Recombination of ortho and para H_3^+ ions with electrons at low temperatures using flowing afterglow technique

P. Dohnal[1]*, A. Kalosi[1], P. Rubovič[1], M. Hejduk[1], R. Plašil[1], J. Glosík[1]

[1]*Department of Surface and Plasma Science, Faculty of Mathematics and Physics, Charles University in Prague, V Holesovickach 2, 180 00 Prague 8, Czech Republic*
**Contact e-mail:* petr.dohnal@mff.cuni.cz

1. Introduction

H_3^+ – the simplest polyatomic ion – plays a pivotal role in the chemical evolution of interstellar clouds [1]. Its recombination with electrons is of interest for modeling hydrogen containing plasmas and has been studied experimentally and theoretically for over 60 years [2].

The quantum mechanical calculations [3] predict that at low temperatures the two spin isomers of H_3^+ ion (ortho and para) have different recombination rates. A small enhancement of para H_3^+ recombination rate was found in storage ion ring experiments [4,5] but the ions stored in the ring were probably not rotationally cold [6]. Theoretical predictions are supported by stationary afterglow experiments with in situ determined populations of recombining ions [7].

As in stationary afterglow setup the reactants are subject to discharge, the presence of excited molecules in afterglow plasma cannot be completely ruled out. Therefore, we decided to study the state specific recombination of H_3^+ ions using Cryogenic Flowing Afterglow apparatus (Cryo-FALP II) where the discharge and the formation of H_3^+ dominated plasma are spatially separated.

2. Experiment

The main diagnostic tool used in this study was Cryo-FALP II apparatus [8], where the recombination rate coefficients are evaluated from the time decay of electron number density and the gas temperature can be varied in the range of 40 – 300 K. The actual ratio between para and ortho H_3^+ ions was changed by using either normal H_2 (75 % ortho H_2, 25 % para H_2) or para enriched H_2 (more than 99% of para H_2) as a precursor gas to form H_3^+ ions. The populations of the different rotational states of H_3^+ were monitored using our Stationary Afterglow with Cavity Ring Down Spectrometer setup [7] at similar conditions that were used during the recombination rate coefficient measurements in Cryo-FALP II. Examples of measured absorption line profiles are shown in Fig. 1.

3. Results

The recombination rate coefficients measured at 80 K for ortho H_3^+: $(0.3 \pm 0.2)\times10^{-7}$ cm^{3}s^{-1} and for para H_3^+: $(1.5 \pm 0.4)\times10^{-7}$ cm^{3}s^{-1} are in a very good agreement with values obtained in previous stationary afterglow experiments [7] and support the theoretical predictions [3]. Results obtained at different temperatures will be also presented.

4. Acknowledgement

This work was partly supported by GACR P209/12/0233, 14-14649P and 15-15077S and by GAUK 692214.

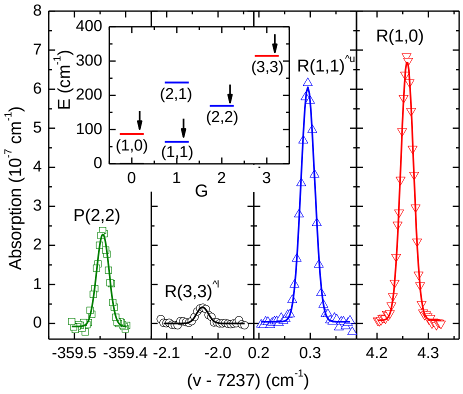

Fig. 1: *Second overtone transitions ($3\nu_2^1 \leftarrow 0\nu_2^0$) of H_3^+ ion as measured at 80 K. The obtained kinetic temperature of the ions $T_{kin-ion}$ = (90 ± 8) K was within experimental error equal to the rotational temperature in both ortho and para states manifolds. Insert: the lowest rotational states of the ground vibrational state of H_3^+ ion. Probed states are denoted by an arrow.*

References

[1] T. Oka 2006 *Proc. Natl. Acad. Sci. USA* **103** pp 12235

[2] M. Larsson and A. E. Orel 2008 *Dissociative Recombination of Molecular Ions* Cambridge University, Cambridge

[3] S. Fonseca dos Santos, V. Kokoouline and C. H. Greene 2007 *J. Chem. Phys.* **127** pp 124309

[4] H. Kreckel et al. 2005 *Phys. Rev. Lett.* **95** pp 263201

[5] B. A. Tom et al. 2009 *J. Chem. Phys.* **130** pp 031101

[6] A. Petrignani et al. 2011 *Phys. Rev. A* **83** pp 032711

[7] J. Varju, M. Hejduk, P. Dohnal et al. 2011 *Phys. Rev. Lett.* **106** pp 203201

[8] T. Kotrík et al. 2011 *Eur. Phys. J. Appl. Phys.* **56** pp 24011