Energetic Processing of Molecular Clusters and Astrophysical Ices by Ion Impact

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In space, the molecular matter is energetically processed by ionizing radiation and two scenarios are proposed to explain the emergence of new molecular species. On the one hand, the *bottom-up* approach proposes the growth of larger molecules from smaller subunits. On the other hand, the *top-down* scenario considers the emission of molecular species from a large piece of matter. In order to study the processes leading to the formation of complex organic molecules, we have considered ion interaction with molecular clusters or icy mantels.

Molecular systems in space are exposed to energetic ions *e.g.* solar wind or ions trapped in the Jupiter magnetosphere and cosmic rays. The GANIL facility (Grand Accélerateur National d'Ions Lourds, Caen, France), a unique tool to study ion interactions with matter, allows to study ion induced fragmentation and reactivity of such systems in a very large range of kinetic energies of projectiles (from keV to GeV, ions from He to U). Recently, we have evidenced that ion collision can lead to molecular complexification within molecular clusters: (i) intra-cluster molecular growth processes in clusters of polycyclic aromatic hydrocarbons or fullerenes (*e.g.* [1-3]). This growth is driven by the prompt fragmentation of molecules in loosely bound clusters when the impacting projectile ion deposits a large amount of energy and momentum to individual atoms through nuclear scattering (*knock-out processes*) leading to the formation of reactive species. These molecular fragments may form covalent bonds with neighboring molecules in the cluster on sub-picosecond time scales, well before the excited cluster dissociates. (ii) Formation of peptide bonds in collisions of a single He^{2+} ion with amino acid b-alanine clusters [4]. We attribute the formation of polypeptides to specific energy transfers resulting from the collision with He^{2+} ions, which are in contrast to photon collisions not localized but rather distributed along the ion trajectory in the cluster. Excitation and ionization processes in the collision, are followed by proton transfer that leads to weakly bound protonated molecular clusters. They are stabilized through the formation of peptide bonds, releasing water molecules via low energy barriers. Examples of ion processing of astrophysical ice analogues and condensed complex organic molecules (like nucleobases) will be also presented (*e.g.* [5-7]).

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