§ 13. Electron Transfer Processes for Collisions of Highly Charged Ions with Laser Excited Atoms

Sakai, Y., Miyauchi, N., Jin, W.G. (Dept. of Phys., Toho Univ.),
Sakaue, H.A., Yamada, I.

In a tokamak plasma, highly charged ions(HCI) collide with the other species at the peripheral region. These atomic processes play an important role in the cooling mechanism and interest in the field of not only fusion science but also fundamental atomic and molecular physics. In slow collisions of HCI with atoms and molecules, multi-electron transfer process is often an important channel, where electrons are transferred into multiply excited levels of the HCI. From this point of view, the absolute total electron transfer cross-sections for the processes,

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

had been measured by the NICE group. 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,

$$\sigma_{total} = 2.6 \times 10^3 q/IP^2 \quad (A^2),$$

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%.

In the present paper, we report the new modified experimental apparatus for the collision experiments for HCI with laser excited alkali atoms. 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.

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 crosses the target atomic beam and the HCI beam at right angles, so that the collisions of HCI with the excited atoms occur. 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.

Figure 2(a) shows the fluorescence Spectrum from excited Rb atoms, and (b) shows the laser power dependence, respectively. Every peak is saturated by the laser power about 5mW in the present condition.

The absolute total electron transfer cross section for neutral alkali atoms, Cs and Rb, had already measured by us.[2] Although these are also scaled by q/IP^2, the scale factor that is a slop of scaling line is much different from it of the rare gas target. 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.

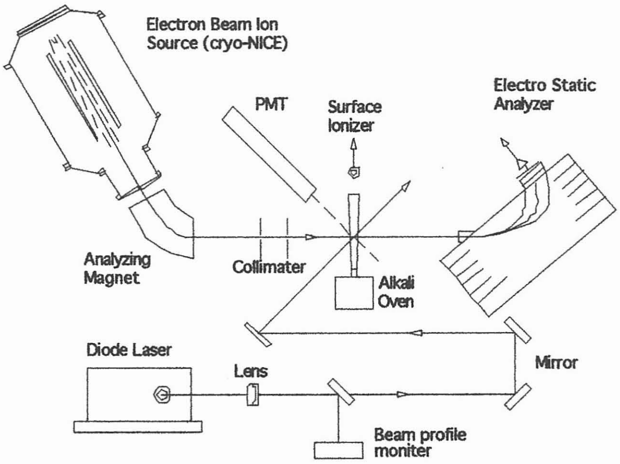

Fig.1. Schematic diagram of the experimental apparatus for excited alkali metal atom targets.

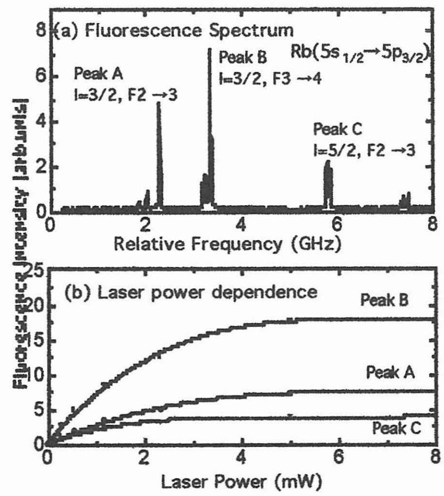

Fig.2. Fluorescence intensity from Rb($5s_{1/2} \rightarrow 5p_{3/2}$)

References

1) M.Kimura et al., J.Phys.B **28**, L643(1995).
2) H.A.Sakaue et al., Abstracts of 21th ICPEAC **2**, 552(1999).