# Low Ar Concentration in Amorphous Water Ice

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In order to estimate the concentration of amorphous water ice formed in the early solar nebula, we conducted simple experiments where water vapor was slowly introduced in the presence of analytical grade Ar at controlled pressure and temperature. A pressure drop of the trace gas after the amorphous ice formation was attributed to gas trapping. Above the equilibrium vapor pressures of Ar, the Ar concentration [Ar] in amorphous ice was proportional to the Ar partial pressure over a wide pressure range between 0.0005 and 10 microbars, over the temperature range between 45 and 70 K, confirming the results at 77K [1].

The evolution of pressure and temperature are positively correlated in the early solar nebula. Based on the experimental [Ar]-$P_{Ar}$ and P-T correlation of the solar nebula, the Ar concentration in amorphous water is estimated between $10^{-6}$ and $10^{-9}$ for a temperature range of 20K and 100K, covering terrestrial surface value of $6.5\times10^{-8}$ [2]. Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (ROSINA) mass spectrometer detected Ar in the coma of the Jupiter family comet 67P/Churyumov-Gerasimenko; the reported $^{36}Ar/H_2O$ ratio was $(0.1\text{-}2.3)\times10^{-5}$ [3]. The observed $^{36}Ar/H_2O$ ratios are significantly higher than the estimated range of amorphous water ice formed in the solar nebula from our experiments.

The Ar and other volatiles have three possible routes for being incorporated in cometary ice: condensation, enclathration and trapping in amorphous water ice. The difference may suggest that cometary volatiles were acquired by the other two routes. Alternatively, the observed $^{36}Ar/H_2O$ ratio of the comet 67P/Churyumov-Gerasimenko could be higher than the bulk composition because of the fractionation caused by the difference in volatility during heterogeneous heating or post-formation evolution of the nucleus [4,5]. In the latter case, significant contribution of cometary materials to the Earth may be permissible from the standpoint of Ar alone.

[1] Yokochi et al. (2012) Icarus 218, 760-770. [2] Marty (2012) EPSL 313–314, 56–66. [3] Balsiger et al. (2015) Sci. Adv. 1, e1500377. [4] Hassig et al. (2015) Science 347, #aaa0276. [5] Rubin et al. (2015) Science 348 232-235.