Pressure and temperature-dependent cryotrapping of Ar in amorphous water ice

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Amorphous solid water (ASW) encapsulates ambient gases during its condensation at low temperature, reflecting the physical and chemical conditions of the surrounding environment. (Kouchi et al., 1994; Bar-Nun et al., 1985; Notesco et al., 2003). Bar-Nun et al. (1985) originally proposed that the chemical and isotopic compositions of those gases could provide clues on the physical conditions of ASW formation. It is essential to understand the mechanisms controlling the efficiency of trace gas trapping in ASW, as well as its release during crystallisation, in order to correctly interpret the volatile molecule composition in the gas phase (coma) released by the nucleus of comets, as revealed in great details by ROSETTA mission.

In the previous study (Yokochi et al., 2012), we conducted simple experiments to determine the gas trapping efficiency of inert gases during ASW formation at 77 K. In a glass volume cooled with liquid N_2, water vapor was slowly introduced in the presence of analytical grade single component gas at controlled pressure. A pressure drop of the trace gas after the ASW formation was attributed to gas trapping in the ASW. This work demonstrated that the trapping efficiency of trace gases depends on the partial pressure of the trace gas present during ASW condensation.

In order to investigate the trapping efficiency and mechanism of inert gases in ASW at conditions more relevant to cometary ice grain formation, we built a new experimental system at the University of Chicago that uses a cryocooler to attain temperature as low as 15 K, equipped with a quadrupole mass spectrometer that is capable of determining much lower gas pressures than existing gas-independent pressure gauges. Above the equilibrium vapor pressures of Ar, we confirmed the positive pressure-dependence of Ar concentration in ASW at temperatures between 45 and 70K, under a wide pressure range between 0.0005 and 10 microbars. The evolution of pressure and temperature are positively correlated in the early solar nebula. Consequently, our preliminary results suggest that the concentration of noble gases in ASW may be much lower than previously estimated.