs^- leading to highly excited states of Cs are presented in this thesis.

In addition to the work at GUNILLA, an experiment has been performed on La^- at the Department of Physics at Denison University using a crossed laser-ion beams setup. Twelve optically allowed transitions between bound states of opposite parity in La^- were observed. One such transition has properties that could make it a candidate for the first laser cooling of a negative ion. If successful, laser cooled negative ions could be used in a proposed process of sympathetic cooling of anti-protons in an effort to enhance the production of anti-hydrogen.