§30. Isotope Effect on Charge Exchange Processes of Multiply Charged Tungsten Ions

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Existence of an isotope effect on energy dependences of charge exchange cross sections in collisions of multiply charged tungsten ions with hydrogen and deuterium atoms is true or not? In a theoretical calculation, the existence of the isotope effect on the energy dependence of charge exchange cross sections has been confirmed [1]. So far there is no experimental data of the isotope effect for charge exchange processes. And absolute cross sections of the charge exchange process give us useful information about controlling and measuring plasmas. The absolute cross sections for tungsten multiply charged ions of W^{q+} are particularly important for edge plasma in the ITER as 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 multiply charged tungsten ions with hydrogen and deuterium atoms at collision energies between 0.1eV to 10 keV. And the existence of isotope effect should be confirmed with the energy dependence data. As a first step of our experimental plan, we try to measure a dissociation rate of hydrogen molecule with new approach of attenuation method, which is necessary value to estimate an absolute cross section.

The experimental apparatus and measuring procedure have been previously described in detail [2]. The main features are only summarized here. The apparatus presented schematically in the right figure 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. An atomic hydrogen source named H-flux install in the perpendicular plane of OPIG center axis as shown in the figure.

A dissociation rate of hydrogen molecule usually determine from gas pressure dependence of hydrogen anion intensity, that is, the double charge exchange process as

$$H^+ + H_2 \rightarrow H^- + (H_2)^{2+}$$

is used. Unfortunately, cross sections of the process are very small in order of 10^{-18} cm^2. Then a reproducibility of the dissociation rate estimated with the method is bad. We need a new method for determination of dissociation rate with high reliability. We have verified an availability of a new determination method with measuring projectile ion intensity as follows; I of projectile ion intensity can be expressed as

$$I = I_0 \exp\{(-\sigma_{H2}+\sigma_H) l (n_{H2}+n_H)\}$$

,where I_0 is initial ion intensity, σ_{H2} and σ_H are attenuation cross sections with H_2 and H targets, respectively. l is a collision length, n_{H2} and n_H are number density of H_2 and H targets, respectively. It is well known that

$$\sigma_{H2} = 2\sigma_H$$

in high collision energy region [3]. The $n_{H2}+n_H$ can be expressed as

$$n_{H2}+n_H = (1+D)\, n_{H2}^0$$

,where D is dissociation rate of hydrogen, n_{H2}^0 is the number density with D=0. Then we can represent the I using D as follows;

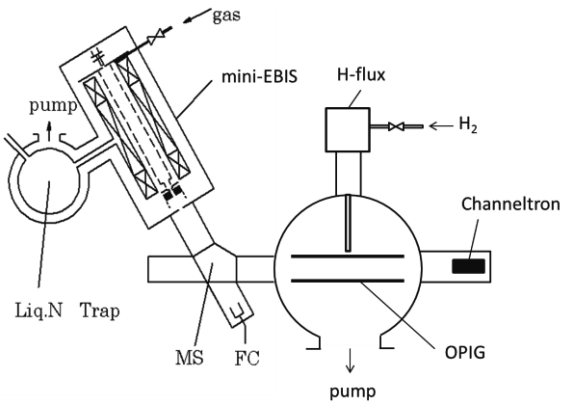
$$I = I_0 \exp\{(-1.5\sigma_{H2}) l (1+D)\, n_{H2}^0\} \quad (1).$$

When the cell temperature of H-flux is room temperature, the D is zero. We can experimentally estimate the value of $\sigma_{H2} l\, n_{H2}^0$ using the H^+ intensity I from equation (1) as follows;

$$\sigma_{H2} l\, n_{H2}^0 = 2/3 \log_e (I_0/ I)$$

at room temperature. We can also estimate the D with high cell temperature using the H^+ intensity I from equation (1) and the value of $\sigma_{H2} l\, n_{H2}^0$. The table below is represented the result of experimental dissociation rates using the attenuation method with the theoretical values. It is clear that the agreement of dissociation rate between experimental and theoretical value is not bad.

We conclude that the attenuation method, which is new approach to obtain the dissociation rate, can be useful to estimate the hydrogen dissociation rate with high reliability.



【Experimental Apparatus】

Cell temp.	dissociation rate	
	experiment	theory
1600K	0.14	0.18
1700K	0.51	0.71

【Dissociation Rate】

[1] I. Y. Tolstikhina et al., J. Phys. B, **47** (2014) 035206.
[2] K. Okuno et al., Nucl. Instrum. Methods B **53** (1991) 387.
[3] M. Imai et al., Fusion Sci. and Tech, **63** (2013) 392.