

Molecular hydrogen in mantle minerals

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The presence of hydrogen, or more commonly water, in the silicate mantle is a key parameter in influencing Earth's climate, habitability, and geochemical evolution; without some hydrogen in the mantle, plate tectonics would likely not exist on Earth. The formation of OH defects in nominally anhydrous minerals requires a sufficiently high oxygen fugacity to oxidize hydrogen to molecular H₂O or OH groups. However, highly reducing conditions may prevail deep in the modern Earth, as well as on the Moon and on Mars. The early Earth, especially during its early accretion, was likely extremely reduced, with an oxygen fugacity far below the Fe-FeO buffer. Under these conditions, hydrogen is not oxidized to H₂O, but present as H₂, and the retention of H in the early mantle would then only be possible if H₂ could be directly dissolved in mantle minerals. This does not appear implausible from available data on He solubility in olivine.

Using piston cylinder and multi anvil apparatus, we have investigated the solubility of H₂ in olivine, orthopyroxene, clinopyroxene and garnet at 2-7 GPa, 1100-1300 °C and with oxygen fugacity buffered by Fe-FeO. Experiments were conducted on gem-quality single crystals, and recovered large crystals (up to 2-3 mm in size) were studied by Fourier-transform infrared (FTIR) spectroscopy. We show for the first time that, under reducing conditions, molecular hydrogen has an appreciable solubility in these minerals. This observation suggests that during the accretion of the Earth, nebular H₂ could have been delivered to the growing solid planet by direct dissolution in a magma ocean and subsequent incorporation in silicates. Moreover, the deep reduced mantle may contain a significant amount of H₂, forming a huge water reservoir that has not been considered before. The results would have important implications for understanding water cycling on the Earth and on other terrestrial bodies.