Storage Ring Experiments on Electron–Molecular-Ion Interactions

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Abstract. In ion storage rings, high-velocity ion beams are recirculated in an ultrahigh vacuum using a lattice of magnetic or electric deflection elements. With magnetic devices, this is applied to molecular ion beams of typical kinetic energies of 1–3 MeV. Using photocathode electron beams [1], the phase space of stored molecular ion beams can be cooled efficiently ensuring well-controlled kinematics for collision studies. By storing the ions various means arise to control their internal excitation. At the Max Planck Institute for Nuclear Physics, we are operating the magnetic storage ring TSR (to be taken out of service at the end of 2012). It will be replaced by an electrostatic ring (CSR) for 20–300 keV·q ions, currently under construction [2]. It will provide a cryogenic environment for heavy-molecule and cluster ion beams and implement ion phase-space cooling by a cold low-energy electron beam.

Here we report on collision studies in velocity-matched merged beams of electrons and stored molecular cations, where collision energies down to ~1 meV are realized. Observed processes are ro-vibrational cooling of the molecular ions and their dissociative recombination (DR). For the latter, fragments are counted and kinematically analyzed by coincidence imaging detectors. The measurements yield collision energy dependent, absolute DR cross sections, product branching ratios, and the excitation states of the products (including their ro-vibrational excitation). The measured fragment energies also probe molecular dissociation energies.

Recent studies have focused on dissociative recombination occurring in interstellar molecular clouds and planetary ionospheres and included nitrogen and halide hydrides (HN^+, HCl^+, D_2Cl^+, D_2F^+, HF^+) and the deuterated forms of protonated species (D_3O^+, $DCND^+$) [3, 4]. An outlook will be given to upcoming merged-beams electron–ion collision studies at CSR. Among others, these studies aim at dissociative recombination cross sections and branching ratios for molecular ions at low-temperature (~10 K) radiative equilibrium (often rotational ground states); moreover, recombination cross sections between a wide range of atomic mono-cations and low-energy electrons will become accessible for merged-beams measurements.

This work was partly supported by the Deutsche Forschungsgemeinschaft Priority Program 1573 (“Physics of the Interstellar Medium”) and the U.S. NSF Astronomy and Astrophysics.

References

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