

## Recommended mineral-melt partition coefficients for FRTEs (Cu), Ga, and Ge during mantle melting

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### ABSTRACT

First-row transition element (FRTE) concentrations in primitive mantle-derived melts have been used as direct indicators of mantle source mineralogy (e.g., Ti, Mn, Fe, Co, Ni, Zn) and as proxies to trace the oxidation state of the mantle (e.g., Sc, V, Cu, Zn). Ga and Ge, which share chemical similarities with FRTEs, may also have the ability to trace mineralogical heterogeneities in the source of mantle-derived melts. Although the partitioning behaviors of most FRTEs are well constrained during mantle melting, partition coefficients of Cu, Ga, and Ge between mantle minerals and melt are still uncertain. Here we report new measurements that constrain partition coefficients of Cu, Ga, and Ge between olivine (Ol), orthopyroxene (Opx), clinopyroxene (Cpx), and basaltic melt from graphite capsule experiments carried out at 1.5–2 GPa and 1290–1500 °C. We suggest that discrepancies between recent experimental studies on Cu partitioning reflect one or more of the following causes: compositional control on partitioning, the effect of oxygen fugacity, Cu loss, Fe loss, non-Henrian behavior, and/or lack of complete chemical equilibrium. The partitioning values obtained from this study are 0.13 ( $\pm 0.06$ ), 0.12 ( $\pm 3$ ), and 0.09 for  $D_{\text{Cu}}^{\text{Ol/melt}}$ ,  $D_{\text{Cu}}^{\text{Opx/melt}}$ , and  $D_{\text{Cu}}^{\text{Cpx/melt}}$ , respectively. Using values from this study and from the literature, we show that melting of a sulfide-bearing peridotite source with an initial  $D_{\text{Cu}}$  peridotite/melt ranging from 0.49 to 0.60 can explain the Cu content of primitive MORBs. Here, we also support the hypothesis that Ga partitioning between pyroxenes and melt strongly depends on the  $\text{Al}_2\text{O}_3$  content of pyroxenes. Using pyroxene compositions from experiments, and previous partition data from literature, we recommend  $D_{\text{Ga}}^{\text{Px/melt}}$  values for low- $P$  (1.5 GPa) spinel peridotite melting ( $D_{\text{Ga}}^{\text{Opx/melt}} = 0.23$  and  $D_{\text{Ga}}^{\text{Cpx/melt}} = 0.28$ ), intermediate- $P$  (2.8 GPa) spinel peridotite melting ( $D_{\text{Ga}}^{\text{Opx/melt}} = 0.42$  and  $D_{\text{Ga}}^{\text{Cpx/melt}} = 0.40$ ), high- $P$  (3 GPa) garnet peridotite melting ( $D_{\text{Ga}}^{\text{Opx/melt}} = 0.38$  and  $D_{\text{Ga}}^{\text{Cpx/melt}} = 0.37$ ), high- $P$  (4 GPa) garnet peridotite melting ( $D_{\text{Ga}}^{\text{Opx/melt}} = 0.26$  and  $D_{\text{Ga}}^{\text{Cpx/melt}} = 0.30$ ), and MORB-like eclogite melting at 2–3 GPa ( $D_{\text{Ga}}^{\text{Cpx/melt}} = 0.78$ ). Consistent with previous studies, we find that Ga is incompatible in olivine during low- $P$  peridotite melting ( $D_{\text{Ga}}^{\text{Ol/melt}} = 0.08$ ). Using values from this study and from the literature, we support the hypothesis that the Ga, Ga/Sc, and Ti contents of most mantle-derived melts require garnet in their source, but that additional lithologies (e.g., metasomatic veins) may be necessary to explain the chemical variability of those melts. Here we also obtain Ge partition coefficients applicable to low- $P$  peridotite melting of 0.67, 1.04, and 1.12 for  $D_{\text{Ge}}^{\text{Ol/melt}}$ ,  $D_{\text{Ge}}^{\text{Opx/melt}}$ , and  $D_{\text{Ge}}^{\text{Cpx/melt}}$ , respectively. Last, to provide a comprehensive picture of FRTE, Ga, and Ge partitioning during mantle melting, we provide a complete set of recommended partitioning values, based on results from this study and from the literature, for all FRTEs, Ga, and Ge, relevant for partial melting of spinel and garnet peridotite, as well as for MORB-like eclogite.

**Keywords:** First-row transition elements (FRTEs), copper (Cu), gallium (Ga), germanium (Ge), mineral/melt partitioning, melting, peridotite, pyroxenite, MORB