

Chemical composition and hydrogen content inside Earth

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Hydrogen is a strongly siderophile (iron-loving) element under typical conditions of Earth's core formation (40–50 GPa, ~3500 K); its metal/silicate partition coefficient $D(H)$ (metal/silicate) = ~50 by weight (Tagawa et al., 2021 Nat. Commun.). Considering the amount of H₂O in the mantle and oceans, such high $D(H)$ (metal/silicate) suggests 0.3–0.6 wt% H in the core, which accounts for 30–60 % of the outer core density deficit and velocity excess compared to pure iron. The 0.3–0.6 wt% H in the outer core is compatible with seismological observations of its density and velocity; indeed, ab initio calculations showed these observations are explained with 1.0 wt% H as a single light element (Umemoto and Hirose, 2020 EPSL). The solid-Fe/liquid-alloy partition coefficient of hydrogen $D(H)$ (solid-Fe/liquid) was recently determined to be 0.7 by weight in the Fe-Si-H system at 50 GPa (Hikosaka et al., 2022 SciRep). If it can be applied to inner core conditions (>330 GPa), the solid core may include 0.2–0.4 wt% H. It agrees with recent theoretical calculations of a possible range of the inner core composition that explains the observed density, compressional and shear velocities (Wang et al., 2021 EPSL). Note that the presence of carbon and/or hydrogen is important to explain the low shear/compressional velocity ratio characteristic of the inner core (He et al., 2022 Nature). In addition, Fe-FeH has recently been found to be an eutectic system (Tagawa et al., 2022 JGR), and the melting (liquidus) temperature of Fe-H alloys is low, in particular when 0.3–0.6 wt% H is included. It suggests low core temperatures, consistent with the fact that the base of the mantle is not globally molten. The 0.3–0.6 wt% H in the core is thus favored, but the present estimate depends largely on the mantle water abundance and the Earth's accretion process. Neutrino observations will be very helpful if they provide additional constraints on hydrogen concentration in the deep interior.

Attendance type

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