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

Sawada, K., Nakauchi, S., Kambe, H., Fujiwara, H., Kamata, D. (Shinshu Univ.),
Ezumi, N. (Nagano National College of Technology),
Fujimoto, T. (Kyoto Univ.),
Goto, M., Takayama, A., Tomita, Y., Nakamura, H.

In divertor study, one of the key issues is the molecular assisted recombination (MAR), which was first proposed by Krashenninikov et al.[1]. They found that the MAR may enhance the plasma recombination in the higher temperature region where the conventional collisioanl-radaitive recombination becomes ineffective. The MAR consists of two series of processes. The first starts with the charge exchange between H_2 and H^+ (CX MAR):

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

where p and q denote the principle quantum number of atomic hydrogen. The second is a process which starts with the dissociative attachment (DA MAR):

$$\begin{aligned}
H_2(X^1\Sigma_g^+, v) + e &\rightarrow H^- + H(1)\\
H^- + H^+ &\rightarrow H(1) + H(2or3)\\
H(2or3) \rightarrow \quad H(q) &\rightarrow H(1)
\end{aligned}$$

The MAR rate coefficient has been calculated in Ref.1 as a function of the electron density and electron temperature. Unfortunately, however, in their original papers, they have not investigated the dependence of MAR on the initial vibrational excitation of molecular hydrogen. We have independently calculated it using our own collisional-radiative model with recent atomic and molecular data. Figure 1 shows an example of the MAR rate coefficients for various initial vibrational level v. The vibrational excited molecules have higher rate coefficients, sometimes by more than an order. This strong v dependence stems mainly from the v dependence of the (CX1) and (DA1) cross sections.

The goal of our study is to include the recent atomic and molecular data especially concerning the MAR in the neutral particle transport code EIRENE and to analyze the LHD plasmas by using the code. As one step to the goal, we have built a rf plasma source at shinshu university which can be used to verify the code before applying it to the LHD. We have produced hydrogen plasmas ($P_{rf} \leq 2.0$kW, $f = 13.56$MHz) with $n_e = 10^{10} - 10^{12}\text{cm}^{-3}$, $T_e = 2.0 - 6.0$eV, where atomic emission lines of Balmer $\alpha, \beta, \gamma, \delta$, and molecular band ($d^3\Pi_u$-$a^3\Sigma_g^+$ fulcher transition) have been observed.

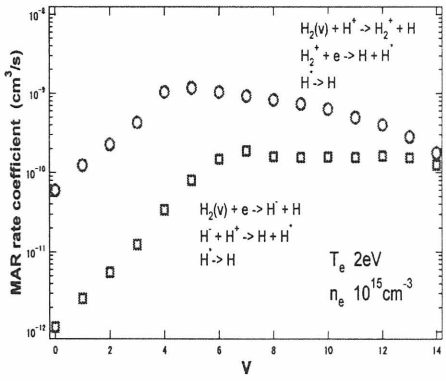

Fig.1. The MAR rate coefficients from various initial vibrational levels in $H_2(X^1\Sigma_g^+)$.

Figure 2 shows the populations of excited levels of atomic hydrogen determined from the intensities of the Balmer lines from a plasma with $n_e = 2.5 \times 10^{11}\text{cm}^{-3}$, $T_e = 3.0$eV, the gas pressure 0.015Torr. Figure 2 also shows population coefficients $R_0(p)$, $R_1(p)$, and $R_{MAR}(p, v)$ which are defined by

$$\begin{aligned}
n(p) = \quad & R_0(p)n_z n_e + R_1(p)n(1)n_e\\
& + \Sigma_v R_{MAR}(p, v)n_{H_2(v)}n_e, \qquad (1)
\end{aligned}$$

where p is the principal quantum number. The experimental populations were well fitted by eq.(1) with $n_H = 2.7 \times 10^{14}\text{cm}^{-3}$, $n_{H_2(v=0)} = 1.0 \times 10^{14}\text{cm}^{-3}$. In order to verify these values, we are planning the studies of the influence of radiation trapping on the atomic emissions, and the analysis of the molecular band emissions.

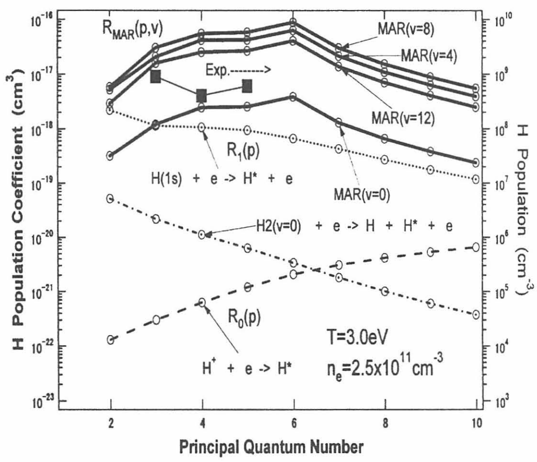

Fig.2. The population coefficients of the atomic hydrogen (open circle). Populations of excited atoms determined from the Balmer line intensities are also shown (closed square).

Reference

1) A.Yu.Pigarov and S.I.Krasheninnikov, PFC/JA-96-7 (1996).