Origin and Evolution of the Atmospheres of Titan, Triton, and Pluto: Role of Impact-Induced Vapor Cloud of Planetary Icy Materials

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Chemical reactions occurred in impact-induced vapor clouds are keys for understanding both the formation of planetary atmospheres and the chemical evolution of surface materials on planets and satellites. However, experimental investigations of chemical products by hypervelocity impacts were difficult in the previous studies using light-gas guns and powder guns. This is because chemical contaminations (such as combustion gases and gun debris) formed by these guns prevented direct measurements of produced gas species. Recently, we developed a new chemically clean technique to accelerate projectiles using a high-energy laser pulse (the laser gun). Using this laser gun, we have been investigating chemistry in impact-induced vapor cloud by measuring gas species produced by impacts onto calcite [1], sulfate salt [2], and NH_3-H_2O ice targets [3].

In this paper, we discuss impact chemistry of nitrogen- and carbon-bearing icy materials proposed to be contained in the surfaces and interiors of both outer icy satellites and dwarf planets. As for nitrogen chemistry, for example, our experimental results show that molecular N_2 is efficiently produced from nitrogen-bearing ice and salt (such as NH_3 and $(NH_4)_2SO_4$) by impacts at velocities > 8 km/s; whereas impact-induced N_2 production does not proceed by impacts at velocities < 3 km/s. These results suggest that cometary impacts onto icy satellites effectively convert nitrogen-bearing surface materials into N_2 under the high impact velocities (i.e., > 8 km/s) resulted in the gravity of giant gas planets. On large icy satellites, such as Titan and Triton, the produced N_2 would have contributed to form the N_2 atmospheres (and frosts on Triton). Considering low impact velocity of comets on Pluto (~2 km/s), however, impact-induced N_2 production is considered to be unlikely. Thus, the origin and evolution of the atmospheres of outer icy bodies would be totally different between Pluto and others. In our talk, we will also discuss impact chemistry of carbon-bearing icy materials (e.g., CO_2 ice and $NaHCO_3$) and its implications for the atmospheres and surface materials of icy satellites. Such information would be essential to interpret the observations by the ongoing and future missions to the outer solar system (e.g., Cassini-Huygens, New Horizons, and Outer Planet Flagship Mission to the Jupiter and Saturn systems).

Keywords: Titan; Triton; Pluto; impacts; planetary atmospheres.

References

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