HOW DID THE TERRESTRIAL PLANETS ACQUIRE THEIR WATER? M. J. Drake, M. Stimpfl, and, D. S. Lauretta, Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona 85721-0092, U.S.A. drake@lpl.arizona.edu

Introduction: There is no consensus on the origin of water in the terrestrial planets. Earth demonstrably has water. Odyssey has shown vast water ice sheets buried under a thin layer of dust polewards of about 60° of latitude in both hemispheres of Mars [1]. The D/H ratio of Venus is about 100 times that of Earth's oceans [2], and is plausibly explained by loss of H_2O through UV photodissociation at the top of the Venus atmosphere. Mercury and the Moon appear to be bone dry, possibly due to volatile loss in giant impacts.

Sources of water: It has generally been thought that the accretion disk was too hot at 1 AU for hydrous minerals to be stable, although the thermal history of the inner disk is based on models, not observations. Comets had been a popular choice for the source of water, as they demonstrably contain water ice. However, the measured D/H ratios in Hale-Bopp, Hyakutake, and Halley are identical within error and, if these measurements are representative of bulk comets, they constrain the contribution of cometary water to less than 15%. The ratio of Ar/H_2O in comet Hale-Bopp and Ar/O in comet LINEAR imply still lower limits on cometary water if the spectral measurements are reliable. Asteroids are dynamically plausible sources of water, but Os isotopes in Earth's mantle rule out known meteorite types as the source of Earth's water. See Drake and Righter [3] for a more thorough discussion. Inward migration of phyllosilicates has also been proposed [4].

Indigenous source revisited: Let us accept for now that the inner accretion disk was too hot for hydrous minerals to be stable and consider an alternative source of H_2O. The dust in the disk was bathed for some time in a sea of H and O. The amount of water vapor present in the accretion disk within 3 A.U. equaled about three times the Earth's mass [5].

Adsorption: It is possible that water from the gas phase could be adsorbed onto grains in the inner solar system and subsequently accreted into the terrestrial planets. Stimpfl *et al.* [6] modeled the adsorption of water from 1500K to 1000K using a Monte Carlo simulation with a grid of 10000 adsorption sites, and an iterative process allowing the surface to reach steady state saturation at each temperature. Water molecules not only interact with the substrate by means of weak bonds (~5kJ/mole) but also establish hydrogen bonds with other water molecules present in a monolayer [7]. The energy of the incoming molecules was computed using the Maxwell-Boltzmann probability distribution. We allowed only for the adsorption of one monolayer, neglected porosity and surface roughness, considered water an infinite reservoir, and assumed that all the particles interacting with the surface were water molecules.

We pulverized the Earth into homogenous spheres of 0.1 m radius. The adsorbed water potentially stored in the dust corresponds to ~3 times the Earth's oceanic + atmospheric + crustal water (OAC) [8] and ~1.5 times the Earth's OAC + mantle water [8]. If the grain size increases, however, the amount of water adsorbed on the surface decreases; in this model the biggest grain size that allows for 1 Earth's OAC water to be adsorbed is ~ 0.3 m. On the other hand, porosity and surface roughness would increase the number of adsorption sites as well as shelter adsorbed molecules from bombardment.

Non-mineral bonding: Ab initio calculations at 0°K in which the Gibbs free energy of Si – O clusters is minimized and then a H_2O molecule is introduced indicate that strong chemical bonds can be formed between the water molecule and the Si – O cluster [9], making retention of H_2O during the later violent stages of accretion more likely. These calculations need to be conducted at realistic nebular temperatures.

Conclusions: These considerations suggest that H_2O may have been obtained by the terrestrial planets directly from the gas phase in the accretion disk. The initial water budgets would be functions of P and T and, hence, heliocentric distance. Accretion of water in the presence of metal will lead to extraction of H into planetary cores and progressive oxidation of planetary mantles [10, 11]. The "feeding zones" of the terrestrial planets would be relatively narrow over most of planetary accretion, consistent with differences in O-isotopes, Cr-isotopes, and major element compositions of Earth and Mars [3]. The "late veneer" could plausibly be of asteroidal origin, consistent with dynamical calculations [8].

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