(Ultra)cold ion-neutral collisions for new (astro)chemistry

M. Hejduk[1], N. Coughlan[1], J. Toscano[1], L. Petralia[1], A. Tsikritea[1], J. Elworthy[1], H. McGhee[1]
T. P. Softley[2] and B. R. Heazlewood[1]

[1] *PTCL, Department of Chemistry, University of Oxford, South Parks Road, Oxford OX1 3QZ, United Kingdom*

[2] *University of Birmingham, Edgbaston, Birmingham B15 2TT, United Kingdom*

Our ultimate goal is to study low energy ion-neutral reactions on the threshold of the so called "quantum regime", i.e. under conditions when the de Broglie wavelength of the particles is comparable to their dimensions. Furthermore, in order to reveal the full quantum nature of the studied reactions, it is desirable to have the reactants in defined (electronic, ro-vibrational) quantum states. Such demands on the reaction environment are not unnatural at all, as temperatures in pre-stellar cores regularly reach approximately 10 K [1] and emission nebulae can reach temperatures lower than 3 K of the microwave background radiation [2].

One way to achieve our objective is to store the ionic species in a cryogenic ion trap and inject very slow neutral particles into it. As the temperature of the ions has to be very low (a few Kelvin), they must be cooled sympathetically in a Coulomb crystal [3]. This would only decrease their kinetic energy, though, so buffer gas cooling has to be employed as well. The neutral reactants can be slowed down in Zeeman or Stark decelerators.

Exactly this kind of equipment is being developed in our group. Internal temperatures of ionic species will reach < 10 K and the velocities of the neutral species will be as low as several tens of metres per second. The reaction products, including those trapped in local minima of potential energy surfaces, will be analysed by a time-of-flight mass spectrometer, by analysis of the Coulomb crystal's fluorescence image, and by action spectroscopy. To our knowledge, this will be the first cryogenic Coulomb crystal device that incorporates neutral particle slowers with these analytical methods.

Here we are going to present the current state of development and plans for the first measurements.

References

[1] A. Roy, Ph. André, P. Palmeirim et al., Astronomy & Astrophysics **562**, A138 (2004)

[2] R. Sahai and L. øA., The Astrophysical Journal Letters **487**, L155 (1997)

[3] B. R. Heazlewood and T. P. Softley, Annual Review of Physical Chemistry **66**, 475 (2015)