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COLLISIONS OF LOW-ENERGY MULTICHARGED IONS*

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Experimental measurements of cross sections for collisions of multiply charged ions with atoms are being carried out at the lowest attainable collision energies. Emphasis is currently on electron capture from atomic hydrogen by multiply charged ions at energies below 1 keV/amu, where the process is difficult to characterize theoretically, and models are being developed. Such collisions are important in magnetic fusion plasmas, astrophysics, ion sources, or any recombining plasma. The principal effort is the development of a merged ion-atom beams apparatus for studies down to 1 eV/amu relative energy. In addition, measurements with low energy ions in static gas targets have recently been made for electron capture in C^{+q} + H collisions in the 10-400 eV/amu energy range and will be extended to O^{+q} and Fe^{+q} ions.

In the ion-beam, gas-target experiments being carried out, an expanding pulsed-laser-produced plasma provides a source of very low energy, highly stripped carbon ions.[1] A schematic of the apparatus is shown in Fig. 1. The analyzer selects ions from the expanding plasma which have a fixed energy per charge, and the various charges present in the pulsed beam are then resolved by time-of-flight. Total electron capture cross sections have been measured for C^{+q} + H and C^{+q} + H_2 collisions (q = 3,4,5,6) in the energy range 11-400 eV/amu.[2] Figure 2 shows a comparison of experimental[3-5] and theoretical[6,7] results for C^{3+} + H and C^{4+} + H collisions.

In general, the experimental cross sections for electron capture from atomic hydrogen by very low velocity, highly stripped carbon ions exhibit neither simple scalings with ionic charge nor uniform velocity dependences, but are consistent with detailed perturbed-stationary-state calculations using accurate potential energy curves.

In the merged-beams approach, a beam of ground state hydrogen atoms will be prepared by laser photodetachment of H^- and merged in a parallel-plate electrostatic analyzer with a multiply charged ion beam from the ORNL-PIG source. After a common interaction path of 50 cm, the ions will be magnetically separated from the neutrals.

A combination of beam modulation and coincidence detection will facilitate separation of beam-beam signal events from those of either beam with residual gas. Ultra high vacuum ($P < 1 \times 10^{-9}$) will be maintained in both the beam interaction and analysis chambers. The spatial overlap of the beams in two dimensions will be measured by movable beam probes at three points along the merge path. The technique is expected to allow measurements down to 1 eV/amu relative energy, where theoretical calculations remain untested. The first system to be studied is $N^{3+} + H$, where electron capture calculations predict a large cross section in the 1-7 eV range. In addition, N^{3+} is one of the most stable and abundant beams produced by the ORNL-PIG source and is a suitable choice for diagnostics on the apparatus.

The present activity has provided partial support for electron-ion crossed-beams experiments since 1975. All of the work was carried out with additional personnel and support from the Office of Fusion Energy (OFE), DOE. A recent brief review[8] summarizes some of the important results of these experiments. The crossed-beams experiments are presently pursued exclusively with OFE support which will allow concentration, within the present activity, on the demanding ion-atom merged-beams development.

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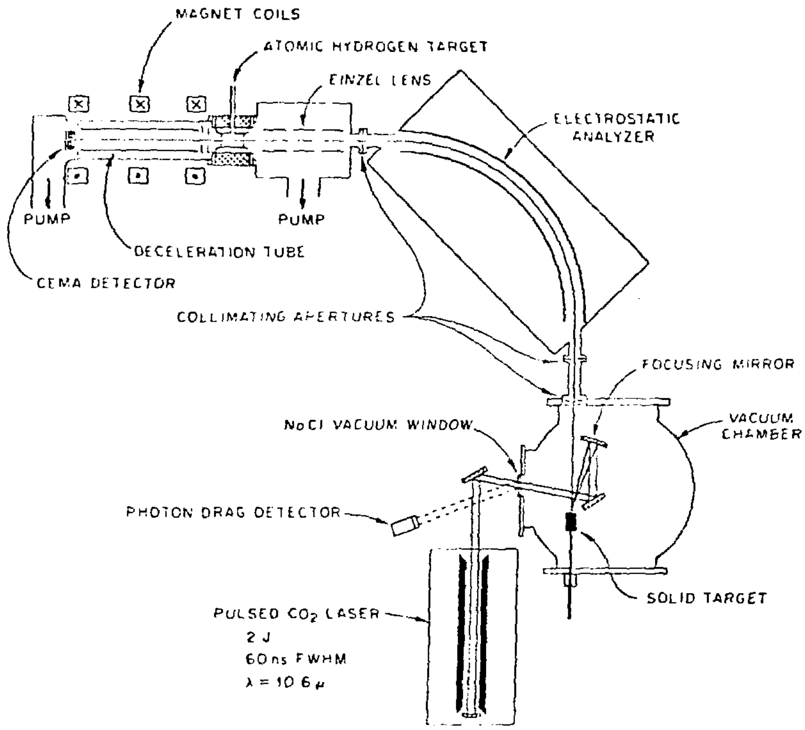

Figure 1. Pulsed-laser ion source and time-of-flight electron capture collision apparatus.

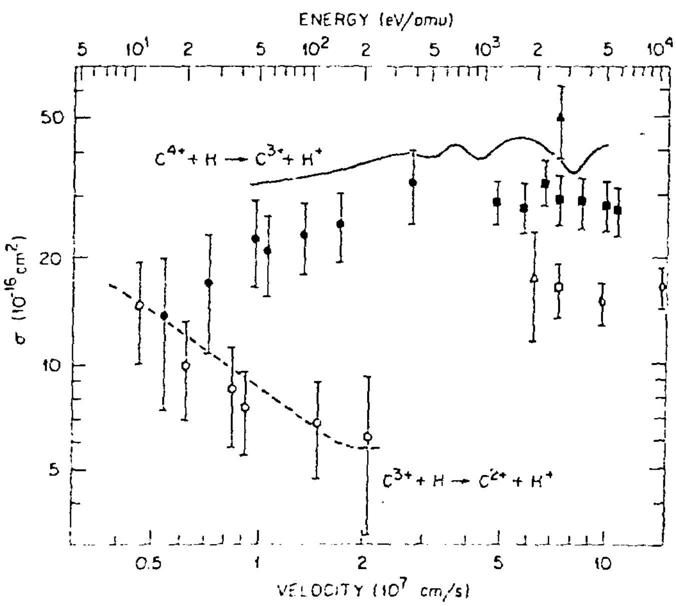

Figure 2. Electron capture cross sections for C^{4+} + H (solid points and solid curve) and C^{3+} + H (open points and dashed curve). Circles are present experimental results, and squares, diamonds, and triangles are measurements of Crandall et al. (Ref. 3), Phaneuf et al. (Ref. 4), and Gardner et al. (Ref. 5) respectively. Solid curve is 7PSS calculation of Olson et al. (Ref. 6), and dashed curve is 6PSS calculation of Bottcher and Heil (Ref. 7).