LABORATORY EXPERIMENTS ON HIGH- AND LOW-TEMPERATURE PROCESSES IN THE EARLY SOLAR SYSTEM.

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Introduction: Pristine Solar-System matter is a non-equilibrium assemblage of materials that formed in various environments such as outflows of evolved stars, the Sun's parent molecular cloud, and the protosolar disk. Such pristine materials should record a wide range of physical and chemical conditions in their forming environments. Laboratory experiments have contributed to understanding the formation processes of pristine extraterrestrial materials and the formation and evolution scenario of the Solar System. In this talk I will present recent progresses in low-temperature experiments to understand molecular evolution in the interstellar medium and in high-temperature experiments to constrain the early evolution of the protosolar disk.

Photochemistry in Molecular Clouds: Water-dominated ice is the most abundant solid in dense molecular clouds. Ultra-violet irradiation to amorphous H_2O-dominated ice may contribute to synthesizing complex organic molecules, and it is important to understand physical and chemical properties of interstellar ice.

A mixture of H_2O-CH_3OH-NH_3 gas was deposited on a substrate at 10-15 K with simultaneous UV irradiation in a low-temperature photolysis apparatus [1, 2]. The photo-irradiated ice deposit, observed in-situ under an optical microscope, started bubbling of hydrogen at ~65 K, and continued bubbling up to ~140 K, where the ice crystallized [2]. This observation clearly suggests that the photo-irradiated vapor-deposited amorphous ice changed into a liquid-like low-viscosity material in a temperature range below its crystallization temperature. The liquid-like behavior was also observed for the photo-irradiated pure-H_2O amorphous ice, which was confirmed as the wetting behavior in a low-temperature TEM. The liquid-like behavior was observed only for UV-irradiated amorphous ices and not for non-UV-irradiated amorphous ices, leading us to conclude that UV-irradiation is a key process for the appearance of the liquid-like behavior. The newly found liquid-like ice is expected to enhance the formation of organic matter, including pre-biotic molecules, under certain interstellar conditions.

Gas-Solid Reactions in the Protosolar Disk: A protoplanetary disk, consisting of gas and dust, formed around the infant Sun, and a variety of chondritic constituents such as CAIs, chondrules, metals, fine dust particles in the matrices and so on formed and/or were altered through chemical reactions within the protosolar disk. Especially, reactions between condensed phases (solid and/or melt) and reactive disk gas (e.g., H_2 and H_2O) would have been essential for making chemically-diverse chondritic components. For instance, evaporation of silicate minerals and melts promoted by hydrogen [e.g., 3–5], evaporation of silicates suppressed by H_2O vapor [6], crystallization of amorphous silicates enhanced by H_2O vapor [7], and oxygen isotopic exchange between amorphous silicates and H_2O vapor [8] would have occurred in the early Solar System. Chondritic components that experienced the chemical reaction with disk gas may record physical and chemical conditions of the protosolar disk (e.g., temperature, pressure, and gas chemistry).

Crystallization experiments of amorphous forsterite in the presence of low-pressure H_2O vapor [7] showed that temperature above 630−700 K is required, irrespective of the expected range of water vapor pressure in the disk, for crystallization of amorphous forsterite dust within the disk lifetime. Amorphous silicates in the matrices of least altered carbonaceous chondrites should thus have been kept below 630–700 K prior to small body accretion. Oxygen isotopic exchange experiments between amorphous forsterite and low-pressure H_2O vapor [8] indicate that the efficient isotopic exchange occurs within the disk lifetime when the reaction occurs at >500–600 K, and that oxygen isotopic signatures of pristine amorphous silicate dust, including presolar silicate grains, would be erased when they were heated above 500–600 K in the protoslar disk.

I am grateful to my colleagues and students for experiments, analysis, and fruitful discussion. This work was supported by Ministry of Education, Sports, Science and Technology Kakenhi Grant.

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