Radical-induced chemistry in interstellar ices: intermediates characterization and reactivity

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Abstract

Astrophysical observations led to the identification of numerous organic molecules. Among them, some have an important number of atoms and are so called Complex Organic Molecules (COMs). COMs are species of interest since they are incorporated in small bodies of the interstellar medium and could have played a role in the emergence of life on Early Earth. Although their characterization in the interstellar medium is confident, their formation mechanism is still under investigation. The particular conditions – UV photons, hydrogen bombardments, thermal effects – makes formation mechanisms hard to be clearly identified. We focus here on radical reactivity in astrophysical conditions. Interstellar ice analogues are made in laboratory and submitted to ISM-like processes -hydrogenation, VUV irradiation, heating effect- while the chemical composition of the ice analogue is monitored by spectroscopic techniques – IR, MS and, if required, GC-MS.

Radical species produced during the experiment are difficult to analyze, due to their short lifespan and high reactivity. To overcome this problem, we use cryogenic matrix isolation technique combined with IR spectroscopy to characterize unstable species and observe their reactivity(1, 2). Nonetheless, this technique detects all species – radical and non-radical molecules – leading to overlapping of some vibration modes from intermediates of interest. By using EPR spectroscopy, we are able to focus only on radical species and to detect them even in low amount.

In this work, we focus on COMs formation from VUV irradiated methanol CH3OH or formaldehyde at low temperature, from radical intermediates identification (HCO, CH2OH, CH3O) to their recombination products(4, 5, 6) (glycolaldehyde, ethylene glycol, methylformate). Quantum calculations were also performed to explain particular chemical pathways(1, 2, 3). We show that HCO dimerization does not produce glyoxal and identified a possible way to form more complex molecules from radical-initiated polymerization. Results from this study could be used to understand data from spatial mission – such as Rosetta mission – or to direct observations towards new organic molecules.

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