DEVELOPING QUANTITATIVE MODELS FOR THE TRAPPING OF NOBLE GASES IN AMORPHOUS ICE.

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Introduction: Experiments show that amorphous water ice formed at low temperatures is able to trap noble gases within its structure [e.g. 1-3]. At very low temperatures (<30 K) and high deposition rates (water flux of ~10^{15} molecules/cm^2/s), the guest-to-H_2O ratio in the ice is found to be identical to that of the ambient gas in the experiment [1,2]. At higher temperatures and lower deposition rates, the concentration of the trapped species decreases in the resulting ice [2,3], though species were still present, providing a means for incorporating the otherwise volatile gases into the solid.

Trapping in this manner may explain the presence of extreme volatiles in comets and be relevant to their delivery to the terrestrial planets and Jupiter [4]. However, trapping experiments were performed at conditions which differed significantly from those expected in the solar nebula or molecular clouds. Thus, we are now developing numerical models which are tuned to reproduce experimental results and applying them to determine how efficient trapping is real astrophysical environments.

Amorphous Ice in the Solar Nebula: While all water ice in the solar nebula was thought to be crystalline due to forming at relatively high tempertures, amorphous ice formation is possible if water molecules were photodesorbed from dust grains above the disk midplane by UV photons from the young Sun and/or the ambient environment [5]. The liberated molecules returned to the grain and freeze-out at rates that were too great for the water ice to reorganize itself into a crystalline structure [5], possibly trapping gases which later were accreted into planetesimals and delivered to planets [6].

Water fluxes of 10^5-10^9 molecules/cm^2/s are expected during deposition after photodesorption [5], ~2-10 orders of magnitude less than those used in trapping experiments. As experiments suggest trapping efficiencies are highly dependent on the rate and temperature of deposition [2,3], and astrophysically relevant deposition rates are technically impossible in a laboratory setting, we are developing mathematical models to track the rates of deposition, thermal desorption, and burial of Ar and other noble gases under continually deposited water ice. Free parameters in the model, including binding energies and abundances of surface pores in the amorphous ice, are defined in order to reproduce experimental results. We are now applying these models to understand the efficiency at which Ar and other species are trapped in ice in interstellar and circumstellar environments.

Preliminary results suggest that the efficiency of noble gas trapping in amorphous ice in the solar nebula was generally lower than estimated based on experimental studies. Trapping efficiencies are found to be highly dependent on the conditions under which the ice formed, meaning that volatile contents would be very sensitive recorders of the formation conditions of comets.

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