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

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Charge exchange processes of highly charged ions are a dominant process in fusion plasmas and process plasmas. Absolute cross sections of the charge exchange process are useful information for controlling and measuring the plasmas. Especially, the absolute cross sections for tungsten highly charged ions of W^{q+} are important for developing the ITER as a basic data. However, there are few absolute measurements of charge exchange cross sections for highly charged ions. In our project, the absolute cross sections for charge exchange processes are measured in collisions of tungsten highly charged ions with hydrogen and deuterium at collision energies between 0.1eV to 10 keV. In the present work, preliminary absolute measurements of charge exchange cross sections were done for W^{q+} (q=5 and 18) with helium at collision energies of q×2 keV.

The experimental apparatus and measuring procedure have been previously described in detail [1]. The main features are only summarized here. Figure 1 shows a schematic diagram of the apparatus used. The apparatus was composed of a tandem mass spectrometer with two electronic magnets of MS1, MS2 and compact EBIS type highly charged ion source named mini-EBIS. An ion beam guide named OPIG with 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 introducing system with the mini-EBIS. A part of a mass spectrum is presented in figure 2 in introducing $W(CO)_6$ about 5×10^{-7} Pa. Tungsten ions with charge q were extracted from mini-EBIS and mass selected with MS1. 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 and mass selected with MS2 and detected with a channeltron multiplier. The absolute cross sections were estimated using initial growth rate method. Gas pressures in the collision cell were measured with MKS baratron pressure gauge of type 690A. Collision energy was determined from a voltage difference between ion source and center of collision cell.

The results of preliminary absolute measurements are presented in table 1. The respective collision energies of W^{5+}, W^{18+} were 10 keV and 36 keV in a laboratory frame. The overall uncertainty in the measured cross sections was estimated to be approximately ±20%. The lack of double charge exchanging cross sections for W^{5+} was due to insufficient magnetic field strength of MS2. As shown in table 1, the single charge exchange cross sections of $\sigma_{q,q-1}$ are increased with increasing of the tungsten ion charge. This tendency is consistent with the well-known nature of highly charged ions. The experimental results were compared with calculated cross sections using scaling law proposed by Selberg et al.[2]. The numerical values in parentheses in table 1 were the calculated results with the scaling law. The experimental results of $\sigma_{q,q-1}$ was about 50% large for calculated results of $\sigma_{q,q-1}$. The scaling low was suggested using many experimental results including xenon ions with high Z like as tungsten. Then, the good agreement between the experimental and calculated results was expected for tungsten ions. In these preliminary 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.

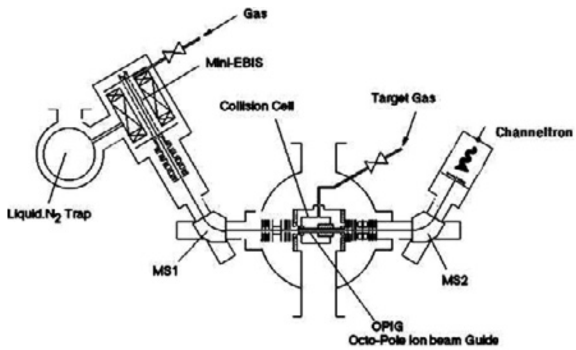

Fig. 1. Schematic diagram of the experimental set up.

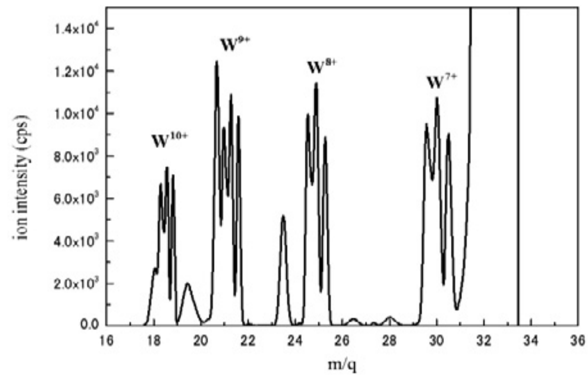

Fig. 2. Mass spectrum in introducing $W(CO)_6$.

	q=5	q=18
Single CE: $\sigma_{q,q-1}$	3.8×10^{-15} cm^2 (1.6×10^{-15})	8.0×10^{-15} cm^2 (5.7×10^{-18})
Double CE: $\sigma_{q,q-2}$		1.9×10^{-15} cm^2 (2.3×10^{-18})

Table 1. Experimental and calculated (within parentheses) absolute cross sections.

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