Compatibility of amino acids in ice: Implications for the origin of life in a freezing world

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Due to the faint young sun, icy environment may have been common on the primitive Earth. Previous studies have proposed that the formation of large icy bodies in the early ocean could concentrate the building blocks of early life from the diluted 'primordial soup' in eutectic fluids and therefore facilitate the polymerization of monomers. This hypothesis of a cold origin of life is based on the assumption that organic molecules are virtually incompatible in ice Ih. However, so far, there is still lacking experimental measurements of partition coefficients of organics between aqueous solution and ice.

In this study, we conducted freezing experiments to explore the distribution behavior of selected amino acids, alanine and glycine between ice Ih and aqueous solutions analog to seawater. We let ice crystals grow slowly from a few seeds in equilibrium with the solution by decreasing temperature very slowly and used Raman spectroscopy to analyze *in situ* concentrations of amino acids in both of ice and solution. Preliminary results showed that considerable amounts of alanine or glycine existed in the ice phase. In addition, there was no precipitation of alanine or glycine crystal during the experiment, meaning that the concentration of amino acids in solution never reached their solubility limit, even close to the solidus. These observations implied little or no incompatibility of alanine and glycine in ice during the freezing of the solutions, if not a small compatibility. Further analysis will be conducted to determine the partition coefficients of alanine and glycine between ice Ih and aqueous solution as a function of temperature.

Our experimental results suggest that small organic molecules can be incorporated into the structure of ice Ih during freezing of aqueous solutions, thus rendering the hypothesis of a cold origin of life debatable. However, this study agrees well with the extraterrestrial delivery of organic molecules in the icy comets and asteroids to the primitive Earth as supported by an increasing number of observations.