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Dissociative recombination measurements of SH^+ with cold electrons

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Synopsis We have experimentally investigated dissociative recombination of SH^+ with low-energy electrons. The merged-beams rate coefficient was measured at the TSR ion storage ring in Heidelberg, Germany. From these data the cross section was extracted and used to generate a plasma rate coefficient for plasma temperatures down to 10 K, which are relevant for astrochemical models. Furthermore, we have determined branching ratios of product excitation states utilizing a novel analysis method for imaging data.

Dissociative recombination (DR) of molecular ions with free electrons is a key neutralization process in plasma environments such as the cold interstellar medium (ISM). The DR rate coefficients for various molecular ions are needed to model ISM in order to deduce its physical properties and draw conclusions on dynamical processes. SH^+ is observed in various lines of sight. However, its high abundance cannot be reproduced by current astrochemical models, with deviations up to several orders of magnitudes [1]. This may be due to an underestimated DR rate coefficient for SH^+.

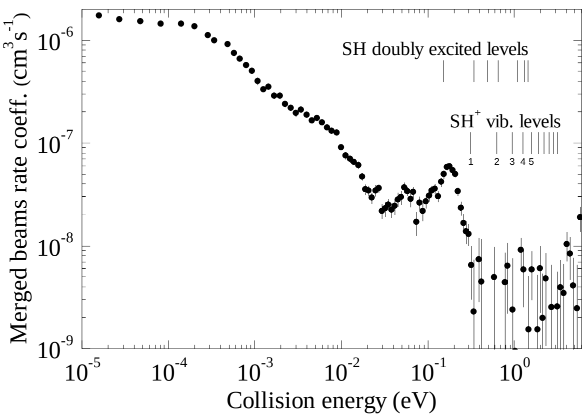

Figure 1. The measured merged beams DR rate coefficient for SH^+ as a function of mean center-of-mass collision energy. The vertical bars mark the known doubly excited electronic states of SH and the vibrational excitation energies of SH^+, all with respect to the $SH^+(X^3\Sigma^-)$ ground state. The rate coefficient enhancement at $\sim 0.04 - 0.2$ eV is attributed to an indirect DR process via neutral ro-vibrational Rydberg states in this energy range.

To this end we have experimentally investigated DR of SH^+ at the TSR ion storage ring of the Max Planck Institute for Nuclear Physics in Heidelberg, Germany. An SH^+ beam was merged with a cold electron beam produced by a photocathode. Utilizing an energy sensitive Si detector to identify neutral fragments, the recombination rate coefficient (see Fig. 1) was determined for collision energies ranging from sub-meV up to 6 eV, covering kinetic temperatures down to 10 K. The inferred DR plasma rate coefficient is not unusually low at the relevant temperatures, leading us to conclude that slow DR is not the reason for the high observed SH^+ abundances.

Moreover, we have determined branching ratios for various DR product excitation states by measuring fragment kinetic energy released on a position-sensitive microchannel plate detector. Here, most H-fragments missed the detector owing to the high mass ratio of the SH^+ constituents. With the low-emittance electron-cooled ion beam it was possible to deduce the product excitation states from the S-fragment distribution only. Our data show a preferred dissociation into a product state with sulfur excited to its $^1D_2$ level versus the ^3P ground level. This experimental method will be a valuable tool for analyzing imaging data of the heavier molecules to be stored at the new Cryogenic Storage Ring [2].

References

[1] Godard *et al* 2012 *Astron. Astrophys.* **540** 87

[2] R von Hahn *et al* 2011 *Nucl Instrum Meth B* **269** 2871

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