Formation of Super-complex Amino Acid Precursors in Interstellar Ice Analogues by Particles Irradiation

*Kensei Kobayashi[1], Tomoyuki Matsuda[1], Shingo Enomoto[1], Midori Eto[1], Yoko Kebukawa[1], Hajime Mita[2], Satoshi Yoshida[3], Hitoshi Fukuda[4], Kotaro Kondo[4], Yoshiyuki Oguri[4]

1.Department of Chemistry, Yokohama National University, 2.Faculty of Engineering, Fukuoka Institute of Technology, 3.National Institute of Radiological Sciences, 4.Tokyo Institute of Technology

A large number of amino acids have been detected in extracts of carbonaceous chondrites, and their relevance to the origin of life on the Earth is discussed. There are several scenarios of the formation of such extraterrestrial amino acids or their precursors. One of them is the interstellar model proposed by Greenberg et al. (2002): Volatiles such as water, carbon monoxide, methanol and ammonia were frozen onto the surface of interstellar dust particles (ISDs) in dense clouds to form ice mantles. The ice mantles were irradiated with cosmic rays and UV induced by cosmic rays, and complex organic compounds were formed in the ice mantles. Such dusts with organics were aggregated into planetesimals or comets when the solar system was formed. Organic compounds were survived with some alteration during the formation of small bodies to be cometary / meteoritic organic compounds. In order to examine possible formation of complex molecules in ISD ice mantles, a frozen mixture of water, methanol and ammonia was irradiated with high-energy carbon ions (290 MeV/u) from HIMAC, NIRS, Japan. For comparison, gaseous mixtures of water, ammonia, carbon monoxide, carbon dioxide, and/or methane were irradiated with protons (2.5 MeV) from a Tandem accelerator, Tokyo Tech, Japan. Amino acids were determined by cation exchange HPLC before and after acid hydrolysis. Products, both before and after acid hydrolysis, were analyzed FT-IR for characterization.
Heavy ion irradiation of the liquid mixtures also yielded amino acids after hydrolysis. When ratio of CH_3OH and NH_3 to H_2O were decreased, amino acid yield decreased, but even in the case of CH_3OH: NH_3: H_2O = 10: 1: 37 (close to those of some of the observed interstellar ices), amino acids were detected. In the HIMAC experiment, the energy of heavy ions were quite high and pass through the target mixtures with only small part of energy was deposited to the target, which is the same situation as what happens in dense clouds. The present results suggested that amino acid precursors can be formed in water-rich ice mantles of interstellar dust particles (ISDs) by the action of cosmic rays.
When gaseous mixtures of possible interstellar media were irradiated, it was shown that carbon monoxide gave much more glycine than methane as a carbon source. However, methane was an important starting material to give alanine and other amino acids with aliphatic side chains.
Actual interstellar ices are complex mixtures of carbon monoxide, methanol, methane, formaldehyde, ammonia and so on. We can expect that a wide variety of molecules including precursors of many kinds of amino acids and nucleic acid bases could be formed in interstellar ices by cosmic rays.

Keywords: Ice mantles of interstellar dust particles, Amino acids, Super-complex organic molecules, Cosmic rays, Heavy ions bombardment

