Energy and charge state dependence of electron capture and loss cross sections for Kr ions traveling in He

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Efforts are currently under way at the National Superconducting Cyclotron Laboratory to develop a cyclotron gas stopper that will enable the stopping and collection of rare isotopes produced by projectile fragmentation prior to use in "stopped-beam" experiments or re-acceleration [1]. This project requires a detailed understanding of the interactions of fast heavy ions with the stopping medium, which in turn relies upon knowledge of the cross sections for electron exchange between projectiles and the media through which they travel. Because these cross sections depend on many variables (e.g., projectile charge, energy, atomic number, and target atomic number), it is not practical to experimentally measure them for all combinations of interest. Therefore, it is necessary to develop theoretical or semi-empirical methods for their prediction.

A procedure that utilizes various computer codes, such as Charge and Global [2], and Etacha [3], together with the semi-empirical formulas of Schlachter et al. [4], Franzke [5], and Schiwietz and Grande [6], has been devised to calculate electron capture and loss cross sections over a wide range of projectile energies [1]. The present measurements were performed for the purpose of testing the accuracy of this calculation procedure.

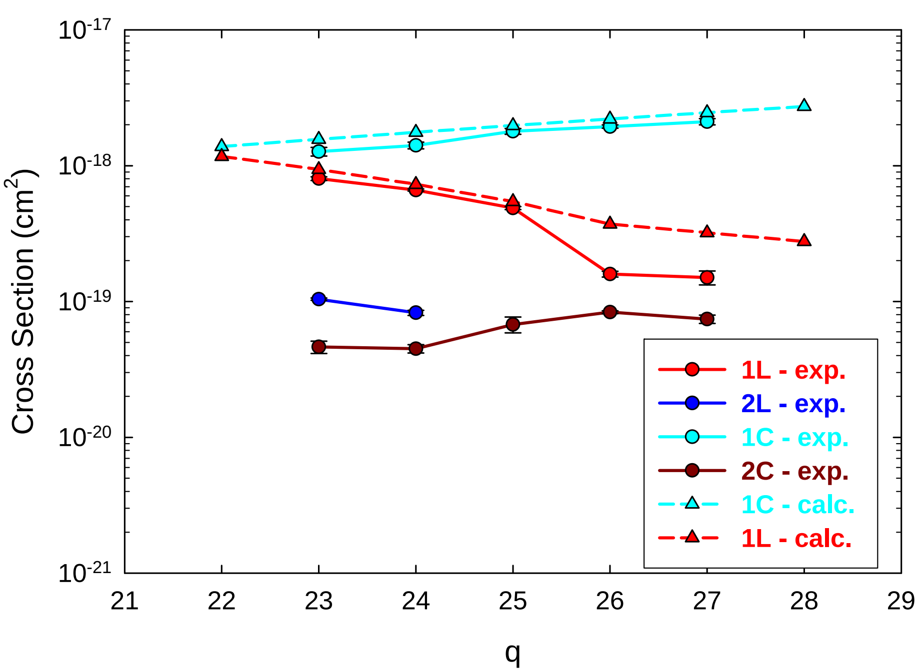

FIG. 1. Cross sections for electron capture and loss by 2.5 MeV/amu Kr^{q+} ions traveling in helium.

Beams of 2.5 MeV/u Kr^{8+}, 7.5 MeV/u Kr^{13+}, and 15 MeV/u Kr^{17+} passed through a 5 μg/cm² carbon foil located in front of a (horizontal) bending magnet, which was used to select individual projectile charge states. Each beam was then collimated to a diameter of 1 mm and directed through a windowless, differentially pumped gas cell having an effective path length of 2.08 cm. After emerging from the gas cell, the beams passed through a second (vertical) bending magnet into a 10 x 1.5 cm one-dimensional position-sensitive microchannel plate detector. The pressure of the He target gas was monitored by a Baratron pressure transducer and the gas flow was regulated by means of an automated control valve and flow controller. Additional details of the experimental setup are described in Ref. [7]. Charge distributions were measured for each selected incident charge state at five pressures ranging from 0 to 394 mTorr. The variation of the charge fractions versus pressure were found to be linear over this pressure range. Consequently, the cross sections for electron capture or loss in single collisions were obtained from the slopes of straight lines fitted to the data.

The experimental results are shown in Figs. 1-3. Also shown in these figures are the single-electron capture and loss cross sections (dashed curves) obtained using the calculation procedure. Overall, the calculated single-electron cross sections agree reasonably well with the experimental cross sections.

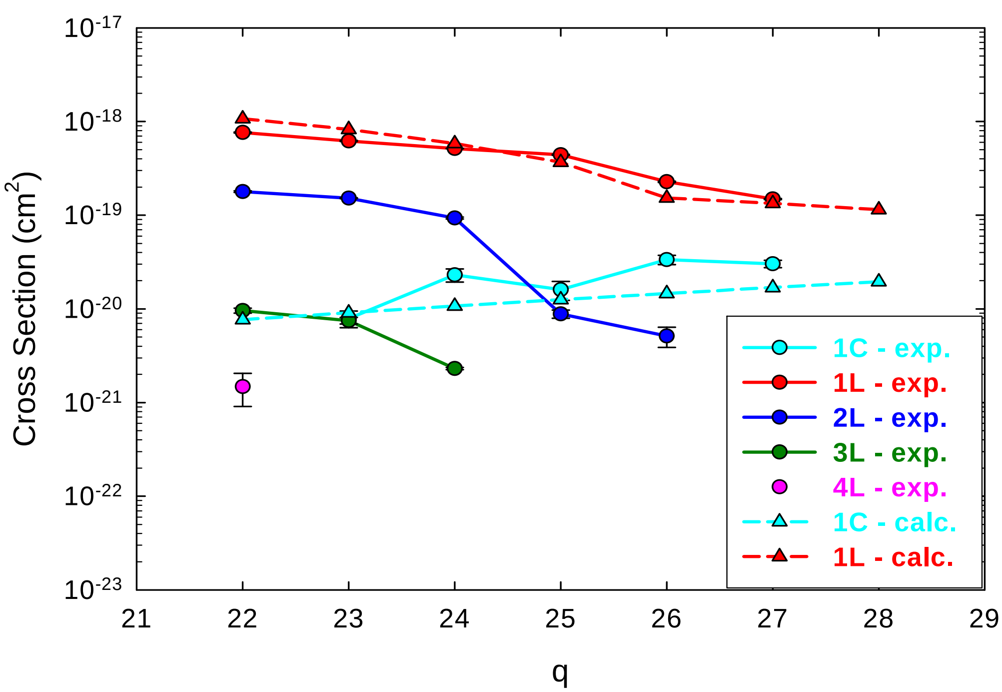

FIG. 2. Cross sections for electron capture and loss by 7.5 MeV/amu Kr^{q+} ions traveling in helium.

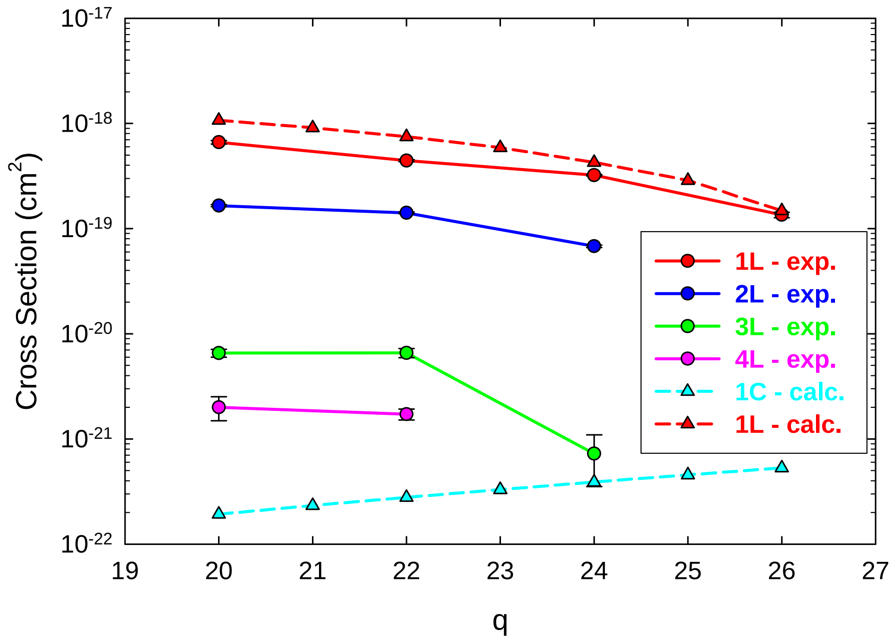

FIG. 3. Cross sections for electron capture and loss by 15 MeV/amu Kr^{q+} ions traveling in helium.

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