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Dissociative Recombination - a Key Process in Ionospheres of Giant Planets and their Satellites

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Ion reactions are amongst the most crucial processes in upper layers of planetary atmospheres. Dissociative recombination (DR) plays a particularly important role, since it usually is a barier-less process and thus feasible at the low collision energies prevalent in colder plasmas like the ones encountered in planetary ionospheres. Because of this fact it constitutes the only destruction mechanism for some ionospheric ions. DR processes are therefore included in model calculation of reaction networks for such environments, which greatly depend on the quality of the input data. Unfortunately, very often experimental results on these reactions are lacking even for the most important species. This is aggravated by the fact that, due to their exoergicity, DR reactions usually can have several pathways leading to very different products and the relative importance of these channels has often proven quite surprising. The CRYRING ion storage ring, located at the Manne Siegbahn laboratory at Stockholm University, allows measurement of DR branching ratios and cross sections at collision energies relevant to planetary ionospheres. We present such data for two different ions that are crucial for the chemistry of Io's and Titan's atmosphere, respectively: SO_2^+ and CH_3CNH^+.

The DR of the SO_2^+ ion deserves special attention since it has been detected in both the exosphere and ionosphere of the Jovian satellite Io, by both the Voyager and Galileo missions (Bridge et al., 1979, Blanco-Cano et al., 2001). Io is especially interesting in this respect since its atmosphere is actually dominated by sulfur dioxide and, consequently, its ionosphere is particularly rich in SO_2^+ ions. The branching ratio of the $S^{18}O_2^+ + e^- \rightarrow S^{18}O + {}^{18}O$ channel amounts to 61%, whilst the three body break-up $S^{18}O_2^+ + e^- \rightarrow S + 2{}^{18}O$ accounts for the remaining 39 % of the total reaction (the ^{18}O isotopomere was used for experimental reasons in the present study). The thermal reaction rate obtained followed the expression k(T) = $4.6 \pm 0.2 \times 10^{-7}$ $(T/300)^{-0.52\pm0.02}$ cm^3s^{-1}.

Protonated acetonitrile (CH_3CNH^+) might play a pivotal role in the ionosphere of Titan since a strong signal with m/z= 42 was detected in the upper by the Ion Neutral Mass Spectrometer (INMS) on board the *Cassini* spacecraft during a flyby on 2005 April 16. Due to the chemistry prevailing in the atmosphere of Titan there seems to be little doubt that this signal should be attributed to CH_3CNH^+ (Vuitton, Yelle & Anicich 2006). In the case of CH_3CNH^+ 65% of the DR events resulted into retention of the bonds between heavy atoms, whereas the remaining 35% lead to breakage of one of these bonds. From the cross section a thermal rate coefficient of k(T) = 8.1×10^{-7} $(T/300)^{-0.69}$ cm^3s^{-1} was deduced.

The impact of these findings on the chemistry of ionospheres of Io and Titan will be discussed. For the former celestial body, removal of photoelectrons by DR of SO_2^+ has been regarded as a possible reason for the fainting of FUV emissions during eclipses (Clarke et al. 1994). In the case of Titan it will be elaborated how the rates and branching ratios of the DR of CH_3CNH^+ and other nitrogen-containing ions could help to explain the abundance of these species detected by the Cassini-Huygens mission (which was much higher than the one expected by previous models).

References

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