Fragmentation from condensed methanol by soft x-rays: Relevance to solid state astrochemistry

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Introduction

Methanol (CH_3OH), the simplest organic alcohol, is an important precursor of more complex prebiotic species and is found abundantly in icy mantles on interstellar and protostellar dust grains. Additionally, methanol has been found in comets, as Hale-Bopp (Crovisier, 1998), and other solar system bodies, such as the centaur 5145 Pholus (Cruikshank et al. 1998). All of these astronomical environments are subjected to some form of ionizing agents such as cosmic rays, electrons and photons (e.g. stellar radiation field).
The enhanced abundance of methanol in the warm gas has been taken as evidence that the methanol is released from grains in these regions (Pilling et al. 2007). The difficulties in combining grain surface processes with gas phase chemical models are well known (Herbst & Shematovich 2003). Thus, simplifications and assumptions must inevitably be made. The validity of these assumptions can only be assured by developing a thorough understanding of the physicochemical processes occurring in the grain mantle. The laboratory experimentation can supply such an understanding (Green et al., 2009).

Results and Discussion

We have employed soft X-ray photons at the oxygen 1s-edge to simulate the effects of stellar radiation field on the astrophysics ices and to compare with effects produced by cosmic rays and electrons. The photodesorption experiments were carried out at the Brazilian Synchrotron Light Source (LNLS), using the Spherical Grating Monochromator (SGM) beam line, operated in the single-bunch mode of the storage ring, with a period of 311 ns and bunch width of 60 ps. Several fragments have been identified and their desorption rates per impact were determined, providing data to astrochemistry models. The results show that fragments released from 290 eV photons and 70 eV electrons interacting with methanol are mainly caused by C-H bond rupture, since the COH_n^+ group ($1 \leq n \leq 4$) yields are higher at these energies. On contrary, 537 eV photons on icy methanol tend to provide fragments due to C-O and O-H bonds rupture, since CH_2^+, O^+, H^+ and H_3^+ are the most intense fragments. Moreover, the negative spectra at 537 eV energy photons present only intense O^- and H^- ions. At 537 eV photon energy, the positive yield for CH_3OH^+ vanishes, suggesting higher degree of dissociation promoted by energetic photons at the O 1s-edge. Photons at 537 eV seem to form OH^+, despite the weak and blended peak, while electrons at 70 eV are not efficient to form such species.

Conclusions

In this work, the positive and negative desorption rates (R, desorbed ion per incident photon) of the most intense ions desorbed from methanol due to soft X-ray bombardment are estimated. The desorption rates are critical parameters for modeling the chemistry of interstellar clouds. Moreover, a comparison among our results and literature using different ionization agents and different phases (photons at 292 eV and electrons at 70 eV in the gas phase and heavy ions ~65 MeV on methanol ice) are discussed.

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