X-ray photon-induced desorption from molecular ices: indirect mechanism and astrophysical implications

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The most recent observations of small organic species in the gas phase of the coldest regions of the interstellar medium imply the existence of efficient non-thermal desorption phenomena, central to maintain a sufficient budget of molecules in the gas which should otherwise be depleted by freezing out on interstellar dust grains. This last decade, laboratory experiments have mainly focused on the desorption induced by vacuum UV photons, cosmic rays and recombinative chemistry. However, processes induced by photons of higher energy, despite being present in star and planet formation regions, were largely unknown and neglected in models, until recently. Indeed, X-ray induced desorption from molecular ices has received a peculiar attention in the past few years[4,5,6]. This process, also known as X-ray photodesorption, should participate to the physical and chemical evolution of different astrophysical environments where the X-ray field is important, such as protoplanetary disks[7]. Recent investigations[1,2,3] have revealed, in the soft X-ray range, an indirect desorption process that induces the desorption of molecules at photon energy where they are not expected to desorb. This indirect mechanism has major implications and still needs to be fully understood.

In this context, X-ray photodesorption experiments were conducted at the SOLEIL synchrotron facility in France by coupling the Ultrahigh Vacuum SPICES setup to the SEXTANTS beamline, in order to measure desorption yields by mass spectrometry, but also to shed light on the involved mechanisms. Desorption of simple molecules such as ^{13}CO and $^{15}N_2$ was studied as a simple case in order to characterize the indirect desorption process. Resonant 1s core excitation near the N (~400 eV) or O (~500 eV) K-edge, reachable thanks to tunable and high spectral resolution X-rays from the synchrotron beamline, allows to selectively photo-excite $^{15}N_2$ or ^{13}CO to trigger desorption from ices containing these molecules. This first set of experiments allows to discuss the desorption mechanisms and their properties with respect to the energy transport in the ice. Finally, X-ray photodesorption is studied for methanol CH_3OH and other small organic molecules in order to explore the desorption process for more complex molecules, especially relevant for astrochemistry.

References

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