Formation of Macromolecular Amino Acid Precursors from CO in Planetary Atmospheres and Interstellar Media

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Methane has been considered as a major carbon species for prebiotic chemistry [1]. In these days, however, it was suggested that not methane, but carbon monoxide was a major reducing carbon species in early Earth atmosphere [2] as well as in interstellar media. We examined possible formation of complex organic compounds including amino acid precursors in the mixtures with carbon monoxide as a carbon source by such energies as high energy proton irradiation.
Mixtures of carbon dioxide, carbon monoxide, nitrogen and water vapor with various mixing ratios were irradiated with high energy protons simulating the action of galactic cosmic rays and solar energetic particles. Methane or ^{13}C-labelled carbon monoxide were used in place of carbon monoxide in some experiments. Resulting products dissolved in water were analyzed with and without acid-hydrolysis. Amino acids in the hydrolysates were determined by HPLC and GC/MS. Unhydrolyzed products were subjected to characterization by various analytical methods.
It was reported that the amino acid yield from the CO-N_2-H_2O mixture by spark discharges was much lower than the CH_4-N_2-H_2O mixture [3]. In the case of proton irradiation, however, the CO-N_2-H_2O mixture could give amino acids with almost the same energy yield as the CH_4-N_2-H_2O mixture [4,5]. CO_2-CO-N_2-H_2O also yielded amino acids whose energy yield depended on CO mixing ratio: When the gas mixture of CO_2 (42%)-CO (8%)-N_2(50%) with water was used, the energy yield (G-value) of glycine was 0.005. If we use the energy flux of the solar energetic particles 4 billion years ago (3×10^{24} eV m^{-2} yr^{-1}), we can expect 10^{10} kg yr^{-1} of glycine formation rate then, which was much higher than the delivery rate of extraterrestrial amino acids ($< 3 \times 10^5$ kg yr^{-1}) [6].
On the other hand, complex organics could be formed in ice mantles of interstellar dust particles in molecular clouds, which contained carbon monoxide [7]. When an icy mixture of carbon monoxide ammonia and water was irradiated with protons, amino acids could be formed [8,9]. It was shown that carbon monoxide was an important carbon source in synthesis of complex organic compounds including amino acids in interstellar environments.
Macromolecular complex organic compounds were formed when mixtures containing carbon monoxide were irradiated with high energy protons [10,11]. The Strecker synthesis is one of the most popular formation mechanisms of amino acids in both planetary and interstellar environments [12]. We found that not aminonitriles, the intermediate of the Strecker synthesis, but macromolecular complex organics were the major amino acid precursors. It was suggested that formation of macromolecular complex organics directly formed from mixtures containing carbon monoxide was an important step to consider the prebiotic chemical evolution pathways toward the generation of life.
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