§ 25. Effect of Vibrational Excitation of Molecular Hydrogen on Hydrogen Recycling in LHD Edge Plasma

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In divertor study, one of the key issues is the molecular assisted recombination (MAR) that may enhance the plasma recombination in the higher (a few eV) temperature region where the conventional collisional-radiative recombination becomes ineffective. We have evaluated the effective rate coefficients by varying the initial vibrational levels of $H_2(X^1\Sigma_g^+, v = 0-14)$ as a parameter[1]:

$$\begin{array}{rcl} H_2(X^1\Sigma_g^+, v) + H^+ & \rightarrow & H_2^+(X^2\Sigma_g^+, v') + H(1) \\ H_2^+(X^2\Sigma_g^+, v') + e & \rightarrow & H_2^+(X^2\Sigma_g^+, v'') + e \\ H_2^+(X^2\Sigma_g^+, v'') + e & \rightarrow & H(1) + H(p) \\ H(p) \rightarrow & H(q) & \rightarrow H(1). \end{array}$$

The results show that the initial level $v = 4$ or 5 gives maximum value, which is more than one order of magnitude larger than that for $v = 0$. In order to estimate the contribution of the MAR to the total recombination in actual plasmas, population densities of the vibrational levels should be known. We have constructed a 1-D neutral transport code in which all the 0-14 vibrational levels are tracked. Figure 1 shows the MAR recombination rate when $v = 0$ molecules are released from a wall with a velocity which corresponds to a temperature of 300°C. The plasma is assumed to be uniform with $n_e = 10^{14}\mathrm{cm}^{-3}$, $T_e = 2.0\mathrm{eV}$. The result of the density of molecule is normalized at the wall surface to $n_{H_2} = 10^{12}, 10^{13}$, and $10^{14}\mathrm{cm}^{-3}$. The MAR recombination rate is larger than that by $H^+ + e \rightarrow H$ near the wall for $n_{H_2} \geq 10^{12}\mathrm{cm}^{-3}$.

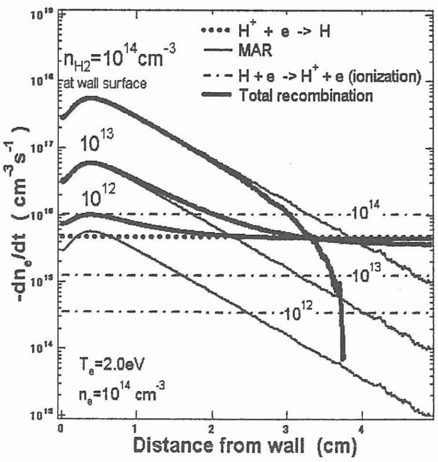

Fig.1. The MAR recombination rate from $H_2(X^1\Sigma_g^+, v = 0)$. The rate of $H^+ + e \rightarrow H$ is also shown.

Figure 2 shows the result by the molecules released from the wall with $v = 4$. Compared with the result for $v = 0$, the rates near the wall are larger, but decrease rapidly with penetrating into plasma.

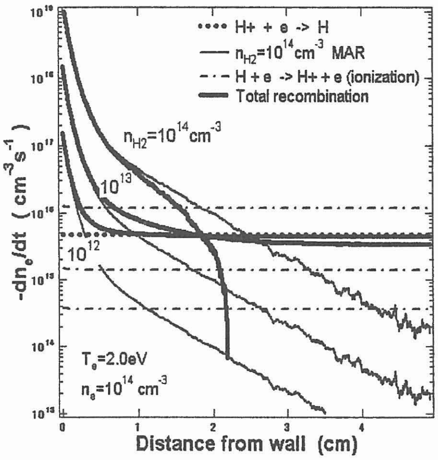

Fig.2. The MAR recombination rate from $H_2(X^1\Sigma_g^+, v = 4)$. The rate of $H^+ + e \rightarrow H$ is also shown.

We have also calculated the effective ionization rate of hydrogen atoms produced by the MAR considering radiation trapping using an iterative method that we have developed. Figure 3 shows that the effective ionization rate increases a factor of two; "Total recombination" denotes the value including the ionization of atoms.

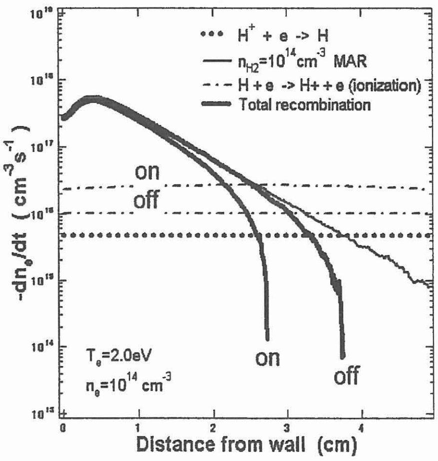

Fig.3. The MAR recombination rate from $H_2(X^1\Sigma_g^+, v = 0)$ considering the radiation trapping "on".

We are now working to extend our 1-D code to 3-D one in order to analyze LHD plasmas.

Reference

1) K.Sawada, T.Fujimoto, Contributions to Plasma Physics 42, 603-607 (2002).