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2012 J. Phys.: Conf. Ser. 388 062047

(http://iopscience.iop.org/1742-6596/388/6/062047)

Journal of Physics: Conference Series **388** (2012) 062047 doi:10.1088/1742-6596/388/6/062047

Dissociative recombination of D_2Cl^+ and other astrophysically relevant polyatomic ions

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Synopsis We report on dissociative recombination measurement of D_2Cl^+ using low-energy-spread merged electron and ion beams.

Dissociative recombination (DR) of molecular ions plays a key role in controlling the charge density and composition of the cold interstellar medium (ISM). Experimental data on DR and reliable predictions based on a good knowledge on the underlying quantum mechanisms are required to understand the chemical network in the ISM and related processes such as star formation from molecular clouds. Needed data include not only total reaction cross sections, but also the chemical composition and excitation states of the neutral products.

Utilizing the TSR storage ring in Heidelberg, Germany, we are carrying out DR measurements on polyatomic molecular ions using a merged electron-ion beam technique together with a recently introduced energy- and position-sensitive imaging detector to record the fragments [1]. Absolute rate coefficients are obtained from the DR fragment count rates. The measurement of the kinetic energies of the fragments allows for their mass identification and thus to identify the fragmentation channel for each DR event. The fragment distances on the imaging detector provide information on the reaction kinematics as well as on the initial and final excitations. Such combined information is essential for studies on DR of polyatomic ions with multi-channel, multi-fragment breakup.

Our work here focuses on H_2Cl^+ and other molecular systems relevant for astrochemistry. H_2Cl^+ plays an important role in the chlorine chemistry of the ISM and was predicted to be abundant in both surface and core regions of dense interstellar clouds [2]. This was partly confirmed by the recent Herschel discovery of H_2Cl^+ towards NGC 6334I [3], however, the observed abundances are significantly higher than those predicted by existing astrochemical models. As DR has been identified to be a dominant destruction channel of interstellar H_2Cl^+, the DR rate coefficient is a crucial parameter for its abundance in ISM. Moreover, fragmentation branching ratios strongly affect abundances of other chlorine-bearing species, especially HCl. So far, branching ratios for the DR of H_2Cl^+ used in current astrochemical models are only estimated or adjusted to fit observed molecular abundances.

At the TSR we have performed a DR study on the isotopomer D_2Cl^+ providing complete DR data at collision energies corresponding to $T \approx 10$ K. The ongoing analysis of DR data shows that the final channel DCl + D is present with a branching ratio of at least 10%, while the branching to the D_2 + Cl channel amounts to only a few percent. The dominant channel is three-body dissociation. From fragment imaging, the strongly bent molecule D_2Cl^+ is found to dissociate mainly into two back-to-back D fragments with a negligible momentum transfer to Cl. Excited potential surfaces of neutral D_2Cl (or H_2Cl) are required to explain this behavior. This should also help to yield theoretical understanding of the astrophysical important pathway to forming D + DCl. Considerable vibrational excitation is found in the DCl and D_2 molecular fragments.

This work was supported in part by the Max Planck Society and by the NSF Astronomy and Astrophysics Grant Program.

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