

## Amino acid analysis of photochemically processed interstellar ice analogues

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Amino acids are one of major constituent of living organisms on the Earth, so they are essential molecules for the origins of life. Many scenarios for the endogenous production of amino acids on the early Earth have been proposed [e.g., 1, 2]. On the one hand, the extraterrestrial delivery of them is also considered as a likely candidate [e.g., 3, 4]. Carbonaceous chondrites are known to contain abundant amino acids up to 250 ppm [5] and more than 80 species were identified [6]. In addition, the simplest amino acid: glycine was also detected in the cometary grains returned by stardust mission [7]. The extraterrestrial amino acids are considered to have been formed by aqueous alteration on the meteoritic parent bodies or in the presolar interstellar environments. Although, the formation process, as well as the place to be taken, is still on a debate, the existence of amino acid in comets as well as the isotopic signatures of them suggest that at least some amino acids and the precursors of them are interstellar origin [8].

In the study, we conducted laboratory experiments to synthesize interstellar ice analogues from typical interstellar gases and analyzed their amino acid composition. For the experiments that simulate the condition in the interstellar medium (ISM), we utilized an apparatus called PICACHU: Photochemistry in Interstellar Cloud for Astro-Chronicle in Hokkaido University. In this PICACHU apparatus, the typical ISM gases ( $\text{H}_2\text{O} : \text{CH}_3\text{OH} : \text{NH}_3 = 2:1:1$ ) were introduced into the chamber and deposited onto the surface of a sappier glass there, which were refrigerated at  $\sim 12$  K. During the deposition of the ice, UV photons were continuously irradiated under highly vacuumed condition for 71 hours, because photochemical reactions in the ice, which were processed by stellar ultraviolet (UV) photons and cosmic rays, are important for the formation of complex organic molecules in ISM. In addition, we made two ice samples and one of them was further irradiated by UV for 232.5 hours after heated to room temperature in order to simulate subsequent decomposition in warmer environments. Then, the organic residues of the two ice samples were extracted by methanol and analyzed by GC-MS and GC/NPD after the derivatization for GC analysis.

The results showed that 11 species of amino acids were formed in the interstellar ice analogues, which were irradiated only at  $\sim 12$  K. The most abundant amino acid was glycine and the second most abundant one were  $\beta$ -alanine and alanine. Their abundances are about fourth of that of glycine. The abundance of each amino acid generally decreased with the increase of the carbon number of the amino acids. This trend was consistent with the previous study [9]. Then, the further irradiated sample showed the general decrease in the abundances of amino acids, but some of them were still remained. The survived ratio differed among amino acids and glycine was the most resistant to the irradiation ( $\sim 80\%$  remained.). These results indicate that amino acids can be formed by the UV irradiation to the interstellar ice and can survive subsequent irradiation in the warmer environments.

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