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Hydrogen in the deep mantle

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Hydrogen is the most abundant element in the universe. While its content may be a few ppm to a few weight percent in the interiors of rocky planets, hydrogen can alter the behaviors of the materials at high pressures and high temperatures. We have conducted a series of high-pressure experiments relevant to the possible incorporation of H in an early magma ocean, storage of H in the deep mantle, and hydrogen's possible role for the chemical exchange between the deep mantle and the core. Melting of (Mg,Fe)-oxides and silicates in a H medium found that Fe and Si would reduce to metal. At the same time, a significant amount of H_2O was produced and incorporated into silicate melt. The process may enable incorporation of nebular H into the deep interior in a form of OH if thick H-rich atmosphere existed and interacted with magma ocean. The storage of H in the lower-mantle silicates (OH) have been debated. Both experiments and density functional theory calculations indicate that up to a few weight percent H_2O storage is possible in $CaSiO_3$ perovskite. Our study also showed that dense silica polymorphs can contain a few weight percent of H_2O and the storage capacity increases with pressure. For silica, structurally bounded OH stabilizes the NiAs type structure (at $P > 60$ GPa), which is not found in dry systems. In $CaSiO_3$ perovskite, H can stabilize tetragonal distortion at high temperature while cubic symmetry was found in dry system. Experiments with Fe-Si alloy and hydroxide found that Si can be oxidized by water to form SiO_2 even under reducing conditions at the P-T conditions relevant for the Earth's core-mantle boundary (CMB). Fe metal in the experiment was hydrogenated. Reaction between Fe_3C and H_2O produces diamond and Fe-H alloy at the P-T conditions relevant for the CMB. Therefore, if some H (or water) can be delivered to the CMB, it can induce some chemical exchange between the core and the mantle. The reaction products could help explain some seismic structures documented in the region, including ultra-low velocity zones and the E' layer.