Diffusion of phosphorus in olivine

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Phosphorus is conspicuously missing from the long list of elements whose diffusion properties in Mg-rich olivine have been charcterized in a systematic way. To address this gap, we conducted an experimental study of P diffusion using oriented slabs (~1×2×3 mm) of San Carlos olivine (SCO) cut from ~cm-sized pieces and finished on one face with at least 4 hours of polishing with colloidal silica, which removes any possible lattice damage caused by the cutting and coarse grinding processes [1]. The experiments were run at 650-850°C in evacuated silica glass ampoules, using the powder-source method and controlling oxygen fugacity with solid-state buffers. For most experiments, the powder source for P was a finely-ground, 60:40 mixture of SCO and $AlPO_4$ that had been pre-reacted at 900°C for 16h. The experiments were run for ~3-70 days, depending on temperature; the total of 20 experiments included a time series at 825°C, f_{O2} buffered at Ni-NiO and WM, different lattice orientations of the olivine slabs, and one experiment run with a P source consisting of ground San Carlos peridotite pre-reacted with $AlPO_4$. Phosphorus was profiled in the quenched experiments by RBS and by NRA using the $^{31}P(\alpha,p)^{34}S$ nuclear reaction.

The Arrhenius parameters for P diffusion in San Carlos olivine are: D_0 = 7.5×10^{-11} m^2/s; E_a = 228 kJ/mol, with no detectable dependence upon crystallographic direction, oxygen fugacity, or mineral assemblage mixed with the phosphate source. The activation energy is similar to reported values for Fe-Mg interdiffusion [e.g., 2], Li diffusion at concentrations of 1-10 ppm [3], and cation vacancy diffusion [4]. However, the P diffusion law falls ~2 orders of magnitude below the lowest reported relation for Fe-Mg interdiffusion, making P a relatively slow-diffusing species — a fact that seems consistent with observations of delicate P zoning preserved in terresrial and meteorite olivines [e.g., 5].

Models addressing P diffusion in olivine during various crystal-growth and annealing scenarios will be explored.

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