§30. Excited Atomic Processes as Fundamental Researches for New Plasma Diagnostic

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Charge exchange spectroscopy (CXS) is a principal diagnostics tool on plasmas using neutral heating beams as diagnostic probes. In particular, hydrogen beams are used as a probe. CXS relies heavily on the accuracy with which the cross sections of the underlying charge-transfer processes are known. For example, charge transfer from atomic hydrogen onto a fully-stripped plasma ion, C^{6+} is given by

$$C^{6+} + H(1s) \rightarrow C^{5+}(n) + H^{+}$$

with n the principal quantum number of the level into which the electron is captured. For this process, the dominantly populated n shell is n=4 while the CXS relevant n shell is n=8. In CXS, the emission line of Δn = 8-7 and λ = 5290Å are often used. If the excited $H(2s)$ beam is used, the dominantly populated n shell is n=8. Then it is expected that the corresponding cross section increases by a factor of 1000. This is the principle of the resonant charge exchange spectroscopy (RCXS) as one of the new plasma diagnostic.

In general, when highly charged ions (HCIs) collide with atoms in plasma, HCIs dominantly strip off the electron from the atom. Since this reaction is a cooling mechanism in the fusion reactor, a lot of the experiments concerning the collision of HCI and ground state atoms had been conducted. But atoms are usually excited in the fusion reactor.

We have started the study of the excited atomic processes considering these situations. As a first step, we selected rubidium(Rb) for a target atom. Figure 1 shows the experimental set-up for HCIs- excited Rb collisions. HCIs are made from Naked Ion Collision Experiment(NICE) that is electron beam ion source (EBIS). Using the laser light 780nm, we make Rb excite from 5s to 5p. It is confirmed by observing the fluorescence by photomultiplier tube (PMT). The density of the Rb is measured by the surface ionizer.

We can determine the total charge exchange cross sections σ_{ex} for I^{q+} - excited Rb collision by comparing our previous results[1),2)] for grand state target as follows,

$$\sigma_{ex} = \sigma_n \frac{\alpha I_{on} - I_{off}}{I_{off}} \beta .$$

Where I_{on} and I_{off} are intensity ratios of the signals at laser on and off to the total ion signals, respectively. Both α and β are coefficients that relate to the rate of excited targets. The rate of excited ^{85}Rb target was estimated about 18 % by according to statistical weight. Figure 2 shows an experimental result of the ratios of I^{29+}/I^{30+} for I^{30+} - Rb and excited Rb collisions. In this experiment, we succeeded in observing the signal from excited Rb target. The total charge exchange cross sections obtained for the atomic process of I^{30+} - Rb(5p) have increased by a factor of 1.7 compared with for the grand state target. However the expected value from the scaling low[3)] was sure to increase to 2.6 times that of the cross section for the grand state target. It is not predicable what this difference between the experiments and calculations means at the present stage.

The research for the excited atomic processes of charge exchange reactions is still done now. In order to explain these processes, we will measure the charge exchange cross sections for not only for excited Rb target but also other alkali metals and alkaline earth metals.

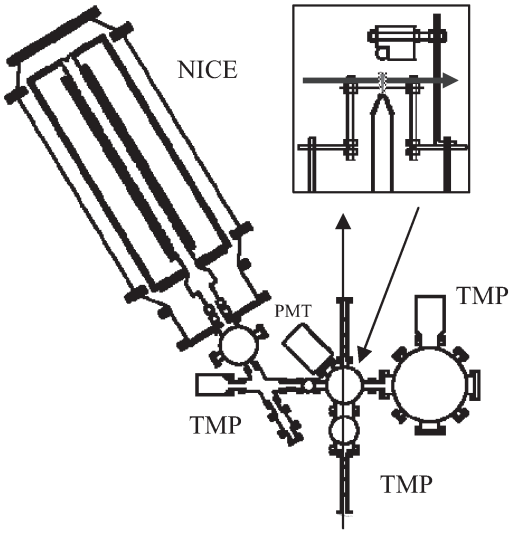

Fig.1 Experimental set-up for HCIs – excited Rb collidions.

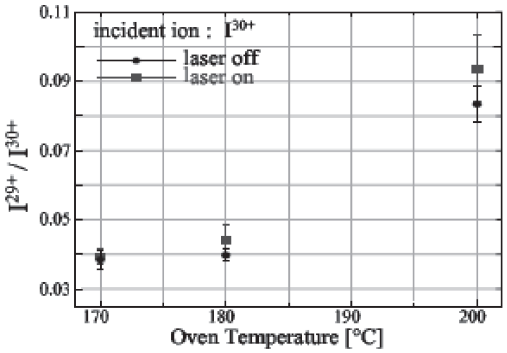

Fig.2 Ratios of I^{29+}/I^{30+} for $I^{30+} - Rb$ collisions.

1) H.A.Sakaue et al., J. Plasma Fusion Research **7**, 195(2006).
2) H.A.Sakaue et.al., Abstracts of Contributed Papers of 21st. ICPEAC **2**, 552 (1999).
3) M.Kimura et al., J.Phys.B., **28**, L643(1995).