Rotational-state resolved dissociative recombination measurements at the Cryogenic Storage Ring (CSR)

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Synopsis Dissociative recombination measurements performed at the cryogenic storage ring are presented. The studies yielded rotational-state resolved rate coefficients down to the ground state, which can lead to dramatic differences from previous room-temperature measurements. Furthermore, the state resolved imaging measurements give unprecedented insight into the fragmentation dynamics.

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 rate coefficients are required in order to understand the abundance of small and large molecules in circumstellar environments and in the ISM. For the laboratory studies currently the main challenge is to measure DR data at conditions relevant for the cold ISM, i.e., at temperatures of 10 – 100 K and correspondingly low rotational excitation. While past storage ring studies did reach that low collisional temperatures, they had no well-controlled access to temperatures below 300 K for the internal molecular excitation.

To overcome these limitations we have built the electrostatic Cryogenic Storage Ring (CSR) at the Max Planck Institute for Nuclear Physics, Heidelberg, Germany [1]. The ring is designed to store ion beams at energies up to 300 keV per unit charge, independently of ion mass. At 6 K wall temperature reached, cryo-pumping on the walls results in low residual gas densities and ion beam storage times of hundreds of seconds. At these conditions ions can to radiatively deexcite towards equilibrium with the cold radiation field [2,3].

The four straight sections of CSR house various experimental setups. In the electron cooler section the ion beam is merged with a cold photocathode-produced electron beam. We have recently demonstrated the electron cooling capability of that setup. The electron beam acts also as a target for experiments such as DR. From the corresponding counting and 3D-imaging detectors operated in the cryogenic environment we derive not only cross sections but also the fragmentation dynamics and internal excitations of reactants and products. A large variety of ion beams to be stored can be produced from specialized ion sources.

Several dissociative recombination experiments at CSR have been conducted so far. Among other ions we studied DR of helium hydride selectively for a number of rotational states. The results differ dramatically from previous rotationally unresolved studies performed at room temperature. The new state-selective quality of the data allows us to derive plasma rates for a variety of internal and collisional temperatures. We have also investigated the DR fragmentation geometries, observing symmetries in the DR dynamics of the ion in the rotational ground state.

References

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