Publ. Astron. Obs. Belgrade No. 99(2020), 75 - 78 *Contributed Paper*

INTRODUCING A NEW GUIDED ION BEAM INSTRUMENT - NOVion

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Abstract. A new Guided Ion Beam instrument (NOVion) for measuring absolute integral cross sections for collisions between ions and neutrals (molecules and atoms) has been assembled and tested. This apparatus is operational since some time in Novi Sad. Our main goal is to use this instrument for studies to understand elementary processes occurring in any kind of technical or astrophysical low temperature plasmas. Some results are presented in this contribution.

1. INTRODUCTION

During the last decades, a lot of theoretical and experimental work has been performed to obtain information about elementary processes in plasmas or gas discharges. Among many other important parameters, knowing absolute cross sections (or reaction rate coefficients) for ion-neutral collisions is crucial. They are needed for understanding and modeling complex chemical system using sophisticated models. Many data used for modeling, have been measured only at one collision energy (or equivalent temperature) or extrapolated from high energy measurements. A lot of effort has been invested to understand these processes below room temperature or to understand state to state specific cross sections. At higher energies, many states are involved, and the situation is more complicated. Understanding plasmas is still far from being complete because of many competing processes.

During last decades, many experimental techniques have been developed for studying ion chemistry, (stationary and afterglow, drift and selected ion tube, ion-cyclotron resonance, radio frequency traps, a 2 K drift tube and the CRESU flow system (cinétique de réactions en écoulement supersonique uniforme)). In addition, the versatile, very sensitive and reliable Guided Ion Beam (GIB) technique has been established. In Novi Sad, a new GIB instrument with the name NOVion is available. According to the best of our knowledge, this instrument is one of the 5 instruments of this type operational in the world.

In this paper NOVion is shortly described and some preliminary results are presented.

2. EXPERIMENTAL

The first GIB instrument has been developed in Freiburg and was described in (Gerlich 1971) and later in (Teloy and Gerlich 1974). Improvements of this early instrument as well as detailed description of the universal GIB instrument can be found in (Gerlich 1992).

NOVion is briefly described and schematically shown in (Savić et al. 2020). A publication with more technical details is in preparation. Here, only a short description of the basics of this instrument is given.

Primary ions are produced in a storage ion source (SIS) by electron bombardment of neutral gas or a mixture of gases. In this way a wide variety of different ions can be produced and stored. The ions internal energy can be influenced by changing the storage time, the electron energy, or the number density of primary and buffer gas in the SIS.

Ions produced in the SIS are mass selected using a first quadrupole ($4P_1$) and transferred into the octopole (8P) ion guide. This octopole guides the ions (in inhomogeneous electric radio frequency fields) through the scattering cell (SC).

Collisions between primary ions and neutral target gas occur in the SC. The collision energy can be changed by superimposing a DC potential to the rf voltage of the 8P. The collision energy is not exactly determined by the DC potential differences between SIS and 8P. Space charge effects in the SIS and differences in surface potentials can introduce some energy shift. To determine the laboratory energy of primary ions, two methods are available: retarding potential method described in (Teloy and Gerlich 1974) and time of flight (TOF) method described in (Gerlich 1992). For our energy calibrations both methods are in use in NOVion.

From the 8P, after collisions, the primary and product ions are transferred to the second quadrupole ($4P_2$), mass selected, detected by a Daly type ion detector and counted.

For determining absolute integral cross sections, the absolute pressure in the SC is measured using a membrane manometer (Pfeiffer CMR 375).

Determination of absolute integral cross sections is thoroughly described in (Savić et al. 2020). Knowing absolute effective integral cross sections, it is trivial to convert them into effective reaction rate coefficients.

3. FIRST RESULTS AND CONCLUSIONS

We have measured absolute integral cross sections for the formation of H_3^+ in collisions of H_2^+ with H_2. This reaction has been used as a first tests for the new instrument because many experimental and theoretical data already exist.
The reaction

$$H_2^+ + H_2 \rightarrow H_3^+ + H \quad (1)$$

is highly exothermic and it is of great importance for hydrogen plasmas. After testing the instrument, reaction (1) has been extensively studied in the collision energy range between 0.1 and 10 eV and the results have been published recently (Savić et al. 2020). Our results and a new analytical function recommended for the energy dependence of the cross section are shown on Figure 1.

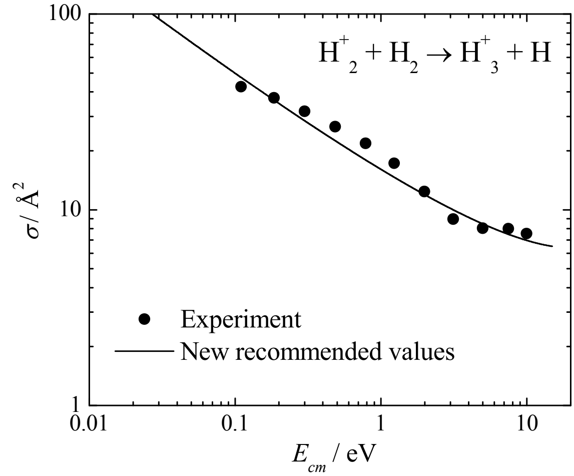

Figure 1: Measured and recommended absolute integral cross sections for reaction $H_2^+ + H_2 \rightarrow H_3^+ + H$ as function on center of mass system collision energy E_{cm}. Previous experimental and theoretical results can be found in (Savić et al. 2020)

Some preliminary results have been measured for the reaction

$$HeH^+ + H_2 \rightarrow H_3^+ + He \quad (2)$$

at a nominal laboratory energy of E_1 = 84 meV, corresponding (for this mass ratio) to an effective temperature of 300 K. For comparing our result with published data, we converted the measured effective cross section into an effective reaction rate coefficient *k*. This value is presented in Table 1 together with those obtained with other techniques – see (Anicich 2003) and references therein.

T (K)	*k* (cm^3s^{-1})	*Technique*
300	$8.6 \cdot 10^{-10}$	GIB (This work)
298	$1.83 \cdot 10^{-9}$	ICR
300	$> 1 \cdot 10^{-9}$	DT
296	$1.5 \cdot 10^{-9}$	SIFT

Table 1: Reaction rate coefficient for reaction $HeH^+ + H_2 \rightarrow H_3^+ + He$. (ICR - Ion Cyclotron Resonance Mass Spectrometry, DT - Drift Tube, SIFT - Selected Ion Flow Tube)

Our value measured with the GIB is almost 2 times lower than literature values and this stimulated us to explore this reaction over a wide range of collision energies. It is interesting to note that the literature data are reached at elevated collision energies, indicating non-thermal conditions, especially in the ICR instrument. The article on this topic is in preparation.

Conclusion of this contribution is that a new versatile and sensitive GIB instrument is operational in Novi Sad and that will successfully contribute to understanding of plasmas.

Acknowledgements

Financial support by the Deutsche Forschungsgemeinschaft (DFG) is gratefully acknowledged, especially via SCHL 341/17-1.

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