

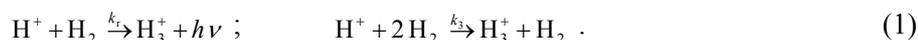
# Ternary association of $H^+$ ions with $H_2$ ; Experiments with normal and para-enriched hydrogen at 11 K

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The ternary association reaction  $H^+ + 2 H_2 \rightarrow H_3^+ + H_2$  for normal and para-enriched hydrogen has been studied. Using a 22-pole rf ion trap, the density dependence of apparent binary reaction rate coefficients has been measured at 11 K. The results indicate that the reaction with para-enriched hydrogen is significantly faster than with normal hydrogen.

**Introduction.**  $H_3^+$  plays an important role in many hydrogen containing plasmas ranging from astrochemistry via spectroscopy to applications [1]. It also has very fundamental aspects and represents a benchmark system for theoretical calculations [2,3]. In understanding the various routes to form this ion, radiative and ternary association have to be accounted for:



The apparent binary reaction rate coefficient is  $k_{eff} = k_r + k_3[H_2]$ . Ternary association was studied several times previously at higher temperatures [4,5,6]. Only very recently both radiative and ternary channels have been studied and the reaction rate coefficients have been determined in our laboratory using normal hydrogen ( $^nH_2$ , i.e.  $\frac{1}{4}$  para- $H_2$  and  $\frac{3}{4}$  ortho- $H_2$ ). These studies, which were carried out at 11 and 22 K, included the experimental determination of the temperature dependences of both rate coefficients [7,8]. In order to clarify the detailed mechanisms of the low temperature association processes, it is important to measure state specific rate coefficients. With this aim we started experiments with well defined composition of para- and ortho-states and with pure para-hydrogen. In this contribution we present the first results for para-enriched hydrogen ( $^eH_2$ ).

**Experiment.** The well-characterized AB-22PT instrument (for a detailed description of the technique and further references see [6,7]) has been used to study mentioned association reactions and to determine separately their rate coefficients. The principle of ion trapping and experimental details have been described elsewhere [6,9].

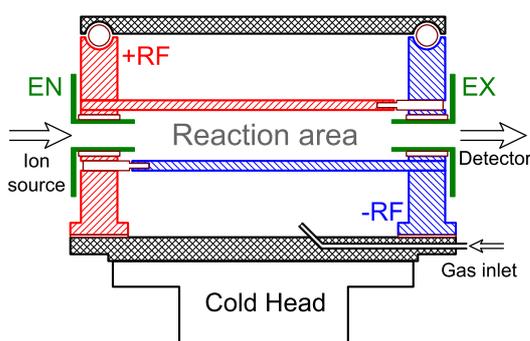


Fig. 1: Schematic view of the 22-pole ion trap. In radial direction ions are confined by the rf field created by two sets of 11 poles (+RF and -RF) mounted on both sides. EN and EX are the entrance and exit electrodes, respectively. These electrodes are used to open and close the trap with electrostatic barriers (a few tens of meV). Normal or para-enriched hydrogen is introduced via the gas inlet into the trap volume.

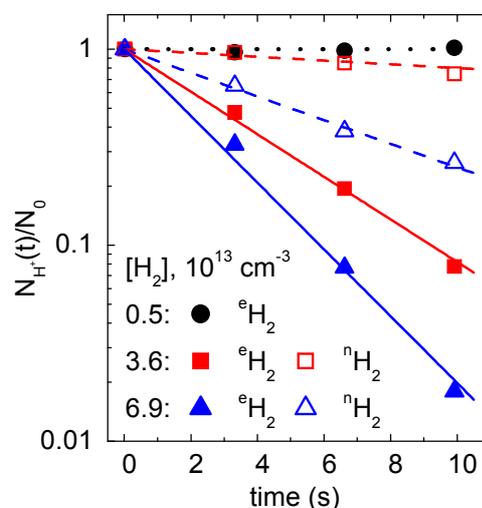


Fig. 2: Decrease of the relative number of  $H^+$  ions due to reaction with normal (open symbols) and with para-enriched (closed symbols)  $H_2$ .

The central part of the instrument, the 22-pole ion trap, is shown schematically in Figure 1. In the present study normal or para-enriched hydrogen was introduced into the trap volume. After a few collisions with the walls the gas is thermalized with the exception of ortho/para ratio which remains constant. The exact population of para-H<sub>2</sub> and ortho-H<sub>2</sub> in the volume of the trap will be determined in an independent study using the state sensitivity of the reaction of N<sup>+</sup> with H<sub>2</sub>(J=0) and H<sub>2</sub>(J=1). For details see [10]. Using this *in situ* determination of the population of the rotational states of the hydrogen molecules, we will be able to determine the state specific rate coefficients for the interaction of protons with H<sub>2</sub>.

In Figure 2 we show some examples of the decay of H<sup>+</sup> ions due to the reaction (1) measured at several densities with normal and para-enriched hydrogen. Inspection reveals that, at otherwise identical conditions, H<sub>3</sub><sup>+</sup> formation with enriched para-hydrogen is faster. Quantitative evaluation indicates that the ternary reaction rate coefficient for H<sub>2</sub>(J=0) is at least three times as high as for H<sub>2</sub>(J=1).

**Conclusion.** To our knowledge we present the first-ever study of the ternary association reaction of H<sup>+</sup>+H<sub>2</sub> using para-enriched hydrogen. The measured decay of the number of H<sup>+</sup> ions in the trap and the production of H<sub>3</sub><sup>+</sup> indicate that the rate coefficient for ternary association is considerably higher for para-enriched hydrogen. Further studies with quantitative determination of the population of rotational states are in progress.

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