§4. 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 atomic data. However, there are few absolute measurements of charge exchange cross sections for W^{q+}. The final goal of our project is measuring the absolute cross sections for charge exchange processes in collisions of tungsten highly charged ions with hydrogen and deuterium atoms at collision energies between 0.1eV to 10 keV. The plan fails to go as our expected since W^{q+} ion beam forms only with great difficulty. For highly charged ions, it is well known that the nature depend on rather the charge state than nuclide. We have measured the charge exchange cross sections for xenon multiply charged ions of Xe^{q+} as a high Z element with easier creation of the ion beam. Then, we confirm whether the cross sections of Xe^{q+} can be alternative cross sections of W^{q+} or not. In the present report, we show the absolute charge exchange cross sections in collisions between Xe^{q+} (q=7,9) with helium in collision energies below 200eV/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 xenon ions were produced in mini-EBIS using research grade xenon gas. Projectile ions were injected to the collision cell with OPIG. In the collision cell, the charge exchanged ions of $Xe^{(q-1)+}$ and $Xe^{(q-2)+}$ were produced as followed reactions;

$Xe^{q+} + He \rightarrow Xe^{(q-1)+} + He^{+}$ single charge exchange $\sigma_{q,q-1}$,
$\rightarrow Xe^{(q-2)+} + He^{2+}$ 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 Xe^{q+} (q=7,9) with helium are shown in Fig. 1 and 2, respectively. 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, the charge exchange cross sections both of Xe^{7+} and Xe^{9+} are almost independent of the collision energy except for lower energy end. The collision energy dependence for $Xe^{q+}$is almost similar to that for W^{q+} , but their absolute value is too much different. The absolute value of the single charge exchange cross sections of W^{8+} are about 5×10^{-15} cm^2. From Fig.1 and 2, it is obvious the absolute value of charge exchange cross sections for $Xe^{7+,9+}$ is one order of small that for W^{8+}. We conclude that the charge exchange cross sections of Xe^{q+} can not be alternative cross sections of W^{q+} in the collision energy measured. We also know that our experimental results of Xe^{q+} go off the estimated values of scaling low proposed by Selberg et al. [2]. The reason of the discrepancy probable come from difference of collision energy measured. Our collision energy is lower than 1keV, on the contrary, the collision energy of Selberg is higher than 100 keV. The absolute measurements for charge exchange processes of highly charged tungsten ions will be continued to investigate the unique property.

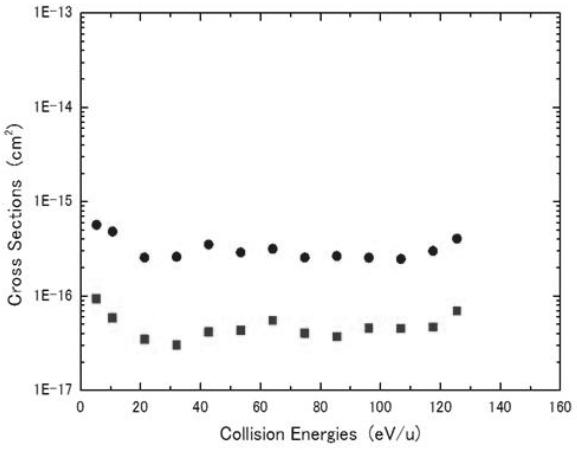

Fig.1 Charge exchange cross sections for Xe^{7+}-He

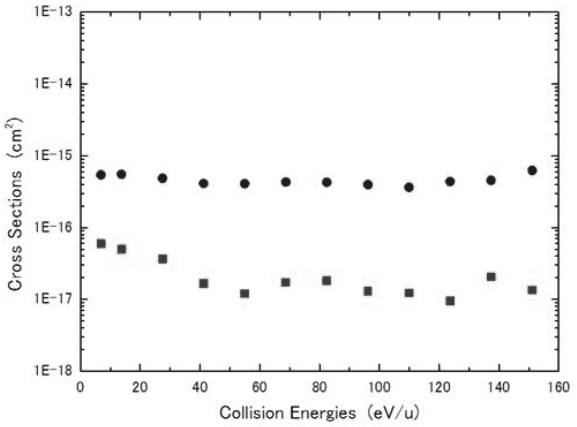

Fig.2 Charge exchange cross sections for Xe^{9+}-He

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