§9. The Charge Exchange Processes of Excited Atoms II

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The charge exchange processes for the collisions between highly charged ion(HCI) and neutral particle work as a cooling mechanism in plasma of the nuclear fusion reactor. For the quantitative analysis of the edge plasma behaviors, we have to measure the total absolute electron capture cross sections in HCI-atom and HCI-molecule collisions involving the excited species. Because most of the particles in plasma are expected to be in excited states. On the other hand, since the charge exchange processes are used for the plasma diagnosis in thermonuclear plasma as the charge exchange spectroscopy (CXS), these cross section data are very important to discuss the possibility of the resonant charge exchange spectroscopy(RCXS) that is proposed substitution for the CXS. However, there are few works reported about those data involving excited species. From these points of view, we decided to measure the total absolute electron capture cross sections in HCI-excited alkali atom collisions.

We had already measured the total absolute electron capture cross sections in the collisions, $I^{q+}(1.5qkeV) + A \rightarrow I^{(q-j)+} + A^{j+}$, where I^{q+} is the q-fold charged ion (q=6~30), A is the target particle, and j is the number of transferred electrons. As a result, we had proposed the following scaling law[1] for rare gas atoms (Ne,Ar,Kr and Xe) and simple molecules (H_2,N_2,CO,CO_2 and CH_4).

$$\sigma_{\mathrm{total}} = 2.6 \times 10^3 q/IP^2\ (\text{Å}^2) \quad , \tag{1}$$

where σ_{total} is the total electron capture cross section, and IP is the first ionization energy (eV) of target particles. Almost all the experimental data are reproduced well by this scaling law within errors of 20%.

Recently, it is found that the coefficient of eq.(1) for alkali atoms, rubidium(Rb) and cesium(Cs), is different from that of rare gas ones[2]. We have also interest in this fact. The difference of the scaling factor may be due to the electron configuration of the target. Alkali atoms dose not have a closed shell but has one left electron in outer s-orbital, and its first ionization energy is much lower than rare gas atoms. In the experiments of excited alkali targets, the first ionization energy of the target becomes further low.

In this work, we aimed to accomplish the collision experiment between the highly charged ions(HCIs) and laser excited Rb atoms. The experimental setup is schematically shown in Fig.1. The HCI was produced by the electron beam ion source(NICE) and led to the collision region after the charge selection. A beam of Rb atoms was generated through a thermal oven and excited from the ground state to np resonance state with a tunable diode laser. The light from laser at 780nm was delivered to the collision chamber, and drived the 5s $\rightarrow$ 5p transition. The photomultiplier tube(PMT) with a band-pass filter was used to ascertain the ratio of excited Rb atoms. When the Rb atoms existed in 5p resonance state were quickly relaxed to the ground state, the fluorescence was observed with the PMT at the same as incident light wavelength. Since the fluorescence signal was saturated, it was found that the 50% Rb atoms were excited in the Rb beam. It has been confirmed that the quantity of excited Rb targets was good enough for the present experiment. The power and wavelength of laser were measured after passing through the Rb beam with the laser power meter and wave meter, respectively, which are not appeared in fig.1. Besides, the laser stabilized system have been built to keep the punctual wavelength for resonance. Both the I^{q+} ions and $I^{(q-j)+}$ ions changed the charge were led toward the four meshed electrodes situated at the front of microchannel plate(MCP) after interacting between HCI beam I^{q+} and Rb beam in the collision chamber. The retarded voltage V_r was applied to the second and third meshes which were connected together. The ions, retarded between the first and second meshes yet passed through the third mesh, were accelerated to the fourth mesh, and the ions were finally detected with MCP.

The HCIs collided with both excited and no-excited Rb atoms when the laser system was operated, while they collided with only no-excited Rb ones when the light from laser was not delivered. Since the absolute electron capture cross sections in I^{q+}-no-excited Rb collision had been already measured, we can determine the cross sections for excited Rb by comparing two results in the different conditions that laser is operated or not.

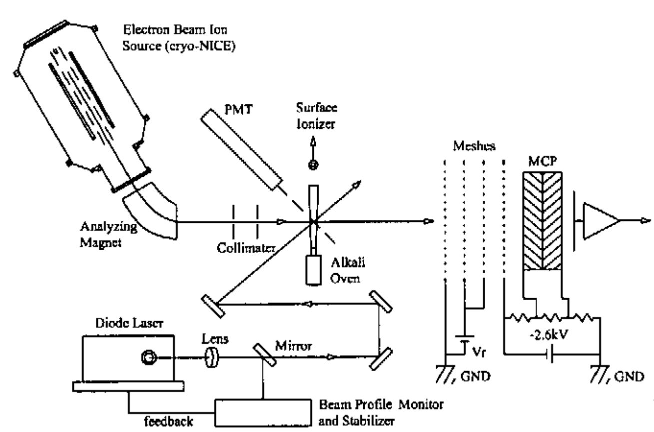

Figure 1: The experimental apparatus for excited alkali metal atom targets.

Although any electron capture signals have not been detected yet, the experiment setup have been constructed. From now on, we are planning to advance the measurements of the total electron capture cross sections for HCI-excited K and Cs atom. The above scaling law would be generalized more by these data. And we hope of obtaining more profound knowledge of the charge exchange processes.

References
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