A.3.5. Charge Transfer in Extremely Slow Collisions between Highly Charged Ions and Helium--*B.D. DePaola, C.W. Fehrenbach, K. Okuno,* M.P. Stöckli and H. Tawara***

Electron capture processes involving slow, multiply charged silicon ions are known to play a key role in determining the balance of ions and their abundance in some extraterrestrial plasmas as well as in material science applications. To date, very few experimental or theoretical studies of Si^{q+} collision systems have been reported. Indeed, in the few cases reported in the literature, there are significant discrepancies (two orders of magnitude) between the experimental and theoretical results at thermal energies. In an effort to begin to address this situation, we have measured the one- and two-electron capture cross sections for Si^{q+} (q = 3, 4 and 5) ions colliding with helium atoms from 100 eV to a few keV collision energy. We have then used our results to test recent quantum mechanical calculations.

The present experiment was performed using the recently developed octopole ion beam guide (OPIG) technique. The K-State OPIG is virtually a copy of the one developed [1] at Tokyo Metropolitan University and was brought to the Macdonald Lab through the TMU K-State collaboration. It is shown schematically in Fig. 1. The entire OPIG is floated at a decelerating potential, and the ion-atom collisions take place inside a differentially pumped cell in the interior of the OPIG. The octopole electric field, which extends over 15 cm along the primary ion beam direction, is driven at 15 MHz and has maximum peak-to-peak amplitudes of approximately 300 V/cm. This field serves to confine the decelerated primary ions as well as the product ions. Two focusing systems in front of and after the OPIG have been used in order to get maximum transmission of the primary ions and product ions through the OPIG and onto a 2-dimensional position-sensitive detector (2D-PSD) system. As shown in Fig. 1, the 2D-PSD, consisting of an electrostatic retardation system of four meshed electrodes followed by channel plates and fluorescent screen, separates the primary ions from the product ions.

The ratios of yields of ions having charge q, q-1, and q-2, together with the measured target thickness, gives cross sections for single and double electron capture. One- and two-electron capture cross sections for Si^{3+} + He collisions as a function of collision energy are shown in Fig. 2, together with a fully quantum mechanical calculation for single capture.

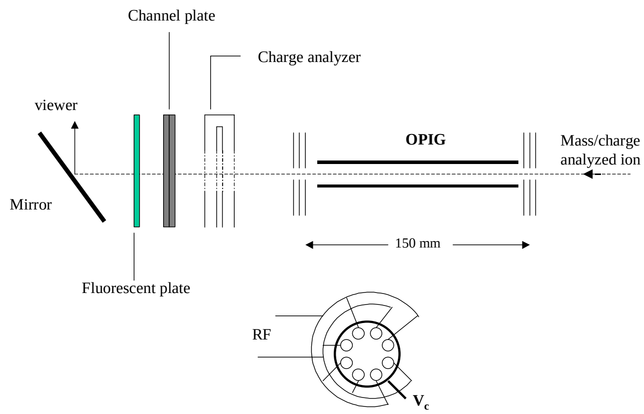

Figure 1. Schematic of OPIG apparatus, showing the OPIG (right and below) and the position-sensitive detector with retarding grids.

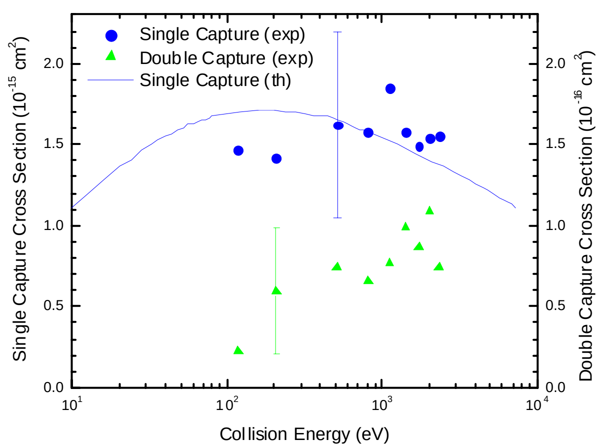

Figure 2. Single and double capture cross sections *versus* collision energy for slow Si^{3+} + He collisions. The circles are single capture data, the triangles double capture data, and the solid line is theory. The error bars shown are typical for all the data and represent uncertainty in the total absolute cross section.

These experimental results are in fair agreement with the recent quantum mechanical calculations [2,3]. The measured cross sections for double-electron capture are roughly one order of magnitude smaller than those for the single-electron capture and tend to increase as the collision energy increases. Unfortunately there are no calculations with which to compare these measurements. The sample error bars are total and are primarily due to short-term beam instabilities and uncertainties in target thickness. Similar results for Si^{4+} and Si^{5+} + He collisions have also been obtained. While the general measurement technique used here will certainly prove useful in future low energy, high charge state collision measurements, it does suffer from some limitations, both in energy resolution and energy lower limit. These limitations will be addressed in the accompanying proposal. This work is part of the Ph.D. project of Chris Verzani.

References

*Department of Physics, Tokyo Metropolitan University, Tokyo, Japan.

**On leave from the National Institute for Fusion Science, Nagoya, Japan.

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