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Hydrogen diffusivity in iron-bearing olivine at asthenospheric mantle conditions

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The effect of pressure on hydrogen diffusivity in San Carlos olivine (Fo_{90}) single crystals was determined from hydrogenation experiments in a multi-anvil press at 6, 9 and 12 GPa, and at high temperature (900-1300 °C), for various durations. Crystallographically oriented prisms of gem-quality San Carlos olivine were hydrogenated under controlled oxygen fugacity (Ni-NiO) and silica activity (10% Opx). Polarized Fourier-transform infrared spectroscopy was used to quantify the hydroxyl distribution in the samples parallel to the crystallographic axes. The diffusivity of hydrogen is consistent with a single diffusion mechanism, proton-vacancy coupled diffusion, which is dominated by the presence of trivalent ions (infrared band doublet at 3357-3329 cm^{-1}). The inferred chemical diffusion coefficients are slower than in olivine hydrogenated at lower pressure (£ 3 GPa) for the same diffusion mechanism and temperatures. Under the given experimental conditions, diffusion along the [001] axis is slightly faster than along [100] or [010]. A global fit to the data provides a master Arrhenius law of the metal vacancy diffusion (which rate-limits the hydrogen diffusion) along [001]: *D,* with the pre-exponential factor , D0 = 10^(-4.0+/-0.46) $m^2.s^{-1}$, the activation energy Q=183,000(±12,000) $J.mol^{-1}$, and the activation volume V=3.38(±0.37)´10^{-6} $m^3.mol^{-1}$, and where pressure (P) is in Pa and the temperature (T) is in K. Despite the pressure effect, hydrogen diffusion coefficients in the entire upper mantle remain fast enough to alter hydrogen concentrations at the grain scale, although too slow to enable km-scale re-equilibration of hydrogen-rich or hydrogen-poor anomalies. Melt migration is thus required to enable large-scale re-equilibration of H heterogeneities.