§42. Mass Effects in Quasi-resonant Charge Exchange at Very Low Energy Collisions of Hydrogen Isotopes and Impurity Particles Emitted from PFC Materials

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Plasma facing components (PFCs) are subject to sputtering by plasma particles and contaminate core plasmas of magnetic confinement fusion devices. The use of lower-Z materials for the PFCs could be preferable to keep the radiation loss powers of the core plasmas below sustainable level. On the other hand, the lower-Z materials would suffer larger sputtering from bombardment by plasma particles. Transport of the sputtered particles in peripheral region has been an important subject of study. Influence of charge exchange with plasma particles on the transport has been investigated. However, hydrogen isotopic effects of the transport are still an issue. For this study, charge exchange cross sections between hydrogen isotopes and impurity particles are required at very low energies. This collaboration studies were conducted to investigate the mass effects in quasi-resonant charge exchange at very low energy collisions between hydrogen isotopes and impurity particles emitted from the low-Z PFCs.

Recent calculations [1,2] of quasi-resonant electron-capture (EC) cross sections involving hydrogen isotopes and its ions show that at very low energies (around 10-100 eV/u) the isotope effect can be very large reaching up to a few orders of magnitude. The heavier is the hydrogen isotope the larger is EC cross section. The difference found is explained by the strong influence of the rotational coupling in a quasi-molecule on the capture probability. In the present work [6], similar calculations are performed for EC cross sections in H^+, D^+, T^+ + Li, Be, C collisions and inverse reactions using the ARSENY code [3] based on the adiabatic approximation. A typical example of calculated capture cross sections for H^+, D^+, T^+ + Li and Li^+ + H, D, T collisions is shown in Fig. 1. As is seen, at energies between 5 and 40 eV/u the isotope effect is very large. With ion energy increasing, the cross sections become nearly the same for all isotopes and correspond to EC cross sections for H^+ + Li and Li^+ + H collisions, respectively. As shown in Fig. 2, the similar results are obtained for H^+, D^+, T^+ + Be and Be^+ + H, D, T collisions.

The EC cross sections are suppressed rapidly (exponentially) as collision energies decrease due to difference in ionization potentials between hydrogen atoms and impurity particles. At very low collision energies, therefore, elastic scattering would dominate the particle transport. However, the present results indicate that velocity dependence of the EC cross sections is different for different masses of hydrogen isotopes. Heaver isotopes possess larger moment of inertia so that two colliding particles come closer to each other against nuclear repulsion at a given velocity, which facilitates the charge exchange through the rotational coupling in the quasi-molecular state. This means that EC cross sections at low collision energies are scaled by the kinetic energy of the projectile (in the case of high energy collisions, cross sections are known scaled by the projectile velocity). It appears that mass effects in charge exchange at low collision energies are qualitatively different from that at high energy collisions.

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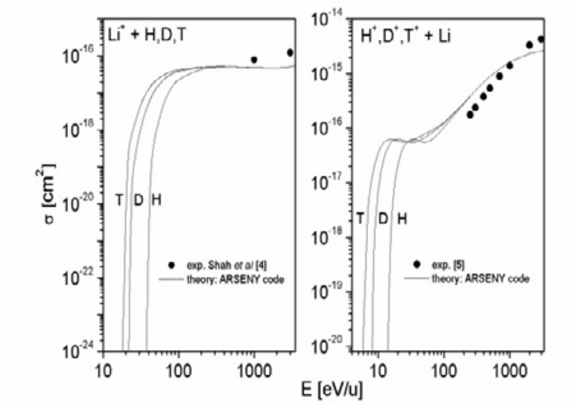

Fig. 1 EC cross sections for H^+, D^+, T^+ + Li and Li^+ + H, D, T collisions. Experiment [4,5]: solid circles for Li^+ + H and H^+ + Li collisions, respectively. Theory: ARSENY code, present work [6].

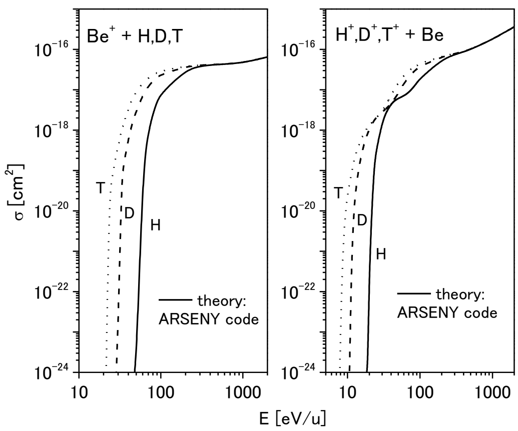

Fig. 2 EC cross sections for H^+, D^+, T^+ + Be and Be^+ + H, D, T collisions. Theory: ARSENY code, present work [6].

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