ION INTERACTION WITH MOLECULAR SYSTEMS: APPLICATION FOR ASTROCHEMISTRY

Alicja Domaracka

Centre de Recherche sur les Ions, les Matériaux et la Photonique (CIMAP) - UMR 6252, (CEA/CNRS/ENSICAEN/Université de Caen Normandie), Boulevard Henri Becquerel, BP 5133, 14070 Caen cedex 5, France

domaracka@ganil.fr

We are living in a molecular Universe [1] which contains both simple dihydrogene molecules and more complex, like fullerenes. However, the routes to form small grains in space and the rich molecular inventory of our universe are still not well understood. Therefore, the knowledge about growth mechanism, starting from individual molecular building blocks (e.g. small carbon molecules) and formation pathways of new molecules is required. In my talk I will present two examples of ion-induced reactivity in systems of astrophysical interest in the gas and the condensed phase, respectively.

The first work combines experimental and theoretical studies of the collisions between keV ions and pyrene clusters (simple PAH molecules) [2]. We have shown that low-energy ion collisions lead to intra-cluster molecular growth processes resulting in the formation of a wide range of new molecules with masses larger than that of pyrene molecule. By comparing the interaction with different low-energy ions (H^+, He^+, N^{3+}, O^{2+}, Ar^{2+}) and using coincidence mass spectrometry technique, it has been shown that the molecular growth process is triggered by nuclear stopping. The experimental results are well-reproduced by classical molecular dynamics simulation, which emphasize the role of prompt knockout of C and/or H atoms from one or several molecules in the cluster due to interaction with the projectile. Subsequently, reactive fragments may interact with intact neighbouring molecules. Moreover, we obtained absolute cross sections of molecular growth. The present results are relevant to understand the physical chemistry of the PAH-rich upper atmosphere of Saturn's moon Titan, indicating that ions can play an important role in particle growth. Furthermore, this opens new perspective to study the molecular growth from linear hydrocarbons to cyclic ones and PAHs in an astrophysical environment.

The second example is dedicated to implantation experiments which are particularly relevant to understand the effects of different ion populations such as solar wind ions and magnetospheric particles, interacting with icy objects in the Solar System. The major components of the Jovian magnetosphere are protons and ions such as S^{q+} and O^{q+}. Their high fluxes justify the need of implantation experiments that are conducted to contribute to the debate on the origin of the observed minor molecular species (CO_2, SO_2, and sulfuric acid): are they native of the given satellite (*endogenic source*) or are they due to external effects such as ion implantation (*exogenic source)*? We have shown that sulfur ion implantation is the dominant formation mechanism of hydrated sulfuric acid on the moon Europa. Moreover, the suggestion that the observed distribution of sulphuric acid on Europa's surface is well correlated with the local flux of sulfur ions, finds a full explanation by obtained experimental data. Mentioned above examples clearly indicate that ion-mediated reactions should be considered in modeling of astrochemistry occurring in atmosphere and on surface of different planets.

[1] A. G. G. M. Tielens, Rev. Mod. Phys. 85 (2013) 1021
[2] R. Delaunay et al, J. Phys. Chem. Lett. 6 (2015) 1536
[3] J.J. Ding et al, Icarus 226 (2013) 860