Self-diffusion in zinc at high pressure: Insight into the rheology of Earth's inner core

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Earth's inner core is structurally complex, with significant seismic anisotropy – seismic waves traveling faster in the polar direction than in the equatorial plane – that varies in magnitude hemispherically and as a function of depth. The seismic anisotropy in Earth's inner core likely results from lattice-preferred orientation (LPO) of the hexagonal close-packed (*hcp)* iron-nickel alloy that is thought to be the stable phase under inner core conditions, but how this texturing developed remains a subject of debate. To evaluate LPO production mechanisms, it is important to understand the rheology of the inner core, which depends on the self-diffusion coefficient in *hcp*-Fe under inner core conditions. Direct diffusion experiments using *hcp*-Fe are not feasible at present because, at temperatures high enough for diffusion to be significant, the phase is stable only at extreme pressures. Therefore, we conducted diffusion experiments on a structurally-analogous material, *hcp*-Zn, using piston-cylinder and multi-anvil presses at $P = 1.7 – 16$ GPa and $T = 576 – 1160$ K ($T/T_m = 0.75 – 0.89$). The diffusion couples consist of a ^{68}Zn-enriched polycrystalline Zn foil sandwiched between two Zn single crystals, one oriented perpendicular to the crystallographic *c*-axis and one oriented parallel to the *c*-axis. We determine the axial self-diffusion coefficients based on ^{68}Zn diffusion profiles measured using secondary ion mass spectrometry. By combining our high-pressure data with published self-diffusion data for a suite of hexagonal close-packed metals (Zn, Cd, Mg, Er, Tl, Hf, Ti, Zr), we predict that self-diffusion ($D_{sd} = \sim 10^{-13} – \sim 10^{-10}$ m^2/s) in an *hcp* metal at the *P*-*T* conditions of Earth's inner core may be 2 – 3 orders of magnitude faster than previous estimates based on experiments using *fcc* Fe-Ni alloys. Furthermore, the *a*-axis should be the faster self-diffusion direction in *hcp*-Fe even considering alloying of Ni and Si. Finally, we discuss our results in the context of the deformation mechanism, lattice-preferred orientation, and viscosity of Earth's inner core.