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A role for iron hydrogenation in the layered redox processes of the post-giant impact Earth

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The Moon-forming impact (MFI) and subsequent formation of the global magma ocean would have set the last major constraints in the chemical and physical co-evolution of the mantle and the core. Based on the scenario that the core of the impactor merged into the proto-Earth, we have investigated depth-dependent partitioning of hydrogen into iron under impact-driven reaction environment between the metallic core of the impactor, e.g., iron, and the volatile component in the post-giant impact Earth, e.g., H_2O. Iron compressed with H_2O at pressures of 8, 12, 24 and 53 GPa, corresponding to depths of ca. 200, 300, 750 and 1200 km, respectively, was irradiated by high-brilliance X-ray free electron laser (XFEL) pulses to pump and probe the chemical reactions at 2.2 MHz and 30 Hz repetitions. Through fast heating process in pico-to-nanosecond range, we have observed depth-dependent formations of iron oxides (FeO and Fe_3O_4), hydrides (γ-FeH_x, ε'-FeH_x and FeH_2) and hydroxides (γ-FeOOH and hydrohematite) in partially-quenched states. We find that the molar ratio of H with respect to Fe in all the reaction products shows ~5 fold decrease in the depth range between from 300 and 750 km. This suggests significant modulation in hydrogen partitioning into the iron compounds in the region including the present-day mantle transition zone (MTZ). The resulting abundance of hydrogen in this region would have enabled the formation of hydrous silicates such as wadsleyite and ringwoodite to explain ca. 34.4% of the water storage capacity in the present MTZ. On the other hand, the H/Fe molar ratio shows over 50% hydrogen partitioning into the iron compounds at depths below 1200 km, which would have migrated downwards to form the early core to account ca. 3.5-10.6 % of its present light element budget.