4.7 RECOMBINATION OF SIMPLE MOLECULAR IONS STUDIED IN STORAGE RING – DISSOCIATIVE RECOMBINATION OF H_2O^+

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4.7.1 Introduction

Dissociative recombination (DR) is a double step reaction in which a molecular ion captures a free electron and in the following step dissociates into neutral fragments. Thus it plays an important role in the evolution and chemical composition of astrophysical plasmas, being one of the processes responsible for the removal of the molecular ions of these media. Proper consideration of this role requires knowledge of absolute cross section, as well as the neutral product branching ratios for polyatomic DR reactions that might occur at temperatures ranging from ten to a few thousand degrees.

The present paper addresses dissociative recombination of H_2O^+. Since it has a well-known structure, it might be helpful in a theoretical understanding of the mechanism that allows the DR reaction to proceed. Different aspects of dissociative recombination of H_2O^+ have been previously studied by means of a variety of experimental methods [1].

We report dissociative recombination cross section for H_2O^+ over an energy interval from 0 eV to 30 eV and complete neutral product branching ratios measured at an energy of 0 eV.

4.7.2 Experimental technique

The experiment has been carried out at the heavy ion storage ring CRYRING at the Manne Siegbahn Laboratory in Stockholm, Sweden. The ions, generated in a cold plasma ion source JIMIS, were extracted and after mass-selection injected into the storage ring. Then they were accelerated to the highest circulation energy, about 0.3 MeV/amu, and stored with a lifetime of 2.4 s. The typical ion beam current was 0.1 μA with an uncertainty of 10%.

The stored ion beam was merged over an effective interaction length of $l \approx 0.85$ m with a magnetically confined, monoenergetic electron beam. A 5 s interval between injection and the start of the measurement was long enough to vibrationally relax the ions. Neutral products created in the cooler were separated from the primary beam as they passed through the first dipole magnet following the electron cooler. Then they were detected with a 3000 mm^2 surface barrier detector mounted at a distance of 3.5 m from the midpoint of the cooler.

4.7.3 Results

4.7.3.1 Cross section

The measurement for the DR cross section was performed by scanning the electron energy over the range which corresponds to collision energies between 0 and 30 eV. The data were collected continuously within the 7 s measurement window, distributed over 1000 energy channels. After each injection of ions the cycle started again.

The data for the absolute cross section are shown by the solid squares in Figure 1. They are compared with the results obtained in a single-pass merged beam experiment performed by Mul *et al.* [2] and the storage ring data reported recently by Jensen *et al.* [3]. The cross section value is about $1x10^{-12}$ cm^2 at 0.001 eV. The two resonant peaks found at energies of 4 and 11 eV can be explained by electron capture to Rydberg states converging to electronically excited ionic states, followed by (pre)dissociation.

The energy dependence of the DR cross section for H_2O^+ found in the present experiment was found to be $E^{-1.24}$ at energies below 0.1 eV. It is

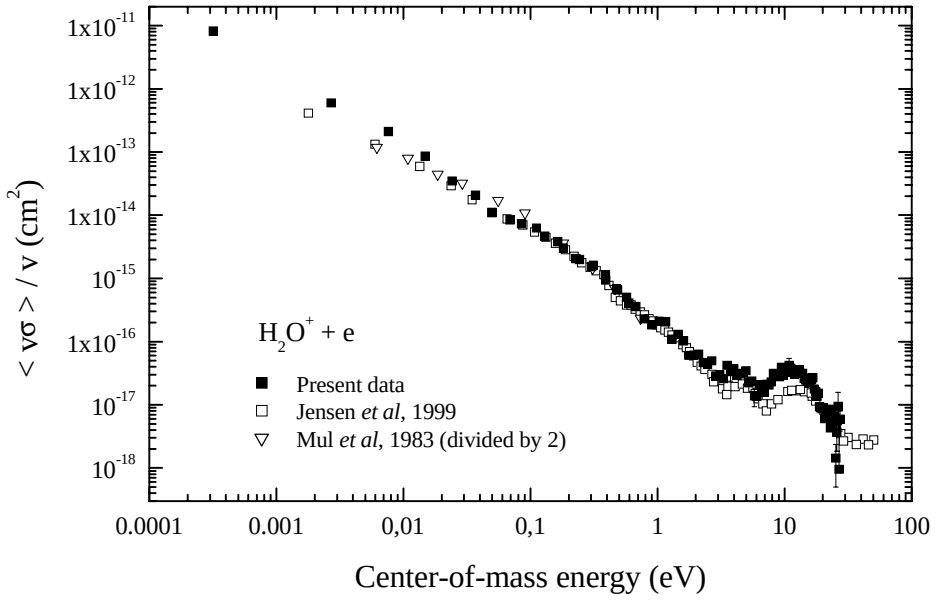

Fig. 1. Absolute cross section for DR of H_2O^+ (solid squares) as a function of center-of-mass energy.

significantly more steep than the E^{-1} behaviour, typical of the direct DR mechanism. In the energy interval between 0.1 eV and 2 eV the DR cross section decrease even faster with an $E^{-1.55}$ energy dependence.

4.7.3.2 Branching ratios

The neutral product branching ratios for DR of H_2O^+ were obtained from the energy spectra measured with a grid inserted in front of the detector. The transmission T of the grid is 0.297 ± 0.015 and energy independent. Each single particle could pass through the grid with a probability of T. Particles stopped by the grid (with a probability of (1-T)) did not contribute to the signal. The neutral product

$$\begin{aligned} & OH + H, && \alpha = 0.20 \pm 0.05, \\ H_2O^+ + e \rightarrow\ & O + H_2, && \beta = 0.09 \pm 0.04, \\ & O + H + H, && \gamma = 0.71 \pm 0.06. \end{aligned}$$

branching ratios in DR of H_2O^+ at collision energy of 0 eV have been obtained as follows:

The dissociation is dominated by the three-body breakup. Branching ratios reported in the present work show that there is more three-body fragmentation than has been previously found in other experiments. One possible mechanism explaining the dominance of the three-body breakup can be that it arises from secondary fragmentation of vibrationally excited molecular products in a two-body channel.

4.7.4 Conclusions

The absolute cross sections for dissociative recombination of H_2O^+ ions have been measured over the energy range between 0 eV and 30 eV. The energy dependence of the cross section in the low energy range indicate the DR yield is more efficient than those predicted by the direct mechanism. Neutral product branching ratios for DR of water ions have been determined at collision energy of 0 eV. The three body O + H + H channel was found to dominate with a branching fraction of 0.71.

4.7.5 Acknowledgements

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4.7.6 References

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