Electron Loss from Low-Charge-State Ions Colliding with Gases

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Research plans for the future facility at GSI and the Heavy Ion Fusion program in the USA are based on accelerating intense beams of low-charge-state heavy ions to high energies. At high energies, projectile electron loss via interactions with background gases decreases the beam intensity and luminosity, plus energy and charge straggled components are generated and these components are lost, resulting in serious vacuum and radiation problems.

To address these questions, a collaborative effort to investigate electron loss from fast (MeV/u and above), low-charge-state, heavy ions was initiated. Our first experimental results were obtained during 2002. Absolute cross sections for total, single, and multiple electron loss were measured for 0.74 and 1.4 MeV/u Ar^{+}, Ar^{2+}, and Xe^{3+} impact on Ne, N_2 and Ar. These represent the first experimental information available in the MeV/u range for low charged heavy ions. In addition, 35-body Classical Trajectory Monte Carlo (n-CTMC) calculations were performed using techniques outlined in [1].

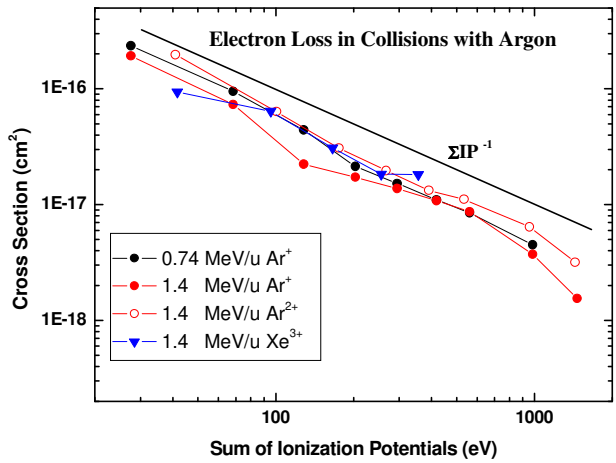

Fig. 1: Single and multiple electron loss cross sections for collisions with argon. The cross sections are plotted versus the sum of the ionization potentials (ΣIP) required to remove the outermost electron in a sequential fashion. The solid line illustrates a ΣIP^{-1} dependence.

The measurements were performed using the gas stripper and the analyzing magnet at the end of the UNILAC as a target and post-collision charge state analyzer. A position sensitive detector was inserted after the analyzing magnet to record the emerging charge state fractions as a function of target pressure. By measuring charge state fractions for He^{+} impact, the absolute target thickness was calibrated and the heavy ion data were placed on an absolute scale.

One important goal of this work was to investigate scaling behaviours in order to extrapolate to systems or parameters not easily measurable. As shown in Fig. 1, in the case of multiple electron removal and independent of impact energy, projectile charge or ion species, the multiple loss cross sections decrease roughly as ΣIP, where ΣIP is the sum of the ionization potentials for removing the outermost electrons in a sequential manner.

A second goal was to test the theoretical calculations and to investigate the energy dependence of the cross sections. As shown below (see Fig. 2), for argon and nitrogen targets there is extremely good agreement between experiment and theory, for neon the experimental results are smaller. More importantly, CTMC calculations predict that the total loss cross sections have an $E^{-1/3}$ energy dependence. This is in contrast to an $E^{-1/2}$ dependence found for Xe^{18+} ions [1]. For the limited energy range investigated, the experimental data are consistent with either dependence although the agreement with $E^{-1/3}$ is better.

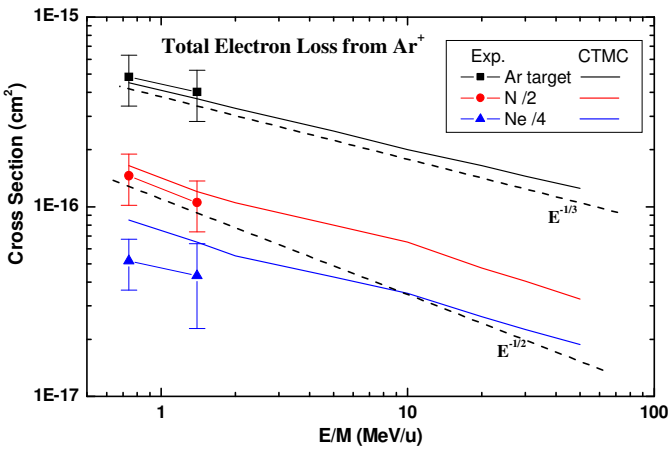

Fig. 2: Cross sections for electron loss from 1.4 MeV/u ions colliding with argon. The dotted curves serve only to guide the eye.

References

[1] R.E. Olson, R.L. Watson, V. Horvat and K.E. Zaharakis, *J. Phys. B* **35**, 1893 (2002).