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Hydrogen in the Earth's core from high pressure-temperature experiments

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To account for the seismically-observed density deficit in the Earth's core (e.g., Dziewonski and Anderson, 1981; Fei et al., 2016; Kuwayama et al., 2020), it is believed to mainly consist of Fe-Ni alloys with 5-10% light elements, such as Si, H, O, S, and C (Hirose et al., 2021). Among these candidate elements, H is the most abundant element in the universe. However, the siderophile (Fe-loving) nature of H in the core is much debated because hydrogen is immiscible with Fe at ambient conditions. Recent experiments on H partitioning between silicate melt and liquid Fe alloys at 30-60 GPa and 3100-4600 K have indicated that H can exhibit siderophile features under high pressure-temperature (P-T) conditions. As a result, a significant amount of H, 0.3-0.6 wt%, could alloy with Fe and enter the Earth's core during the early magma ocean evolution (Tagawa et al., 2021). In this study, we performed high P-T melting experiments on H-bearing Fe alloys (Fe-H and Fe-H-O systems) up to 120 GPa and 4000 K employing laser-heated diamond anvil cell technique together with synchrotron X-ray diffraction. We quantitatively measured the chemical compositions of the melt and liquidus phases on the recovered samples using electron probe microanalysis. These results were used to construct the melting diagram of H-bearing Fe alloy systems. Results reveal that in a H-unsaturated environment, H tends to alloy with Fe to form hexagonal close packed (hcp) or face cubic centered (fcc) FeH_x (x <1) alloys at high P-T, suggesting H is siderophile in the Earth's core. We also found that both H and O could greatly lower the melting curve of Fe alloys. As the O content increases in the melt, the H partitioning coefficient between solid and liquid Fe alloys would increase, and can exceed 1. That is, during the formation of inner core as the early liquid Earth's core cools, O would remain in the liquid outer core, while most H would preferentially partition into the solid inner core. These results could provide a crucial dataset for constraining the composition of Earth's core.