

EXPLOITING TUNABLE VACUUM ULTRAVIOLET PHOTOIONIZATION COMBINED WITH REFLECTRON TIME-OF-FLIGHT MASS SPECTROMETRY TO UNRAVEL THE NITROGEN CHEMISTRY OF COMPLEX ORGANICS IN THE INTERSTELLAR MEDIUM

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For more than half a century, gas-phase reaction networks of rapid ion-molecule and neutral-neutral reactions have played a fundamental role in aiding our understanding of the evolution of the interstellar medium (ISM). However, with about 200 molecules detected in interstellar and circumstellar environments, these models fail to explain the synthesis of ubiquitous complex organic molecules (COMs) – organics containing several atoms of carbon, hydrogen, nitrogen, and oxygen – predicting abundances which are lower by several orders of magnitude compared to observations toward hot molecular cores like Sagittarius B₂(N). Here, we report that key COMs - methanimine (CH₂NH) and ethylenediamine (NH₂CH₂CH₂NH₂) along with n-methylformamide (CH₃NHC(O)H) can be synthesized within interstellar ices containing methylamine (CH₃NH₂) at temperatures as low as 5 K via an facile non-equilibrium chemistry initiated by energetic electrons initiated by galactic cosmic rays once penetrating interstellar ices. After the radiation exposure, the subliming molecules were analyzed isomer selectively after single photon vacuum ultraviolet ionization coupled with a reflectron time-of-flight mass spectrometer (PI-ReTOF-MS). This methodology has several advantages compared to traditional infrared spectroscopy of ices such as the possibility to identify structural isomers of complex organics. The underlying reaction mechanisms leading to methanimine, ethylenediamine, and n-methylformamide in methylamine bearing ices are compared to the chemistry of isoelectronic methanol ices studies previously in our laboratory, revealing exciting similarities, but also differences in the synthesis of complex organic molecules in the interstellar medium.

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