§38. Influence of the Isotope Effect on the Charge-exchange Process between Hydrogen Isotopes and Ions and Atoms of Plasma Facing Component Materials

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The plasma-wall interactions remain one of the main areas of research in the physics and technology of controlled thermonuclear fusion. The conditions in the peripheral region largely determine also the processes in the main plasma. Numerical simulations of the near-wall and divertor region plasma in fusion devices are based on the knowledge of the rates of the elementary processes involving plasma particles and ions and atoms sputtered from the plasma facing components (PFC). The energies of collisions in the peripheral region are very low (about 1 – 500 eV/u). Under these conditions the charge-exchange becomes the dominant process for the neutralization and population of the excited states of plasma impurities and plays an important role in radiative cooling, particle transport and ions charge distribution. The isotope effect, found recently in charge-exchange reactions between hydrogen isotopes and α-particles [1-3] and PFC's ions (Li, Be, C) [4], manifests in a significant difference (up to several orders of magnitude) in the charge-exchange cross sections: the heavier the isotope the larger the cross section. This effect occurs at very low collision energies due to rotational interaction in close collisions – the scattering angle depends on reduced mass of colliding particles. Since DT burning plasma experiments are planned in ITER, hydrogen isotopic effects on transport of the sputtered particles is an important issue.

We calculated the charge-exchange cross sections in slow collisions of Li, Be, C and W ions with H, D and T. The isotope effect is studied in adiabatic approximation [5] which, in the theory of atomic collisions, is used to describe electronic transitions when the collision velocity is small and the nuclear motion can be treated classically. In this theory, there are no assumptions on the specific form of the electronic Hamiltonian, and only the smallness of the relative nuclear velocity is used. It results in a deeper understanding of the nature of non-adiabatic transitions. Since the isotope effect occurs at collision energies where the adiabatic theory applies, the adiabatic approximation is a natural theoretical framework for studying the effect. The cross sections are calculated with ARSENY code [6] based on the hidden crossing method. The charge-exchange cross sections in collisions of W^+ (6s) with H, D, T at the collision energy of 30 eV/u are 1.56E-19 cm^2, 1.18E-18 cm^2, and 1.25E-16 cm^2, correspondingly (see Fig. 1). This significant difference in the cross sections for H and T targets (three orders of magnitude) indicates the necessity for accounting the isotope effect in edge plasma modeling.

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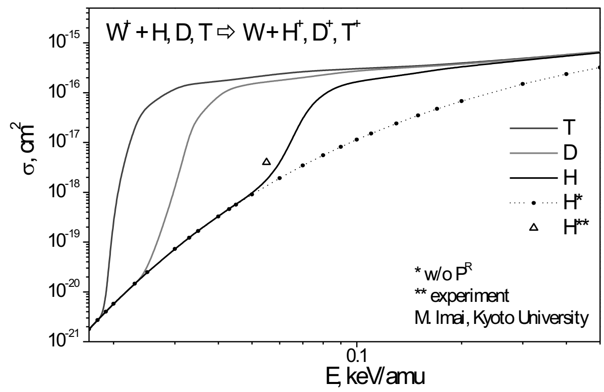

Fig. 1 Charge exchange cross sections. Sold lines are calculations including the rotational interaction, dotted line calculations without the rotational interaction. Open triangle is an available experimental data [7] for molecular targets (H_2) divided by 2 for comparison.

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