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Studies on stabillity of nucleic acid bases by irradiation with soft X-rays and heavy ions

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Biological molecules such as amino acids and nucleic acid bases have been found in carbonaceous chondries. It was supposed that they were synthesized from interstellar media, and brought in parent bodies of meteorites or comets in the early solar system. Organic compounds in extraterrestrial bodies are exposed to both cosmic and solar radiation. Organics in microscopic cosmic dusts are, especially, exposed to high-energy solar photons including soft X-rays and extreme UV light. In the present study, we irradiated nucleic acid bases with high-energy particles and photons from accelerator, and evaluate their stability in space.

Aqueous solution of nucleic acid bases (adenine, cytosine, uracil or guanine) was evaporated to dryness on a glass plate, and was irradiated with continuous light (infrared to the soft X-ray; hereafter referred to as soft X-rays) at BL-6 of NewSUBARU synchrotron facility (University of Hyogo) under high vacuum (ca. 10^{-4} Pa). In the case of guanine, dried sample was covered with hexatriacontane to prevent sublimation during irradiation under vacuum. Irradiation through CaF_2 window was also performed in the case of adenine and uracil, where soft-X rays and UV below 130 nm were cut. Aqueous solution (1 mM each) of nucleic acid bases (adenine, uracil, cytosine) were irradiated with high energy carbon ions (290 MeV) at HIMAC (NIRS, Chiba, Japan). Nucleic acid bases after irradiation were determined by reversed-phase HPLC. Irradiated cytosine was also analyzed by MALDI-MS.

In the soft X-rays irradiation experiments, decomposition of nucleic acid bases was observed: purines (adenine, guanine) were more stable than pyrimidines (cytosine, uracil). By using a CaF_2 window, survival ratio of bases was increased. Soft X-rays were more effective for the decomposition of bases than VUV and UV. By reversed-phase HPLC analysis, no new compounds other than the original bases were detected, but water insoluble materials were observed on the glass plate. We are going to analyze the insoluble residues by MALDI-MS. Compared to the results of irradiation of amino acids and hydantoins (amino acid precursors) [1], nucleic acid bases were more stable than amino acids and hydantoins.

In the heavy ions irradiation, adenine was most stable among the bases examined. New peaks were observed in MALDI mass spectrum of cytosine after irradiation (m/z =128, 222, 237, 333, etc.), which suggested the possible formation of multimers.

[1] Y. Kawamoto et al., Stability and alteration of amino acid-related compounds against soft X-rays and extreme UV in interplanetary space, JpGU 2012.

Keywords: nucleic acid bases, soft X-rays, heavy ions, origins of life, interplanetary dust particles, meteorites