Origin of planetary water by adsorption in the accretion disk

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Two main scenarios can account for the delivery of water to the inner planets: either the water originated outside of the inner solar system and was later delivered to the terrestrial planets or the source of water was local. A source for this 'endogenous' water could be represented by dust grains present in the accretion disk onto which water had been previously adsorbed [1].

Monte Carlo simulation of adsorption at nebular T, P and f_{H2O} onto spherical grains showed that this mechanism can store up to 3 times the Earth's oceans [2]. This model, however, did not take into account the specific surface interactions between water gas and the crystalline surface nor did it investigate rigorously the role of porosity.

To fill this gap, we are performing molecular dynamics simulations of the system water - olivine using the open source code LAMMPS [3]. The bulk olivine was modelled using periodic boundary conditions (PBC) and Buckingham potentials for the short-range interactions with a cut off distance of 10 Å for both short and long-range interactions. Long-range Coulombic interactions were calculated using the Ewald method. To allow for partially covalent bonds in the silica group and in water molecules we allowed for angle dependent forces by introducing angle interactions among triplet of atoms. The "virtual crystal" was then cleaved by removing the PBC in the positive z direction, thus creating a free surface. After the top layered relaxed we inserted water molecules and studied their trajectories. This simulation will allow construction of surface site adsorption probabilities at P, T condition of the nebula.

References

[1] Drake M.J. (2005) MAPS 39, A31.
[2] Stimpfl M., Lauretta D.S., and Drake M.J. (2004) MAPS 39, A99.
[3] Plimpton S.J. (1996) J.Comp Phys. 117, 1-19.

Origin of water by inward migration of phyllosilicates or hydrous asteroids

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Hydrated minerals occur in accretionary rims around chondrules in CM chondrites [1] . The most abundant phase is Mg-rich serpentine, which occurs as small (~20 nm) crystals with cylindrical or fibrous morphologies [2]. Previous models of gas-grain kinetics suggest that these phyllosilicates did not form by gas-solid reactions in the solar nebula [3]. However, anhydrous minerals also occur in these chondrule rims. The hydrated and anhydrous regions are in direct contact with each other, suggesting that the rims formed by accreting material from multiple nebular reservoirs [2]. These results are consistent with a nebular origin for fine-grained phyllosilicates.

We have shown that shock waves in icy regions of the nebula produced conditions that allowed rapid mineral hydration [4,5]. The time scales for phyllosilicate formation are similar to the time it takes for a shocked system to cool from the temperature of phyllosilicate stability to that of water ice condensation. This scenario allows for simultaneous formation of chondrules and fine-grained accretionary rims.

Recent calculations show that these hydrous minerals could have been transported into the hotter regions of the nebula by gas drag and incorporated into the planetesimals which formed there [6]. The hydrated minerals were able to survive for long periods of time in this hot region due to the sluggish dehydration kinetics.

The total amount of water in the Earth's hydrosphere is ~1.6×10^{24} g. Delivery of this mass of water requires the Earth to have accreted ~2.5×10^{25} g of serpentine, which is ~0.4% of the total mass of the Earth. Thus, the delivery of hydrated material to the inner solar system need not be very efficient to supply all of the water present on Earth today.

References

[1] Metzler K. et al. (1992) GCA 56, 2873.
[2] Lauretta D. S. et al (2000) GCA 64, 3262
[3] Prinn R. G. and Fegley Jr. B., Ann. Rev. Earth Planet. Sci., 15, 171
[4] Ciesla F. J. et al. (2003) Science 299, 549
[5] Ciesla F. J. and Hood L. L. (2002) Icarus 153, 430.
[6] Ciesla F. J. and Lauretta D. S. (2005) EPSL (in press)