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Cold origins: Prebiotic Chemistry at the ice matrix

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Abstract

The *ice world* experimental model (i.e., the chemical evolution in the range between freezing point of water and the limit of stability of liquid brines, ≈273 to 210 K) is summarized. Overall, the ice matrix is an adequate environment for the abiotic synthesis of nitrogen heterocycles (including nucleobases).

1. Introduction

The origin of nucleobases and other heterocycles is a classic question in the chemistry of the origins of life. The construction of laboratory models for the abiotic synthesis of nitrogen heterocycles in plausible natural conditions also aids the understanding and prediction of chemical species in the Solar System. If we support the idea of a prebiotic origin of nucleobases, a "cold origin of life" [1] or "ice world" is the preferred prebiotic environment because the nucleobases would be stable under cold conditions, and such an environment supports the relevance of eutectic water solutions of reactants in an ice matrix. During the lasts years, we performed a series of experiments [2,3] which demonstrate the feasibility of the prebiotic synthesis of nucleobases at the ice matrix in the range of existence of eutectic solutions of organic solutes.

2. Results

The irradiation (by spark discharges or UV irradiation) of an atmosphere containing methane/ nitrogen or acetylene, lead to the formation of organic precursors whose fate depends on the environmental conditions. If a water pool is present at a temperature sufficiently low as freeze-thaw cycles are set, products of atmospheric irradiation could react with organic solutes, especially in the concentrated brines formed during the freezing process. The low temperature and freezing gives different results from the classic prebiotic chemistry simulations. Thus, the irradiation of a system composed by methane-rich atmosphere and an ice pool (Figure 1), lead to the concentration of polycyclic aromatic hydrocarbons in water. If a nitrogen solute is present in eutectic solutions, as urea, the formation of pyrimidines (mainly uracil) and purines (mainly adenine).

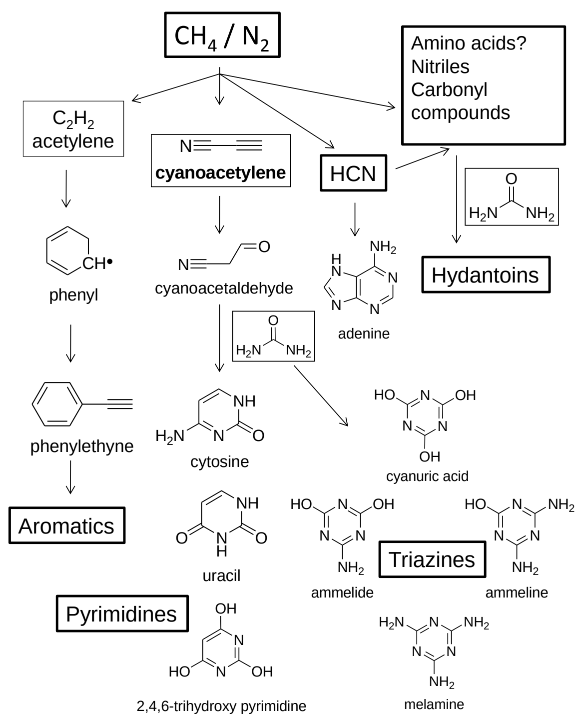

Figure 1: Summary of the products found by prebiotic chemistry simulations based on methane/nitrogen atmospheres and water in the temperature range between -25ºC and the water triple point. The cold conditions favor the formation of nitrogen heterocycles.

If acetylene (a molecule that has received little attention in the development of Prebiotic Chemistry) is present in the atmosphere, its photolysis products could react with efficient condensing agents, as urea, leading to the efficient formation of nitrogen heterocycles (Figure 2).

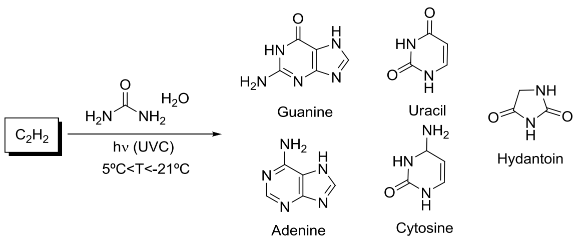

Figure 2: Summary of the prebiotic chemistry of acetylene in presence of urea eutectic solutions.

3. Summary and Conclusions

The cold prebiotic chemistry experimental model could contribute to the understanding of chemical evolution in cold water-rich planetary environments.

The experiments performed demonstrated that the synthesis of aromatic hydrocarbons, purines and pyrimidines and other nitrogen heterocycles of potential prebiotic interest (such as triazines and hydantoins) are favoured in the ice matrix by classic cyanide and cyanoacetylene pathways or by condensation of acetylene photolysis products. Despite these results, the experimental prebiotic chemistry in the solute-concentrated solutions that fill the space confined by ice matrix has received relatively little attention in the elaboration of the models for the origin of organics in Solar System bodies and prebiotic evolution. Consequently, it is necessary to perform more experiments under plausible prebiotic conditions, especially if geochemical models support stable icy environments on the prebiotic Earth. The *ice world* constitutes an interesting prebiotic chemistry scenario that awaits further investigation

References

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