CONSTRAINTS ON H_2O AND H_2 PROPORTIONS IN THE VOLATILE ENVELOPES OF YOUNG, H_2-PRODUCING, SMALL-RADIUS EXOPLANETS. M. Melwani Daswani[1] and E. S. Kite[1], Department of the Geophysical Sciences, University of Chicago (5734 S Ellis Ave., Chicago, IL 60637, melwani@uchicago.edu).

Introduction: Small-radius exoplanets with low densities discovered by *Kepler* could have either accreted their volatiles from the nebular disk, or produced them via outgassing, i.e., through water-rock interaction. In the simplest scenario, *Kepler* exoplanets can be interpreted as rocky Earth-like core compositions, under a low molecular weight enveloping layer dominated by H_2. Two main reactions can generate H_2 in planetary formation conditions: elemental Fe oxidation [e.g., 1]:

$Fe^0 + H_2O \rightarrow FeO + H_2$ (Reaction 1),

and Fe-silicate hydration [e.g., 2]:

$6Fe_2SiO_4$ (fayalite) + $11H_2O \rightarrow 3Fe_2Si_2O_5(OH)_4$ (serpentine) + $2Fe_3O_4$ (magnetite) + $5H_2$ (Reaction 2).

In order to test the potential for small-radius exoplanets to generate the entire volatile inventory of their envelopes from water-rock interaction, we must first constrain the equilibrium H_2O/H_2 for plausible fO_2 conditions that existed during planetary formation, since the upper weight limit of the envelope is ~ 1.7 wt. % for terrestrial-like rocky core compositions [3, 4, 5].

Methods: H_2O/H_2 was calculated for 5 log units below the iron-wüstite (IW) fO_2 buffer to 2 log units above IW, at pressures of 1 and 10 kbar, and varying temperatures using the van Laar gas mixing model [6], and the compensated-Redlich-Kwong ("CORK") equation of state and CHO program by T. Holland [7] for H_2O and H_2 molar volumes in mixed gases. Low H_2O/H_2 would signify that a low molecular weight envelope could be achieved at planet-forming conditions and may be achieved by outgassing, whereas high H_2O/H_2 would produce a high molecular weight envelope – a "water-world" different from the two-layer (core + envelope) models of e.g., [8, 9].

Results: Fig. 1 summarizes the H_2O/H_2 calculations for the studied range of conditions. Overall, for fO_2 from IW-2 to IW+2, H_2O/H_2 increases at 10 kbar compared to 1 kbar, while at IW-5 to IW-3, H_2O/H_2 is comparable at both pressures. Temperature also has a more marked effect on the ratio at 10 kbar than at 1 kbar, with IW-2 to IW+2 decreasing H_2O/H_2 sharply from 200 to 1000 °C.

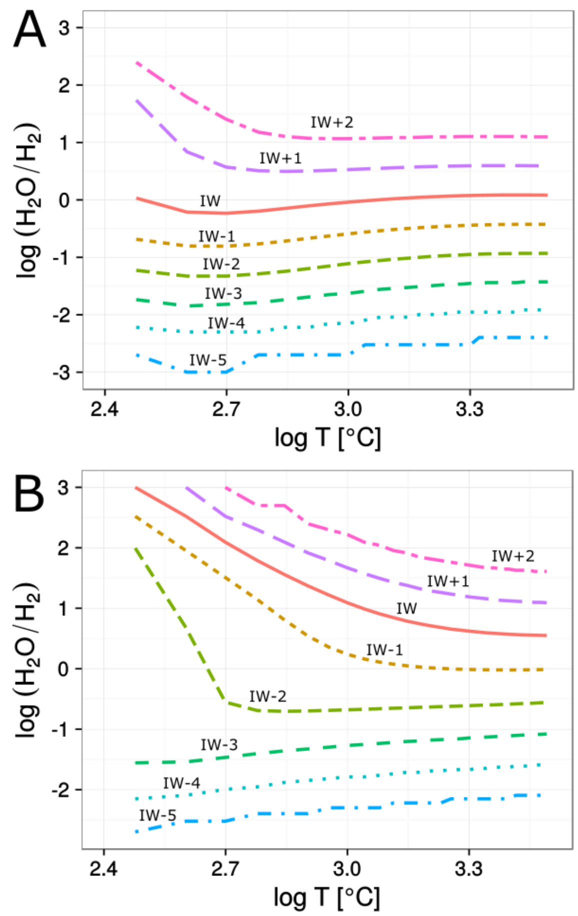

Figure 1. $\log_{10}(H_2O/H_2)$ as a function of ($\log_{10}$) temperature at specified fO_2 conditions, calculated for A) 1 kbar pressure, and B) 10 kbar.

Discussion and further work: Constraints can now be placed on the fO_2 conditions during planetary formation if outgassing produced the low molecular weight envelopes of small-radius exoplanets. Further refinements to the H_2O/H_2 could be carried out by calculating the ratio with different equations of state (e.g., Pitzer-Sterner [10]) and extending the range of H_2O/H_2 values to higher temperatures.

In future work, we will integrate these constraints with calculations of H_2 production in a thermally evolving planet using a dynamical model incorporating nebular disk migration. The model will account for H_2 accretion and loss to space, water-rock interactions during planetary accretion and up to the planetary embryo stage, and surface-interior recycling of volatiles.

The model results will be compared to constraints for the abundance of volatiles on small-radius planets discovered by *Kepler* and *K2*, using mass constraints from Radial Velocity and Transit-Timing Variation analyses.

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