Formation of the simplest amide in molecular clouds: formamide and its derivatives in interstellar ice analogs upon VUV irradiation

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Formamide has been astronomically identified in various star-forming regions and comets, suggesting the simplest amide might have a cold origin in interstellar molecular clouds before a star formed. Solid-state studies in the laboratory have proven the possible NH_2CHO formation in interstellar ice upon (non-)energetic processing at cryogenic temperatures.[1,2,3] However, it is under debate whether one of the proposed formation mechanisms via radical-radical recombination reactions forming interstellar large organic molecules is still valid in an abundant H_2O environment.[4] This work, for the first time, aims at verifying the formation of NH_2CHO and its chemical derivatives in $CO:NH_3$ ice mixtures with or without H_2O triggered by the cosmic ray induced secondary vacuum UV photons (mainly H_2 emission bands at ~160 nm). The goal of this study is to reveal a potential chemical network involving the three abundant molecules H_2O, CO, and NH_3 in interstellar ice and underpin the formation of complex organic molecules (COMs) in H_2O-rich ice mantles.

Three selected interstellar ice analogs, including $H_2O:CO:NH_3$ (10:5:1), $CO:NH_3$ (4:1), and $CO:NH_3$ (0.6:1), were studied in an ultra-high vacuum chamber at 10 K. Fourier-transform infrared spectroscopy (FTIR) was used to monitor in situ the initial and newly formed species as a function of photon fluence. The infrared spectral identifications are complementarily secured by a temperature-programmed desorption (TPD) experiment combined with a quadrupole mass spectrometer. The experimental results show that the UV photolysis of $CO:NH_3$ ice mixture mainly leads to the NH_2CHO formation with its chemical derivatives, including isocyanic acid (HNCO) and cyanate (OCN^-). The formation kinetics suggest a strong dependency on the initial ice composition; the highest production yield of NH_2CHO is observed in the H_2O-rich ice mixture. The proposed reaction network (Fig. 1) and its astronomical relevance are further discussed.

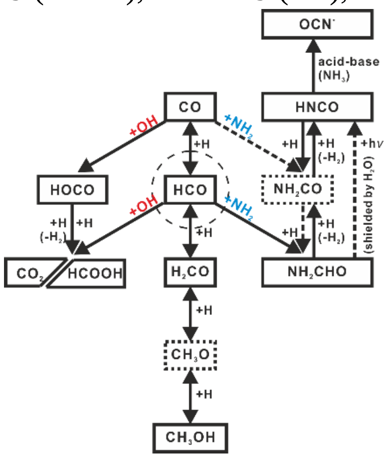

Figure 1. Proposed reaction diagram linking simple interstellar molecules at 10 K upon UV photons impact.

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