§8. Measurements of Charge Exchange Cross Sections for Highly Charged Tungsten Ions with Hydrogen Atoms

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Absolute cross sections of the charge exchange process allow us useful information for controlling and measuring the plasma. The absolute cross sections for tungsten highly charged ions of W^{q+} are particularly important for edge plasma in the ITER as a basic data. However, there are few absolute measurements of charge exchange cross sections for W^{q+}. In our project, the absolute cross sections for charge exchange processes are measured in collisions of tungsten highly charged ions with hydrogen and deuterium atoms at collision energies between 0.1eV to 10 keV. In the present report, we show preliminary data of absolute charge exchange cross sections for W^{8+} with helium at collision energies between 20 to 150 eV/u. And a charge state dependence of the cross sections for W^{q+} (q=5,8,16,18) with helium at collision energies of 10.9×q eV/u.

The experimental apparatus and measuring procedure have been previously described in detail [1]. The main features are only summarized here. The apparatus was composed of a tandem mass spectrometer and compact EBIS type highly charged ion source named mini-EBIS. An ion beam guide named OPIG within a collision cell is a key technique for low energy collision experiments. Supplying a high frequency electronic field to OPIG enable us to measure the cross section down to 0.1 eV/u collision energy. Projectile tungsten ions were produced in mini-EBIS using $W(CO)_6$. Stable producing of W^{q+} (q=5～20) is succeeded under sever temperature control on a sample gas handling system with the mini-EBIS. Projectile ions were injected to the collision cell with OPIG. In the collision cell, the charge exchanged ions of $W^{(q-1)+}$ and $W^{(q-2)+}$ were produced as followed reactions;

$W^{q+} + He \rightarrow W^{(q-1)+} + He^{+}$ single charge exchange $\sigma_{q,q-1}$,
$\rightarrow W^{(q-2)+} + He^{2+}$ double charge exchange $\sigma_{q,q-2}$.

Projectile and product ions were extracted from the collision cell and mass selected then detected with a channeltron multiplier. The absolute cross sections were estimated using initial growth rate method. Collision energy was determined from a voltage difference between ion source and center of collision cell.

The results of collision energy dependences of the absolute charge exchange cross sections for W^{8+} with helium are shown in Figure 1. The overall uncertainty in the measured cross sections was estimated to be approximately ±20%. Closed circles and squares represent $\sigma_{q,q-1}$ and $\sigma_{q,q-2}$,respectively. In the energy range measured, both the charge exchange cross sections are almost independent of the collision energy. Solid line with closed triangle in Figure 1 presents a calculated result using semi-classical approximation with hidden curve crossing method by Inga et al.[2]. The calculated result is well reproduced our cross sections in the energy range measured. Below the lowest energy measured of 20 eV/u, the cross sections become drastically decreasing in the calculation. The energy dependence of the calculated cross sections is responsible for getting week rotational coupling. Then, we should measure the cross sections below 20eV/u to confirm whether the calculated energy dependence is true or not since the confirmation lead to the existence of an isotope effect. The results of charge state dependences of the absolute charge exchange cross sections for W^{q+} (q=5,8,16,18) with helium are shown in Figure 2. Though a less steep increasing of the $\sigma_{q,q-1}$ is consistent with the well-known nature of highly charged ions, the almost flat charge state dependence of the$\sigma_{q,q-2}$ is off of a characteristic of highly charged ions. The experimental results were compared with calculated cross sections using scaling law proposed by Selberg et al.[3]. The solid lines in Figure 2 are the calculated results with the scaling law. The experimental and calculated charge state dependences do not correspond well. The scaling low was suggested using many experimental results including xenon ions with high Z element like as tungsten. Then, the good agreement between the experimental and calculated results was expected for tungsten ions. In the results, an existence of a unique property can be expected for tungsten highly charged ions. The absolute measurements for charge exchange processes of highly charged tungsten ions will be continued to investigate the unique property.

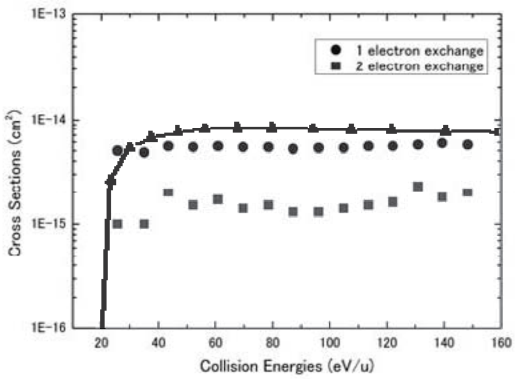

Fig. 1. Collision energy dependence of the cross sections.

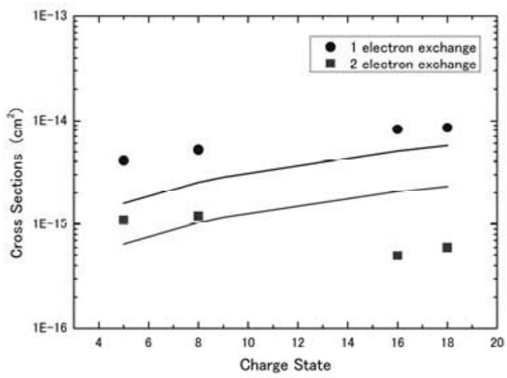

Fig. 2. Charge state dependence of the cross sections.

[1] Okuno, K. et al., Nucl. Instrum. Methods B **53** (1991) 387.
[2] Inga Yu Tolstikhina , private communication.
[3] Selberg, N. et al., Phys. Rev. A, **54**, (1996) 4127.