

SPECIAL COLLECTION: WATER IN NOMINALLY HYDROUS AND ANHYDROUS MINERALS

Crystal/melt partitioning of water and other volatiles during the near-solidus melting of mantle peridotite: Comparisons with non-volatile incompatible elements and implications for the generation of intraplate magmatism

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ABSTRACT

Concentrations of H₂O, F, Cl, C, P, and S have been measured by secondary ion mass spectrometry (SIMS) in experimentally produced peridotite phases (including clinopyroxene, orthopyroxene, olivine, garnet, amphibole, and mica) and coexisting basanitic glasses. Because only two experiments produced glasses on quenching (with the melt phase in others reverting to felt-like crystallite masses) H₂O concentrations in melts were also separately determined from mass-balance relationships and by assuming constant H₂O/La in melts and starting materials. The resulting values were used to calculate mineral/melt partition coefficients (*D* values) for H₂O [where $D_{\text{H}_2\text{O}}^{\text{crystal/melt}} = (\text{mass fraction of H}_2\text{O in crystal})/(\text{mass fraction of H}_2\text{O in melt})$] for conditions of 1025–1190 °C and 1.0–3.5 GPa. These gave 0.0064–0.0164 for clinopyroxene, 0.0046–0.0142 for orthopyroxene, 0.0015–0.0016 for olivine, and 0.0016–0.0022 for garnet. Although less information was obtained for the other volatiles, F was found to be significantly more compatible than H₂O during peridotite melting, whereas Cl is significantly less compatible. S also has small but appreciable solubilities in amphiboles and micas, but not in pyroxenes or olivine. The solubility of C in silicate minerals appears to be negligible, although C was present in coexisting melts (~0.5 wt% as CO₂) and as residual graphite during experiments. The *D* values for H₂O in clinopyroxene and orthopyroxene are positively correlated with ^{iv}Al but negatively correlated with the H₂O concentrations of melts (when considered as wt%). These relationships are consistent with the broad trends of previously published partitioning data. Although some of the concentration dependence can be related to cross-correlation between ^{iv}Al in pyroxenes and H₂O concentrations in melts (via the latter's control of liquidus temperatures) this relationship is too inconsistent to be a complete explanation. A concentration dependence for $D_{\text{H}_2\text{O}}^{\text{mineral/melt}}$ can also be independently predicted from speciation models for H₂O in silicate melts. Thus it is likely that $D_{\text{H}_2\text{O}}^{\text{pyx/melt}}$ is influenced by both ^{iv}Al and the absolute concentration of H₂O in melts. $D_{\text{H}_2\text{O}}/D_{\text{Ce}}$ for clinopyroxene is inversely correlated with M2 site radii. Because the latter decrease with increasing pressure and temperature, relatively hot and/or deeply derived melts should be enriched in Ce relative to H₂O when compared to melts from cooler and shallower mantle sources. Conversely, melts from H₂O-rich settings (e.g., subduction zones) should have higher H₂O/Ce than their source rocks. When combined with previously obtained partitioning data for non-volatile elements (from the same experiments), our data are consistent with the enrichment of intraplate basalt sources in both volatile and non-volatile incompatible elements by small-degree melts derived from local mid-ocean ridge basalt sources. In this way, volatiles can be seen to play an active role (via their promotion of partial-melting and metasomatic processes) in the auto-regulation of incompatible element concentrations in the depleted upper mantle.

Keywords: Experiments, partitioning, basanite melts, peridotite minerals, H₂O, water, halides, carbon, sulfur, volatiles, incompatible elements, intraplate magmatism