Surface science investigations of small aromatic molecules in astrophysical ices

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The interstellar medium (ISM) has a rich chemistry, in spite of the low temperatures and pressures that occur there. This is in part due to the presence of dust grains, carbonaceous or silicaceous in nature, that provide a surface for molecular formation and processing. Chemical reactions on these surfaces can be induced by thermal processing, UV or electron irradiation, and gas-phase bombardment.

Around 200 molecules have been detected in astrophysical regions. Polycyclic aromatic hydrocarbons (PAHs) are thought to be one of the most abundant molecules present, and account for around 20% of the galactic carbon. Carbonaceous dust grains could be formed from the agglomeration of PAH molecules. Benzene is the simplest building block of PAHs, and it has been detected in proto-planetary nebulae [1, 2]. Formation routes of toluene and xylene, precursors to methylated PAHs, have also been postulated in interstellar and circumstellar space [3, 4].

We present laboratory investigations of a series of simple aromatic molecules of increasing molecular weight and complexity: benzene, toluene and two isomers of xylene (para and ortho). Using an ultra-high vacuum chamber (at a pressure of 10^{-10} mbar) with a base temperature of 25 K, we are able to simulate the conditions of interstellar space. Molecular ices of benzene, toluene, xylene and water are grown upon highly oriented pyrolytic graphite, a carbonaceous dust grain analogue surface. We use temperature programmed desorption (TPD) and reflection absorption infrared spectroscopy (RAIRS) to investigate the interactions between these molecules and water, both in layered configurations and as co-deposited mixtures. These techniques allow us to probe the bonding and trapping in different environments, including those more representative of interstellar conditions. We show that the size and polarity of these four molecules affect their desorption behaviour and interaction with water.

Desorption orders and energies have been calculated from data analysis of TPD traces. These parameters are incorporated into astrophysical models using non-linear interstellar heating rates. We present models for each aromatic molecule, as a pure ice and in the presence of water. These models help us to understand the implications of our work for interstellar chemistry.

References:
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