Low-Energy Electron Collisions of Molecular Ions in Ion Storage Rings

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Collisions of molecular ions with low-energy electrons have large cross sections and reflect many types of energy exchange dynamics between electronic and ro-vibrational degrees of freedom in molecular systems. In particular the dissociative recombination between electrons and molecular ions is an important process in cold ionized media, whose rate coefficient depends on detailed aspects of molecular collision dynamics such as Rydberg resonances on a ro-vibrationally excited ion core.

Merged beams of cold electrons and molecular ions in storage rings are used successfully since several years to study such reactions in energy-resolved, event-by-event collision experiments. The lecture will present work at the storage ring facility TSR in Heidelberg, Germany, which recently achieved strong improvements in the energy resolution, in the control of initial molecular excitation, and in the analysis of the dissociation products. Systems under study are mostly light di- and triatomic molecular ions. In particular the hydrogen isotopomers (H_2^+, HD^+, D_2^+) [1,2], the triatomic hydrogen molecular ion H_3^+ and isotopomers [3,4], as well as the helium dimer He_2^+ [5]. The different landscapes of electronic potential curves for these systems lead to a large variation of the reaction rates, the underlying dynamics, and the dependence on initial ro-vibrational excitation.

Improvements of the energy resolution were achieved by a new electron target [6] using a cold (100-K) photocathode electron source [7], yielding a center-of-mass electron energy spread down to ~500 μeV. The internal excitation of the molecular ions can be monitored by fragment imaging techniques. Storage of the molecules over times up to ~90 s makes it possible to observe radiative cooling of the vibrational and rotational degrees of freedom of the molecular ions. In addition, the long storage times allowed us to observe vibrational and rotational cooling of the molecular ions by inelastic electron collisions.

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1. A. AlKhalili et al., Phys. Rev. A **68**, 042702 (2003)
2. S. Krohn et al., Phys. Rev. A **62**, 032713 (2000) ; V. Ngassam, et al., Phys. Rev. A **68**, 032704 (2003)
3. L. Lammich et al., Phys. Rev. Lett. **91**, 143201 (2003)
4. D. Strasser et al., Phys. Rev. A **69**, 064702 (2004)
5. H. B. Pedersen et al., Phys. Rev. A, in press (preprint: arXiv.org/physics/0412144)
6. F. Sprenger et al., Nucl. Instrum. Methods A **532**, 418 (2004)
7. D. A. Orlov et al., J. Phys.: Conf. Ser. **4**, 290 (2005)