July 16-21, 2017 at UC San Diego, CA, USA

Roles of Solar Energetic Particles in Production of Bioorganic Compounds in Primitive Earth Atmosphere

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Introduction: A large number of experiments have been conducted to examine possible formation of bioorganic compounds such as amino acids in the primitive Earth atmosphere. Amino acids were easily formed from strongly reducing gas mixtures by spark discharges, ultraviolet light, and other sources. Current models of the early Earth atmosphere were modified to less reducing environments, such as a mixture of CO_2, N_2 and trace amount of reducing carbon species like CH_4 [1]. Simulation experiments suggest, however, that amino acid formation is strongly inhibited under these conditions [2]. We examined the formation of amino acids from such slightly reducing gas mixtures by applying ionizing radiation to simulate the action of galactic and solar energetic particles, though they have been ignored as prebiotic energy sources for their lower energy fluxes [3].

Experimental: Gas mixtures of N_2, CO_2 and CH_4 (total 700 Torr) were introduced to a Pyrex tube together with 5 mL of pure water. The gas mixture was irradiated with 2.5 MeV protons from a Tandem accelerator (Tokyo Tech, Japan). The same composition of gas mixtures were subjected to spark discharges by using a Tesla coil. Each product was acid-hydrolyzed and was subjected to amino acid analysis by HPLC and/or GC/MS.

Results and Discussion: Amino acids were detected when gas mixture with CH_4 molar ratio (r_{CH4}) was as low as 0.5 % was irradiated by energetic protons. The maximum of G-value in production of glycine is reached at r_{CH4}=5%. However, when the same mixture is subject to the irradiation by the spark discharge (accelerated elecrons) or UV irradiation, amino acids were not detected for r_{CH4} lower than 15 %. Considering fluxes of various energies on the primitive Earth [4], energetic protons appear to be an efficient factor to produce N-containing organics than any other conventional energy sources like thundering or solar UV emission irradiated the early Earth atmosphere.

Not only galactic cosmic rays, but also frequent solar energetic particles (SEPs) associated with solar explosive events could have served as energy sources for prebiotic chemistry in the atmosphere of early Earth. Frequent superflares have been observed in young sun-like stars [5], which suggests that high energy SEPs produced during solar magnetic storms could have been efficient in supplying energy for efficient production of HCN and N_2O [6]. Further experimental studies of effects of SEP events on prebiotic chemistry on primitive Earth are in progress.

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