Amino acid production by heating and gamma-ray irradiation experiments simulating the process of aqueous alteration inside asteroids

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Organic substances such as amino acids are indispensable for the origin of life, and they could have been delivered by meteorites. The meteorites containing organic matter are known as carbonaceous chondrites, and their parent bodies have been subjected to aqueous alteration mostly due to the heat generated by the radioactive decay of short-lived radionuclides such as ^{26}Al. Macromolecular organic matter and amino acids in carbonaceous chondrites could be produced during such hydrothermal process [1] [2]. On the other hand, the possibility that the gamma-ray from the decay of ^{26}Al directly contributes to the formation of amino acids has not been considered. We have studied that amino acid precursors are formed from HCHO and NH_3 solutions by irradiation of gamma rays [3]. In this study, we investigated the effects of gamma rays for the production of amino acids from various starting solutions containing simple molecules likely excited in the small bodies such as HCHO, NH_3, glycolaldehyde, and hexamethylenetetramine (HMT)[4], and compared with the effects of thermal heating.
The following samples were prepared as starting materials: A mixture of ammonia, formaldehyde, and water in the molar ratios of (1) 5:5:100, (2) 10:5:100, (3) 5:10:100, (4) 5:0:100, (5) 0:5:100, and (6) 1:5:100; a mixture of ammonia, formaldehyde, glycolaldehyde, and water in the molar ratios of (7) 0:5:1:100, (8) 1:5:1:100, and (9) 5:5:1:100; and a mixed solution of HMT and water with a molar ratio of 5:100. Each 200 μL each of the solution was vacuum-sealed in a glass tube. The samples were heated (7 days at 80 ℃) or subjected to gamma-ray irradiation (0.15 kGy/h for 60, 600 h, 1.5 kGy/h for 60, 600 h) from a ^{60}Co source at Tokyo Institute of Technology. The experimental products were acid hydrolyzed with 6 M hydrochloric acid (24 h at 110 ℃), and then analyzed by cation exchange high performance liquid chromatography (HPLC) for amino acid concentrations.
About 10 amino acids were detected, particularly glycine, alanine, β-alanine, and γ-aminobutyric acid (GABA) were produced in high yields. A higher amount of GABA was observed in the heated samples, and a large amount of alanine was also produced in the product (3). In both the heated and gamma-irradiated samples, the amount of alanine produced was higher in the starting material of (3). Increasing the ratio of formaldehyde tended to increase the amount of amino acids produced. In the system containing glycolaldehyde, the amount of amino acids increased significantly. Gamma-ray irradiation resulted in different amounts and types of amino acids produced depending on the irradiation rate and dose, but the general regularity was not found.
In this study, we confirmed that precursors of amino acids can be formed from simple molecules that could present in interior of small bodies by energy such as heating or gamma-ray irradiation. It was found that the yields of amino acids tended to increase when the molar ratio of formaldehyde in the starting material was higher and when glycolaldehyde was added to the starting material.

References

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