Influence of H_2 number density on recombination of H_3^+ ions with electrons

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1. Introduction

H_3^+, the simplest polyatomic ion, is of key importance in the chemistry of some interstellar clouds and in hydrogen containing plasma environments. It's recombination with electrons has been extensively studied both theoretically and experimentally [1]. The order of magnitude discrepancies between results from storage ion rings and plasma afterglow experiments [1] were largely resolved after taking into account the fast helium assisted three body recombination of H_3^+ ions [2]. Recently, a similar three body process with H_2 as a third particle was discovered [3]. The present contribution focuses on the competition between H_2 assisted recombination of H_3^+ ions and production and subsequent recombination of H_5^+ ions.

2. Experimental setup

Technical details of the SA-CRDS apparatus have been in detail described elsewhere [4]. The plasma is formed in a pulsed microwave discharge in a mixture of He/Ar/H_2 ($10^{17}/10^{14}/10^{14}$–10^{16} cm^{-3}), and the densities of three rotational states of the ground vibrational state of H_3^+ are monitored using second overtone transitions (for details see [4]). The kinetic temperature of the ions is measured from Doppler broadening of the absorption lines, and the rotational temperature is obtained from the populations of the measured states. The effective recombination rate coefficients $\alpha_{\text{eff-ion}}$ were derived for a wide range of H_2 densities from state resolved ion number density decay measurements.

3. Results and discussion

Apart from enhancement of measured effective recombination rate coefficient arising from three body recombination processes an additional process can influence the effective recombination coefficient at high H_2 number densities: formation of H_5^+ cluster ions that recombine very fast at 300 K. To set the best conditions for our experiment (temperature, reactant number densities) we employed a model of chemical kinetics based on a set of equations describing processes in He/Ar/H_2 containing afterglow plasma, as published in [4,5]. The calculated ion number density decays were fitted using the same procedure as for experimentally obtained data [4]. The results of the model together with the measured effective recombination rate coefficients are displayed in Fig. 1 for 300 K. A good agreement between results of the model and the measured recombination rate coefficients were achieved in the whole temperature range covered by our experiment (240 – 340 K). The model shows that the losses of charged particles due to formation and subsequent recombination of H_5^+ ions are, at used number densities of H_2, negligible for temperatures higher than 300 K and become comparable to losses due to H_2 assisted ternary recombination at 240 K, seriously complicating evaluation of ternary H_2 assisted recombination rate coefficients at lower temperatures.

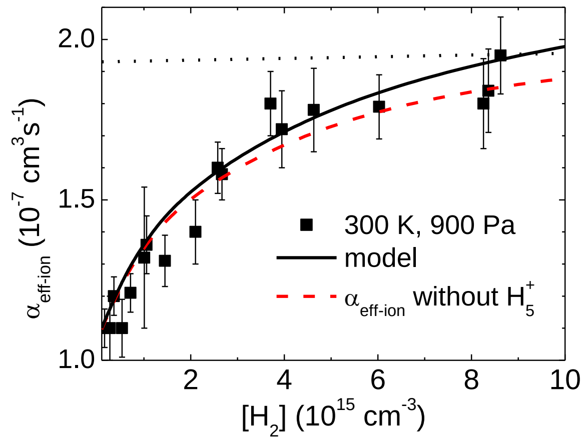

Fig. 1: *Measured dependency of the effective rate coefficient of H_3^+ recombination with electrons on H_2 number density. The full and the dashed lines are result of model of chemical kinetics with or without contribution from formation and destruction of H_5^+ ions, respectively.*

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References

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