§7. A Study of Charge Exchange Processes by Collision with Excited Atoms

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

In collision between highly charged ions(HCIs) and neutral species, charge exchange processes are the dominant ones. In the charge exchange spectroscopy(CXS), using these processes the plasma diagnosis is carried out for thermonuclear plasma. When HCIs collide with excited neutral species, a large growth in charge exchange cross section is possible under the classical overbarrier model as a resonance. The present study is a elementary experiment to discuss the probability of the resonant charge exchange spectroscopy(RCXS) that is proposed substitution for the CXS. On the other hand, since the charge exchange processes work as a cooling mechanism in plasma of the nuclear fusion reactor and most of the particles in plasma are expected to be in excited states, this study is fundamental one for the quantitative analysis of the edge plasma behaviors. In this study, we used alkali atom as the target, because it is easy to produce excited species. The goal for this study is the measurement of the total absolute electron capture cross sections for HCI-excited atom collisions.

We had already reported about the total absolute electron capture cross sections in the HCI collisions with rare gas atom targets (Ne, Ar, Kr and Xe) and simple molecular targets(H_2, N_2, CO, CO_2 and CH_4), and a scaling law had been proposed, which is described by the ratio of the charge to the squared first ionization energy of target[1]. In the previous work, it is found that the coefficient of that scaling law as a scaling factor for alkali atom targets, Na, Rb and Cs, is different from that of rare gas ones[2]. In this work, we tried to do the experiment on HCI collision with the excited Rb target.
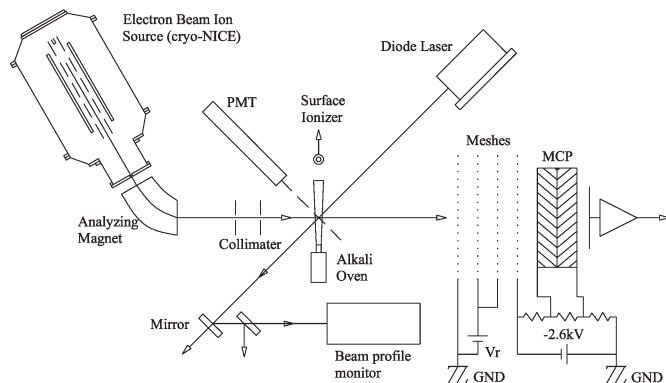

Figure 1: The experimental apparatus for excited alkali metal atom targets.

Figure1 shows the simplified schematic of experimental setup. The HCI was produced by the electron beam ion source(NICE) and led to the collision region after the charge

selection. In this work, I^{q+} ions were used as the HCI, where I^{q+} is the q-fold charged iodine ion(q=6∼30).

The Rb atom beam was generated through a thermal oven and excited from the ground state to np resonance state with a diode laser. The light from laser at center wavelength 780 nm was delivered to the collision chamber, and operated on the $5s \to 5p$ transition. The photomultiplier tube(PMT) with a band-pass filter was used to ascertain the ratio of excited Rb atoms to no-excited ons. When the fluorescence signal observed from $5p$ resonance state was saturated, it is indicated that the 50% Rb atoms were excited in the Rb beam. The power and wavelength of laser were measured after passing through the Rb beam. We modulated the laser wavelength by using an externally generated analog signal to modulate the voltage of the piezoelectric actuator.

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, as follows.

$$\sigma_{ex} = \sigma_n \times (2I_{ex} - I_n)/I_n. \quad (1)$$

Where σ_{ex} and σ_n mean the total electron capture cross sections, and I_{ex} and I_n are the signal intensities, the subscript ex is for the excited target and n for the no-excited one, respectively.

In order to determine the correct cross sections for excited Rb, we have to keep the Rb beam intensity, laser power and wavelength. The Rb beam intensity was monitored by a surface ionizer. We can change the target density from the current and temperature of the atomic oven. The current is about 20 nA on average at that beam monitor under the condition of the temperature at 50°C in the Rb oven. Besides, it was confirm that the fluorescence signal was saturated and the stray light of laser is less than 1% for any laser power conditions. Thus the quantity of excited Rb target was good enough for this experiment. Although any electron capture signals have not been detected yet, the experimental setup have been constructed.

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