The Robustness of the Urea-Ammonium Formate-Water Mixture as a Prebiotic Solvent

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Introduction:

The dehydration reaction between a phosphate mineral and an organic substance is unfavorable in a water-based environment. On the early Earth it is hypothesized that apatite was the dominant phosphate mineral [1]. Phosphates are poorly soluble and poorly reactive in water under typical (pH ~7) conditions. This is problematic because an efficient process for the synthesis of organophosphates relies on the availability of soluble and/or reactive phosphorus compounds.

Purpose of study:

A semi-aqueous solvent consisting of urea (U), ammonium formate (AF), and water (W) was investigated for the range of fluid-forming conditions potentially available. This solvent was chosen due to the prebiotic nature of the compounds and their prebiotic availability [3,4]. In recent work this semi-aqueous solvent, in the 1:2:4 (U:AF:W) molar ratio, has been shown to create formamide under mild conditions. Furthermore, phosphate minerals are increased in solubility and phosphorylate of nucleosides proceed spontaneously in appreciable quantities [5].

Methods:

The solvent, in varying U:AF molar ratios, were analyzed in a mild environment of an open system heated to 70 °C. The solvents were scanned with H-NMR to determine the composition of fluids present in these solvents over a one week period. Following this study the solvents, in varying molar ratios, were then subjected to wet/dry cycling over a 1 month time frame and again analyzed by H-NMR to determine final compositions.

Significance:

This semi-aqueous solvent has demonstrated robustness through various conditions. Independent of initial molar ratios, the composition of this solvent settles onto a specific final composition in which a four compound milieu of urea, ammonium formate, formamide, and water was created. The one-pot, “warm little pond” origin of life hypothesis was suggested by Charles Darwin in 1871. This work gives credence to this postulate demonstrating that the “pond” may actually be a very robust semi-aqueous solvent composed of simple inorganic compounds that arises spontaneously under a number of geochemical conditions, and enhances solubility of phosphates while simultaneously permitting dehydration reactions.

References:

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