TEST MEASUREMENT ON ION-MOLECULE
REACTIONS IN A RINGELECTRODE ION TRAP

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Abstract. Very recently a new experimental setup has been developed allowing studies of astrophysically relevant collisions between neutral atoms and small pure carbon molecules from one side and ions from the other side and first results are obtained (Savić et al., 2005). The ions are stored in a radio- frequency (rf) ringelectrode trap and during reaction time exposed to the effusive carbon beam. In this paper, one of the final tests of the experimental setup is presented.

1. INTRODUCTION

In general, ionmolecule reactions have no barriers and therefore are faster then neutral-neutral reactions. From this reason, this type of reactions is dominant in reaction models. Until today, more then 120 interstellar molecules (including neutrals and ions) have been detected. Around 80 % of these molecules are carbon containing. Since carbon play a very important role in the interstellar medium, detailed and systematic studies on formation and destruction of carbon containing molecules are needed. It is especially important to find pathways leading from small molecules like C, C_2, C_3, C_2H or C_3H to complex molecular structures.

Until now, reactions between neutrals and small carbon containing ions are studied experimentally. Very recently a new experimental setup has been developed allowing studies of astrophysically relevant collisions between neutral atoms and small pure carbon molecules from one side and ions from the other side and first results are obtained (Savić et al., 2005).

The machine

The CRET machine and measurement sequence is fully described in the (Savić et al., 2005 and Čermak et al., 2002). Here would be given only short overview.

CRET is an iontrapping machine that combines the trapping technique with a beam of neutral carbon atoms and molecules. The machine consists of a carbon vaporization source, an electron bombardment ion source, ring electrode radiofrequency ion trap (RET) and singleion mass analyzer. The primary ions are produced by electron impact directly in the trap. They are stored for a given reaction time and during this time exposed to the carbon beam. After this, content of the trap is extracted, mass selected and counted. Immediately after this, the flux of the carbon beam is monitored to correct for drifts of the carbon source.

Experiment and discussion

In order to test measurement sequence and the overall performance of the machine, rate coefficients for the reaction

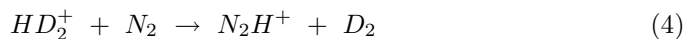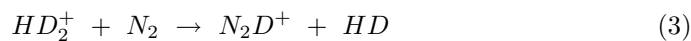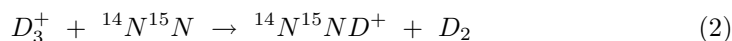$$D_3^+ \; + \; N_2 \; \rightarrow \; N_2 D^+ \; + \; D_2 \tag{1}$$
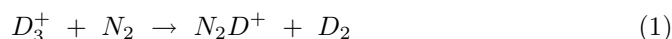
have been measured.

The primary ions have been produced by introducing a short pulse of deuterium (Deuterium 2.7, Messer Griesheim) directly in the trap. After a certain delay, to ionize deuterium, an electron pulse of suitable energy (70 eV) is injected. On this way, deuterium is ionized and created ions undergo interactions with neutral D_2 still presented in the trap. Ions produced using such scheme (in details described in Čermak et al., 2002), are predominantly D_3^+ ions and some HD_2^+. The number of HD_2^+ ions is two order of magnitude smaller then that of D_3^+ ions.

In present experiment, instead the carbon beam, the neutral target gas N_2 was been used. N_2 is introduced into the chamber.

Experiments were performed without any buffer gas, at conditions where the trap was hold at room and at liquid nitrogen temperatures.

In Fig. 1 typical experimental results are shown when the trap was been hold at liquid nitrogen temperature. The time dependence of the averaged number of trapped ions as a function of storage time is plotted. In addition to the reaction (1), the reactions

$$D_3^+ \; + \; {}^{14}N^{15}N \; \rightarrow \; {}^{14}N^{15}ND^+ \; + \; D_2 \tag{2}$$

$$HD_2^+ \; + \; N_2 \; \rightarrow \; N_2 D^+ \; + \; HD \tag{3}$$

$$HD_2^+ \; + \; N_2 \; \rightarrow \; N_2 H^+ \; + \; D_2 \tag{4}$$

also have been observed.

The solid lines in Fig. 1 represent solutions of an appropriate system of differential equations describing the chemical reactions (1) – (4).

At room temperature the trap also contains traces of water and additional product ions are observed. These reaction channels complicate the data evaluation, especially since the rate coefficients for reactions between H_2O and D_3^+ and HD_2^+ are not known.
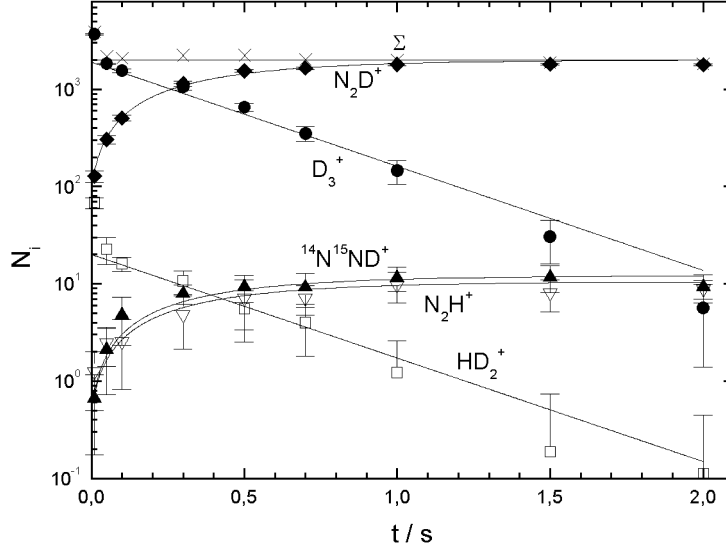
Figure 1: Typical experimental result showing the time dependence of an average number of trapped ions as a function of time. D_3^+ ions are stored in a RET which have been hold at liquid nitrogen temperature. In reaction with N_2 ($[N_2] = 2.06 \times 10^9$ cm^{-3}) they produce N_2D^+ and $^{14}N^{15}ND^+$. HD_2^+ ions also react with N_2 forming N_2H^+.

Therefore these rate coefficients have been measured by calibrating the number density of H_2O using reactions with known rate coefficients. Despite these complications, rate coefficient for reaction (1) has been extracted by using an simplified model, describing the reactions occurring in the trap. In this model it was assumed that primary D_3^+ ions react either with the target N_2 producing N_2D^+ (reaction (1)) or alternatively with impurities (summarized in X) producing Y^+ ions. Reactions with these neutrals X, i.e.,:

$$D_3^+ \; + \; X \; \rightarrow \; Y^+ \; + \; Z \tag{5}$$

can be just treated as loss.

Using this model, like it is described in details in Savić (2004), the rate coefficient for reaction (1) has been determined to be $k_1 = (1 \pm 0.25) \times 10^9$ cm^{3}s^1. This value is in agreement with previously reported values of $(7.49 \pm 0.75) \times 10^{-10}$ cm^{3}s^{-1} and $(1.1 \pm 0.17) \times 10^{-9}$ cm^{3}s^{-1} measured with an ICR apparatus (see Anicich, 2003 and references therein).

2. CONCLUSIONS

Since the measured reaction rate coefficient is in agreement with previously reported values, the setup can be used for further experiments.

In general, the CRET machine needs some more improvements. Many of interesting ions produced by an electron bombardment of neutral precursors in the ion source are fragments of the parent ion, leading to mixture of secondary ions. In order to simplify the chemistry in the ion trap, a mass selection quadrupole between the ion source and the ion trap has to be introduced. Many carbon based molecules and ions have isomers which can be distinguished by chemical probing and therefore injection of probing gases through a piezo valve would be beneficial in the experiments. In order to prepare different ion isomers for studies of reactions with neutral carbon, an additional valve for introducing the gas into ion source could be used.

References

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