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Gas-phase chemical analysis in an open system using a 2-stage light gas gun: HCN production due to small-scale impacts

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Hydrogen cyanide (HCN) is one of the most important molecules in the origin of life. Amino acids and Nucleic acid basis can be produced from concentrated solution of HCN. We focus on HCN production by meteoritic impacts because the impact-induced HCN is concentrated into a narrow region and produced within a very short period of time.

The geologic record of the Moon investigated by the Apollo Project show that impact flux on the Earth at 3.8 ? 4.0 Gyr ago is ~103 times higher than that on the present Earth (late heavy bombardment period). In this period, the influx of both materials and energy into the Earth may have been the largest in its history. Such intense bombardment may have controlled the evolution of surface environments on the early Earth. Our goal is to investigate the production efficiency of HCN due to hypervelocity impacts and to understand the role of meteoritic impacts on the origin of life on the early Earth.

We are developing the experimental method to reproduce hypervelocity impacts in the early Earth atmosphere using a 2-stage light gas gun at JAXA. As a first step, we developed the experimental procedure of gas-phase chemical analysis in an open system. In previous studies with 2-stage light gas guns, chemical analyses were usually conducted in closed systems using containers to pretend the chemical contamination by gunpowder. In this case, thermodynamic path of shock-heated material, however, is different from natural impacts. To conduct chemical analysis in an open system, we set a large-volume chamber, an air-driven automatic gate valve, and an Al diaphragm to uprange of an experimental chamber to prevent intrusion of contaminant gas into the chamber. In this study, we used polycarbonate, polystyrene, and N2 gas as projectiles, targets, and atmospheres respectively. The total pressure in the chamber was fixed at 105 Pa. The impact velocity was fixed at 6.5 km/s. After the shoot, we measured the final gas phase products in the chamber using a detecting tube for HCN. We successfully detected HCN with molar concentration of ~50 ppm. We roughly estimated the conversion efficiency from vaporized carbon to gaseous HCN as ~0.1%.

For the future works, we are planning to a series of hypervelocity impact experiments using actual meteoritic materials and simulated early Earth atmospheres. The developed procedure can be widely used for impact-induced degassing phenomena.

Keywords: Hypervelocity impacts, Chemical gas-phase analysis in an open system, 2-stage light gas gun, Hydrogen cyanide, The origin of life, Impact degassing