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Speciation and Partitioning of Carbon and Hydrogen During Magma Ocean Crystallization

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The original budget and speciation of major volatiles, such as hydrogen (H) and carbon (C), in the silicate material and atmospheres of rocky bodies was determined during their formation and early evolution. Nearly all the large rocky bodies in the Solar System are thought to have experienced at least one magma ocean phase as an outcome of formation processes. Highly reducing conditions well below the iron-wüstite buffer (IW) characterized by low oxygen fugacity (fO_2) are expected to be prevalent during the differentiation stages of rocky bodies. In such highly reducing conditions, the effect of volatile speciation on the mineral/melt partitioning and on H solubility in olivine is largely unknown. After three decades of interest, the influence of pressure, temperature, and composition is fairly well constrained for the storage capacity and solubility of H in olivine. However, considerably less work has been conducted on the effect of fO_2 on H solubility in olivine, especially at very low fO_2, and the few available reports on this topic show substantial inconsistency. Here, we present SIMS and Raman data to determine the H content and speciation of C-O-H volatiles in olivine and silicate glasses from experiments at high pressure (1-3.5 GPa) and temperature (1435-1750 °C) (Figure 1). Using a Cr-Cr_2O_3 buffer and hydride-bearing starting material, the fO_2 is estimated to be ~ IW-4, which can be directly compared to more oxidized experiments run at ~ IW+4. Results demonstrate the systematic variance of C-O-H speciation, solubility, and partitioning as a function of fO_2. This variance can be further explored, but not sufficiently predicted, through C-O-H fluid models (Figure 2). The diminished H contents of olivine under reducing conditions indicates that future work concerning magma ocean crystallization or the reducing deep mantle of the Earth must consider the effects of low fO_2, high fH_2, and the existence of appreciable amounts of C.