Pressure-dependent trace gas trapping in amorphous water ice at 77 K: Implications for determining conditions of comet formation. R. Yokochi[1,2], U. Marboeuf[2], E. Quirico[2] and B. Schmitt[2] [1]The University of Chicago, Chicago, 5734 S. Ellis Ave., Chicago, IL 60637, USA (Yokochi@uchicago.edu), [2]UJF-Grenoble 1/CNRS-INSU, Institut de Planétologie et d'Astrophysique de Grenoble (IPAG), UMR 5274, Grenoble F-38041, France

Introduction: Previous experimental studies reported that amorphous water can efficiently encapsulates ambient gases during its condensation at low temperature and high deposition rates [1,2], reflecting the physical and chemical conditions of the surrounding environment. Assuming that cometary ice at least partially formed by condensation of nebula gas at low temperature in a form of amorphous ice, the experimental data was applied for determining the formation condition of the cometary ice and volatile budget of terrestrial planets [2,3,4]. In this work, we conducted new, simple and reliable, experiments at 77 K in order to understand the physical mechanism controlling the trapping efficiency of trace gases in amorphous water ice.

Method: Amorphous water ice was deposited by transferring water vapor from a volume at ambient temperature (R1) to another (R2) containing inert gas at 77 K (submerged in liquid nitrogen). The two volumes were equipped with pressure sensors allowing quantification of water ice deposition and gas lost. Heating tape was installed on the top surface of the cylindrical deposition reservoir (R2) immediately above the liquid nitrogen surface in order to minimize the zone of thermal gradient.

In most experiments, the gas pressure of R2 decreased after water ice deposition, which was interpreted as a trapping of gas into the deposited water ice. The quantity of ice deposition and gas trapping was determined by the pressure decrease in R1 and R2, respectively. Water ice formed is assumed to be amorphous since the flux of water is higher by several orders of magnitude than the rates given by Kouchi et al. [5] and clathrate formation is kinetically unfavorable.

Results: Amorphous water ice deposited quantitatively trapped gases at 77 K. The concentration of trapped gas in water ice and the partial pressure of gas during ice deposition show a clear positive correlation at low trace gas pressures (< about 20 μbar, Fig.1) for all gas species, independent of the water vapor pressure during ice deposition (i.e. deposition rate). This suggests that the efficiency of gas trapping in water ice is primarily controlled by the partial pressure of gas present with the depositing ice. The slope of this correlation, when assumed to be linear, is $(1.8 - 8.8) \times 10^{-4}$ μbar^{-1}. The trapping efficiencies of gas species decrease in the order of Kr>CH_4>CO>Ar>N_2 at 77 K, in agreement with previous studies [1,2,3]. The data depart from this general correlation at higher gas pressures and plot below the linear correlation, indicating a somewhat lower gas trapping efficiency [6].

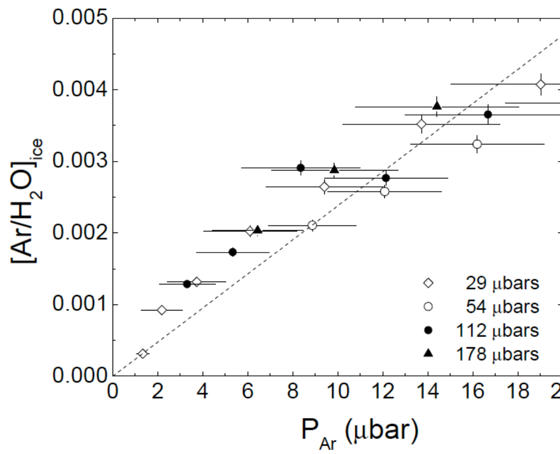

Figure 1: Correlation between Ar partial pressure and concentration of Ar in deposited ice. Different symbols represent different water vapor pressure under which ice condensed.

Discussions and Astrophysical Implications: Based on the observation that the trapping efficiency of gas is independent of (i) ice deposition rate and (ii) gas/H_2O ratio in the vapor phase, we suggest that the efficiency of gas trapping is governed by equilibrium adsorption, rather than condensation kinetics or limited gas diffusivity. This contrasts with previous studies where it has been assumed that the quantity of trapped gas scales with the ratio of the trace gas to water vapor [1,2,3]. An astrophysical implication of this result, at places in the solar nebula where amorphous ice forms, is that the partial pressure of the trace gas in ambient nebula gas would be an important controlling factor of noble gas concentration in depositing amorphous water ice, aside from temperature.

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