Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

BAO01-P02 Room:Convention Hall Time:May 21 18:15-19:30

Experimental studies on abiotic formation of amino acid precursors from interstellar media by cosmic rays

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Various organic compounds including amino acid precursors have been found in extraterrestrial bodies such as meteorites and comets, and their relevance to the origin of life are discussed. It has been suggested that these extraterrestrial organics were formed in interstellar media in dense clouds. In the present study, we examined possible formation of amino acid precursors from interstellar media by irradiation of high-energy protons or heavy ions.

Carbon monoxide (350 Torr), ammonia (350 Torr) and liquid water (5 mL) was put in a Pyrex tube, and the gas mixture was irradiated with 2.5 MeV protons from a Tandem accelerator (Tokyo Institute of Technology). Total electric quantity irradiated was 1 - 4 mC, and the products were hereafter referred to as CAW. Gas mixtures of carbon monoxide (350 Torr) and ammonia (87.5 - 350 Torr) were also irradiated with 2 mC of 2.5 MeV protons, and the products were referred to as CA. A mixture of methanol, ammonia and water (molar ratio was 1:1:2.8) was irradiated with heavy ions (290 MeV/u carbon ions, or 500 MeV/u argon ions) from HIMAC, NIRS, Japan. Total irradiation dose was 1.5 - 15 kGy, and the products were referred to as MeAW. All the irradiated products were acid-hydrolyzed and then were subjected to amino acid analysis by HPLC and/or GC/MS.

When the gas mixture was irradiated with protons, white mist was formed in the gas phase that suggested that high molecular weight organic compounds were produced in the gas phase by the action of high-energy protons. The products dissolved water yielded a wide variety of amino acids after acid-hydrolysis. In all the CAW and CA products, glycine was predominant, followed by aspartic acid, serine, alpha-aminobutyric acid and beta-alanine. Yield of each amino acid was proportionate to the total electric quantity (or the total dose to the gas mixture). Heterocyclic compounds including uracil were also identified in CAW. MeAW also yielded glycine and other amino acids after acid-hydrolysis, but the yield of amino acids was not proportionate to the total dose.

The facts that solid products (mist) were formed in the gas mixture by proton irradiation and that the amino acid yield were proportionate to the dose showed that high molecular weight amino acid precursors were formed directly from the gas mixtures. Further study including irradiation to simulated interstellar ices will be done to examine possible formation mechanisms of amino acid precursors in space.

Keywords: cosmic rays, interstellar media, amino acid precursors, proton irradiation, origins of life, heavy ions