Characterization of Pre-Cometary Residues by Orbitrap Pyrolysis-GC-MS: A High-Resolution Approach

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Résumé

Since the Viking mission (1975), pyrolysis coupled with gas chromatography and mass spectrometry (Pyr-GC-MS) has become a commonly used technique in space exploration missions. In this context, the analysis of organic residues from interstellar ices by high-resolution pyrolysis-GC-MS (Orbitrap) is part of the continuation of analytical protocols developed in astrochemistry. We explored several analytical techniques: evolved gas analysis (EGA-MS) and thermodesorption. Previous studies on refractory organic residues from analogues of interstellar and cometary ices have revealed a high molecular diversity, notably including hexamethylenetetramine (HMT, CHN). This stable polyheterocyclic molecule is particularly interesting for understanding the abiotic formation pathways of organic compounds with prebiotic interest.

In this study, a pre-cometary organic matter analogue was synthesized from a gas mixture (HO, CHOH, NH) under conditions simulating the formation of interstellar ices on silicate grains (pressure: 10 to 10 mbar; temperature: 77 K), irradiated by VUV radiation to reproduce stellar radiation effects, then heated to 300 K to form an organic residue. The residue was solubilized in methanol and analyzed by pyrolysis-GC-MS after solvent evaporation. The setup includes a furnace pyrolyzer (Multi-Shot EGA/PY-3030D, Frontier Lab) coupled to a GC Trace 1310 and a high-resolution mass spectrometer Q-Exactive FT-Orbitrap (Thermo Fisher Scientific).

The EGA-MS analysis revealed two predominant desorption profiles. Thanks to the high mass resolution of the Orbitrap analyzer, the identification of hexamethylenetetramine (HMT) in the first profile was achieved with an error of less than 2 ppm, along with a polymer of HCN type in the second desorption profile. This method provides an initial overview of the residue's composition, along with information on the desorption temperatures of the compounds. Thermodesorption-GC-MS analysis then confirmed the presence of HMT and identified several of its derivatives, in agreement with the literature.

*Intervenant

Mots-Clés: Astrochemistry, Pyrolysis, GC, MS, Interstellar Ice Analogue