Cross sections for charge change of 4 MeV/u argon ions traveling in argon

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The ionization and electron transfer mechanisms that determine the charges of energetic ions passing through matter have been of continuing interest since the discovery of natural radioactivity. The close connection between the charge of an ion and the strength of its Coulomb interaction with atoms of the medium makes it one of the most important factors in determining the rate of energy loss or stopping power. Consequently, new information pertaining to the fundamental atomic collision processes responsible for the evolution of fast-projectile charge-state distributions is of potential interest to many areas of basic and applied research. We have measured the cross sections for single and multiple electron capture and loss for 4 MeV/u argon ions traveling in argon gas as a function of incident charge state. The measurements covered all incident charge states between 5+ and 18+. The results of this case study will be used to test the predictions of various theoretical models and to determine the evolution of the projectile charge distribution and its parameters as a function of distance traveled through the target gas.

In the experiment, an electron cyclotron resonance ion source was used to produce Ar^{5+} ions which then were injected into the Texas A&M K500 superconducting cyclotron, accelerated to an energy of 4 MeV/u, and directed to an analyzing magnet located upstream from the target chamber. Before entering the magnet, the beam was allowed to pass through either a carbon stripper foil, an aluminum stripper foil, or a high residual gas pressure region in the vicinity of the magnet to produce a distribution of projectile charge states. Ions having the desired charge state (q_i) were then selected using the analyzing magnet and passed through a series of four collimators before entering a windowless, differentially pumped gas cell containing Ar gas. Projectiles that exited the gas cell passed through a collimator and then between the poles of a vertical charge dispersing magnet (producing a horizontal magnetic field) before stopping in a one-dimensional position-sensitive microchannel plate detector. Signals from the detector were used to determine the height of the projectile at impact, which in turn was used to identify the charge state (q_f) of the ion when it emerged from the gas cell. The pressure of Ar gas inside the cell was monitored by a Baratron pressure transducer and the gas flow was regulated using an automatic control valve and a flow controller. The charge state distribution of the ions emerging from the gas cell was measured at nominal target gas pressures (p) of 0, 2, 4, 8, 16, 32 and 64 mTorr for each of the fourteen incident projectile charge states. Some typical charge state spectra are shown in Fig. 1 (for q_i = 5, 13, 18 and p = 64 mTorr).

After the fractions of detected ions in each charge state were determined as a function of target gas pressure, the cross sections for charge change in a single collision were determined using the well-known growth rate method [1]. A representative set of growth curves (for q_i = 13) is shown in Fig. 2, while the preliminary results for selected cross sections are shown in Fig. 3 as a function of charge change ($\Delta q = q_f - q_i$).

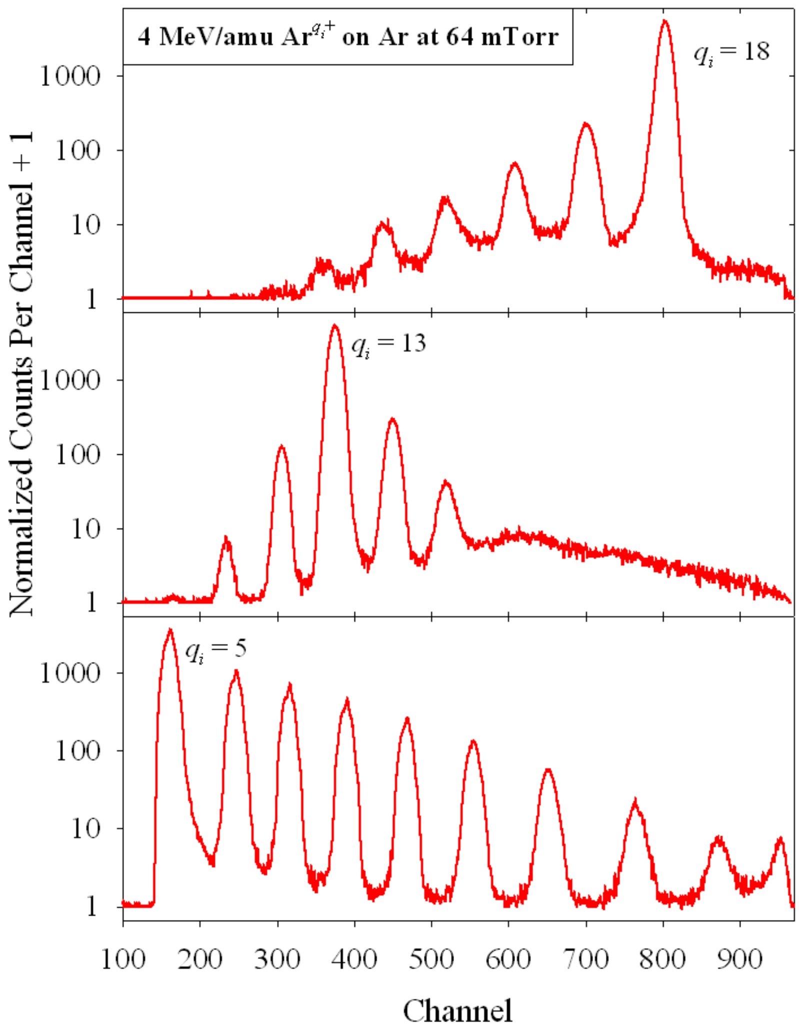

FIG. 1. Charge state spectra of 4 MeV/u Ar(q_i+) ions (q_i = 5, 13, 18) in Ar gas at the pressure of 64 mTorr.

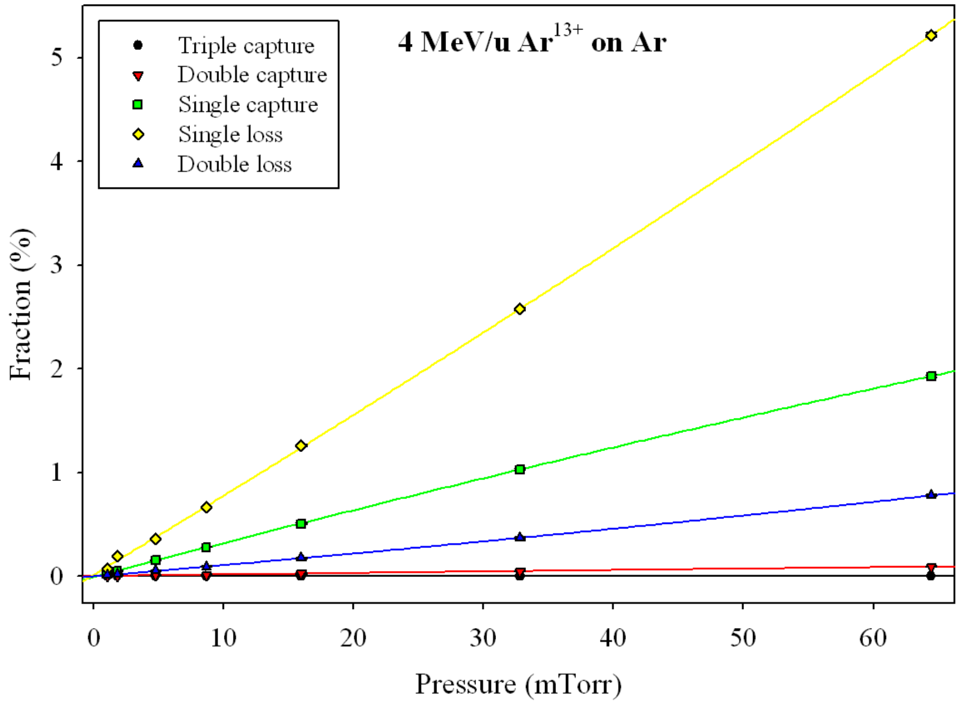

FIG. 3. Growth curves for 4 MeV/u Ar^{13+} ions in Ar gas.

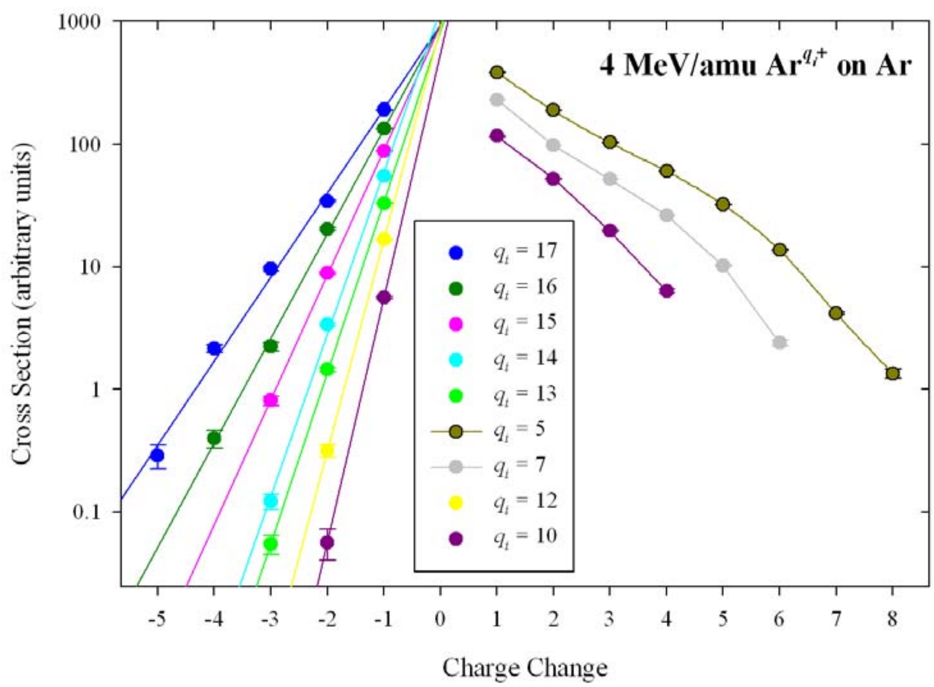

FIG. 2. Cross sections for charge change (in arbitrary units) of 4 MeV/u Ar ions in Ar gas.

[1] H. Tawara and A. Russek, Rev. Mod. Phys. **45**, 178 (1973).