§17. Isotope Effect in Dissociation Processes of Deuterated Molecules

Sakai, Y. (Toho Univ.), Takahashi, K. (Toho Univ.), Kato, D., Miyauchi, N. (Toho Univ.), Murakami, I., Sakaue, H.A.

It goes without saying that atomic and molecular processes are important in plasma science. In particular, since dissociative recombination(DR) processes occur more than radiative recombination processes in divertor plasmas in which molecular collision participates, many scientists investigate the DR process by theoretical and experimental approaches. In many cases, the DR processes originate from excited states produced by low energy electron-molecular ion collision. This is a molecular assisted recombination. When a molecular ion captures an electron in the electron-molecular ion collision, doubly excited molecule will be produced. In general, doubly excited states are dissociated by either the neutral dissociation corresponded to the DR or the dissociative ionization. In these dissociation processes, it is expected that isotope effects are observed. Information on isotope effects is very important for predicting the performance of the future fusion reactor. Therefore, it is necessary to know how doubly excited molecules dissociate; i.e. branching ratios and cross sections.

In this paper, we report about absolute total generalized oscillator strength distributions (GOSDs), total partial ionic GOSDs of hydrogen(H_2) and deuterium(D_2). The experiments were performed with the scattered electron ion coincidence (SEICO) spectrometer in our laboratory of Toho University. Details of the spectrometer and experimental procedure has been described elsewhere [1,2]; hence, they will be only briefly explained here. The spectrometer consisted of a pulsed electron gun, an electron energy analyzer, and a long and short time-of-flight(TOF) mass analyzers. For the present experiment, only the short TOF mass analyzer, having high collection efficiency for fragmented ions, was used. In the SEICO experiments, the measurements were carried out by electron energy-loss spectroscopy and the electron-ion coincidence technique. and the mixed-gas method was used for normalization for GOSDs.

Figure 1(a) shows the total GOSDs of H_2 and D_2 determined for a 200 eV incident electron energy and a scattering angle of 6 degrees. The magnitude of the momentum transfer, K^2, for the given experimental conditions in shown in the upper horizontal axis. The large peak around 12eV was associated with excitations mainly from $(1s\sigma_g)^{-1}(2p\sigma_u)$ and $(1s\sigma_g)^{-1}(2p\pi_u)$, corresponding to the $B^1\Sigma^+_u$ and $C^1\Pi_u$ states, respectively. Although the GOSD of D_2 around $(1s\sigma_g)^{-1}$ ionization threshold was slightly smaller than that of H_2, the behavior against the electron energy-loss was almost similar.

The partial ionic GOSDs of H_2^+ and D_2^+ are shown in Fig.1(b). Both GOSDs increased from the first ionization threshold $(1s\sigma_g)^{-1}$ at 15.4 eV, which has a maximum value at about 18 eV. After the energy-loss value exceeded the peak, both the ionic GOSD decreased gradually with further increase in the energy-loss values. There was little difference in their ionic GOSDs. However, the D^+ formation by dissociative ionization was completely different from that of H^+, as can be seen from Fig.1(c). The partial ionic GOSD of D^+ was half of the H^+ one in magnitude. In particular, the GOSD of D^+ was very small in the energy-loss region of 18 to 22eV. This mechanism is being considered at present. Besides, we estimated the ratio of the dissociative ionization to neutral dissociation. When doubly excited molecules were decayed by dissociation from the $Q_1{}^1\Sigma g^+(1)$ state, the ratio in the case of H_2 was 3:7, while that of D_2 was 1:9. It seems that this is so-called isotope effect.

We have carried out the SEICO experiments about the dissociation processes of D_2 as the first step of the isotope effect in dissociation processes of deuterated molecules. As a result, we found the isotope effects about the dissociative ionization and neutral dissociation of D_2 molecule.

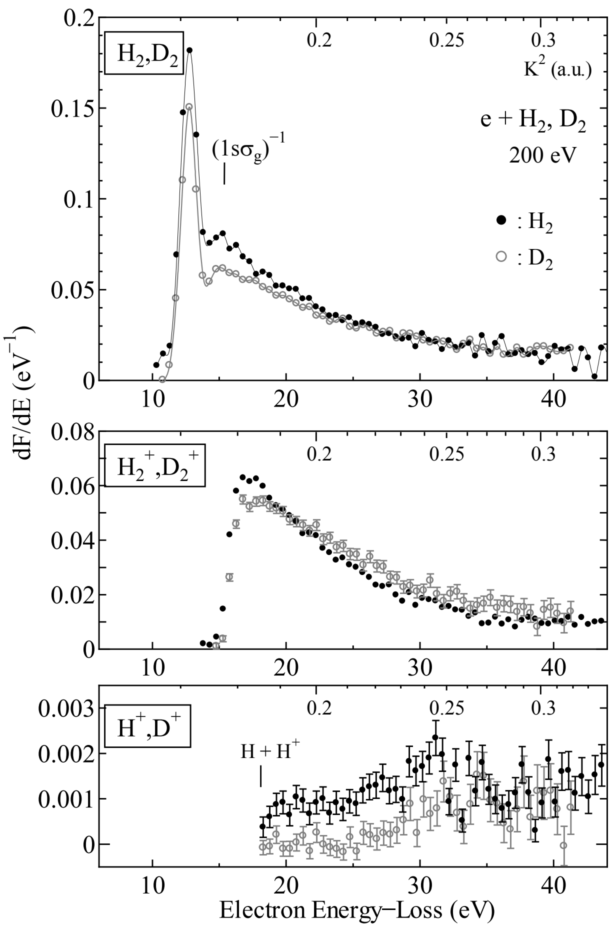

Fig. 1. (a)The absolute total generalized oscillator strength distributions(GOSDs) of H_2 and D_2, (b) the partial ionic GOSDs of H_2^+ and D_2^+, (c)the partial ionic GOSDs of H^+ and D^+, respectively.

[1] K.Yamamoto and Y.Sakai, J.Phys.B, 48, 055201 (2012).
[2] K.Takahashi et al., Eur.Phys.J., D, 68, 83 (2014)