§12. Highly Charged Ion – Excited Atom Collision Processes

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The charge transfer collisions of highly charged ion (HCI) with excited atom are very important atomic processes for understanding the edge plasma behavior in thermonuclear plasma. Because most of particles are excited to highly excited states in plasma. Also the charge transfer cross sections for the HCI - excited atom collisions are large in comparison with HCI-ground state atom collisions. However, there are few atomic data of excited atoms because of difficulty in experiments.

We had already measured the absolute total electron transfer cross sections in HCI-atom and HCI-molecule collisions as follows,

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

where q is the initial charge of the incident ion (q=6~30), j is the number of transfer electrons, and A is the target particle, rare gas atoms (Ne, Ar, Kr and Xe) and simple molecules (H_2, N_2, CO, CO_2 and CH_4). As a result of analysis, we had proposed the following scaling law [1] that is based on the extended classical over barrier model,

$$\sigma_{total}=2.6\times 10^3 q/P^2 \quad (\text{Å}^2),$$

where σ_{total} is the total electron capture cross section, and P is the first ionization energy (eV) of target particles. This scaling law is able to reproduce well both our experimental data and the other ones within errors of 20%.

On the other hands, we have also measured those cross sections in HCI-alkali metal atom collisions. In these cases, since the ionization energy of alkali metal atoms is small, it is expected that the total electron transfer cross section will be large. Although the cross section data measured for Cs, Rb and Na targets were also scaled by q/P^2, the slope of the profile for alkali metal atom targets was different from that of rare gas and molecule targets.

In order to study the electron transfer collision processes systematically, it is necessary to change the first ionization energy of target. By using the excited targets of alkali metal atoms, it is attained.

The experimental set up is shown in fig.1. The highly charged ions were produced by electron beam ion source (NICE). The alkali metal atom targets, which were generated through a thermal oven, were excited from the ground state to nP resonance state with the diode laser. The laser beam pass through the collision region on a common line to the ion beam in the opposite direction. The ions changed the charge state during collision are detected with the parallel plate electrostatic charge state analyzer. We can distinguish between the signals from the excited targets and ones from the ground state target by using the technique which the laser power is turned on and off. Since the absolute total electron transfer cross sections for alkali metal atom targets have already been measured, the cross sections for excited atoms are able to be determined by comparing with that of ground state.

Figure 2 shows the radiation spectrum ($5P_{3/2}\rightarrow 5S_{1/2}$) from Rb excited with the diode laser. There are many peaks on that spectrum for its hyperfine structure. We will choose the transition $5S_{1/2}\rightarrow 5P_{3/2}(I_{5/2},\ F\ 3\rightarrow 4)$ for our experiment, because the radiation from that excited state is the most powerful of all. We have already ascertained that the excited atom targets have been generated enough to do the experiment, by means of observing the saturated photon signal from excited atom. The collision experiments between the highly charged ions and excited atoms have started at present.

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

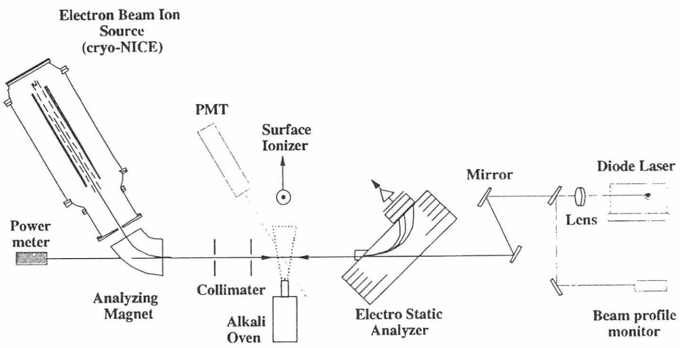

Fig.1. The experimental apparatus for excited atom targets.

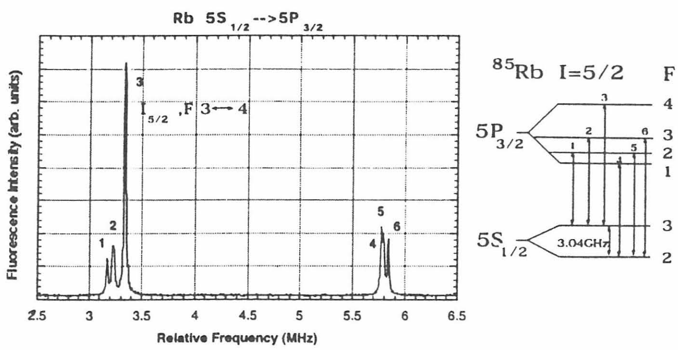

Fig.2. The radiation spectrum from excited Rb targets.