Dissociative recombination of internally cold CH^+ molecules

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Heavy ion storage rings provide an ideal environment for internal state preparation of atomic and molecular ions and subsequent collision experiments over a large range of collision energies using the merged-beams technique. We have studied the dissociative recombination (DR) of CH^+ in the electrostatic Cryogenic Storage Ring (CSR; [1]). In the cryogenic environment of CSR ($T < 20$ K), CH^+ ions radiatively decayed toward their lowest rovibrational states [2,3] and the internally relaxed ions were used for DR experiments. Merging an electron beam in the CSR electron cooler with the ion beam, low energy (meV) collisions could be probed. Measurements for different internal state populations enabled us to extract the rate coefficient for the (v=0, J=0) ground state.

DR reactions for CH^+(v=0, J=0) at meV collision energies are an important part of the chemistry in diffuse interstellar clouds, out of which stars and planets can form [4]. The DR rate coefficient is needed to model this chemistry and interpret astronomical observations. Theoretical calculations are not yet reliably able to produce the required DR data due to the large number of intermediate states involved in the dynamics. Thus, laboratory studies of DR are needed to understand the CH^+ chemistry. With our experimental results at diffuse cloud conditions, we have significantly increased the reliability of the CH^+ diffuse cloud astrochemical models.

References

[1] von Hahn et al., Rev. Sci. Instrum. **87**, 063115 (2016)
[2] O'Connor et al., Phys. Rev. Lett. **116**, 113002 (2016)
[3] Kálosi et al., Phys. Rev. Lett. **128**, 183402 (2022)
[4] Krumholz, Phys. Rep. **539**, 49 (2014)