§2. Atomic Collision Processes Involving Excited Species

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Highly charged ions (HCI) in a plasma collide with the other species at the peripheral region in tokamak plasma. Since these atomic processes function as a cooling mechanism, it is very important to investigate the HCI collisions with other atoms, molecules, and ions. Although most of the neutral species are excited in the plasma, there are few work reported for the atomic processes involving excited species. These data are indispensable to the control and the measurement of plasma, and the accumulation of data are earnestly desired for atomic physics, too. From this point of view, we measure the absolute total electron transfer cross sections for the collisions of HCI with atoms and molecules involving excited species.

The HCI was produced by electron beam ion source (NICE) and led to the collision region after the charge selection. The ions changed the charge state during collisions with target particles were detected with the parallel plate electrostatic charge state analyzer or retarding type analyzer. The targets are on various atoms and molecules, for example rare gas atoms and simple molecules. When the target is an excited alkali metal atom, those were generated through a thermal oven, which were excited from the ground state to nP resonance state by the diode laser. The laser beam passes through the collision region on a common line to the HCI beam in the opposite direction. The apparatus used for excited alkali atoms is shown in fig.1. When the laser beams are on, the signals detected is from the targets in both excited and ground states. When the laser beams are off, the signals come from only ground state targets. Thus we can distinguish between the signals from excited targets and those from the ground state target. If the absolute cross sections for alkali metal atoms are known, the cross sections for excited atoms are determined by comparing with them.

The absolute total electron transfer cross sections were measured for the following processes,

$$I^{q+}\,(1.5q\text{keV}) + A \rightarrow I^{(q-j)+} + A^{j+}\ .$$

Where q is the initial charge of an incident ion (q=6-30), j is the number of transfer electrons, and A is the target particle. For rare gas atoms (Ne, Ar, Kr and Xe) and simple molecules (H_2, N_2, CO, CO_2 and CH_4), we had proposed the scaling law[1] as follows,

$$\sigma_{total}=2.6\times10^{3}q/IP^{2}\quad (\text{Å}^{2})\ .$$

Where σ_{total} is the total electron transfer cross section and IP is the first ionization energy (eV) of the target species. This scaling law is based on the extended classical over barrier model. This is able to reproduce well both our experimental data and the other ones within errors of 20%.

Based on our scaling, the cross section for alkali metal atoms will be large since the ionization energy is small compared with those of rare gas atoms. For alkali metal targets in ground and excited states (Cs(6s) and Cs*(6p)), the observed total electron transfer cross section increased up to $\sim10^{-13}$cm^2 as the initial ion charge increased, as expected. Although the experimental data scaled by q/IP^2 formed a line, the slope of the profile was different from that for rare gas atoms and simple molecules, as shown in fig.2. The experimental data for other alkali targets (Rb and Na) after scaling were plotted on the line formed by that of Cs within error bars. It is indicated that the total electron transfer cross sections for all species are not described by the same scaling law.

In order to investigate the electron transfer collision processes systematically, it is necessary that the total electron transfer cross sections for various species involving excited targets are measured, so that the generalized scaling law is constructed. The measurements of the total electron transfer cross sections for HCI - excited Rb and K collisions have been done at present.

References
1) M.Kimura et al., J.Phys.B **28**, L643(1995).

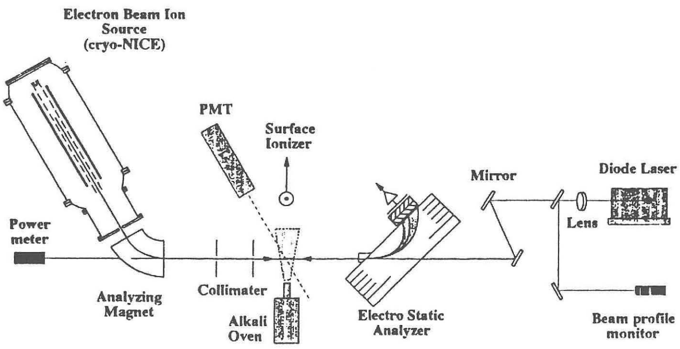

Fig.1. The experimental apparatus for excited alkali metal atom targets.

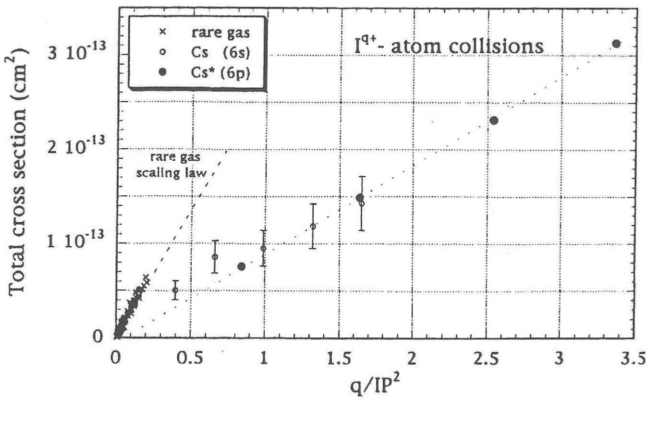

Fig.2. The total cross section for various targets involving excited ones scaled by q/IP^2