Yb partitioning between olivine and melt: a solution to the REE diffusion in olivine problem?

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Yb partitioning between olivine and melt was studied in CMAS (1400 °C, 1 bar, $fO_2=10^{-0.7}$ bar, 7 d) and basaltic (1300-1325 °C, 10 kbar, fO_2=graphite-O_2, 0-48 hr) systems. For the CMAS experiments, XAl$_2$O$_3$ and XSiO$_2$ were varied along with XYb (ppm to ~10 wt%). For the basaltic experiments, the major and minor oxides proportions were kept constant, and the Yb content varied as above.

Nernst partition coefficients show non-Henrian behaviour at Yb contents of over around 100 ppm in olivine (1400 °C). Within the usual range of Yb contents in olivine-bearing rocks, partitioning behaviour follows Henry's law.

At relatively low Yb contents, there is no correlation between Al and Yb in olivine, but a small inverse correlation between XSiO$_2$ (melt) and Yb in olivine, suggesting a vacancy-balanced Yb substitution mechanism (Yb$_{4/3}$[vac]$_{2/3}$SiO$_4$), in line with Evans et al. [1]. At high Yb contents (>1000 ppm), there is a positive correlation between Yb and Al in olivine, suggesting Yb substitutes in Tschermaks defects (MgYbAlO$_4$). In the more complex basaltic system, there also exists the possibility for charge balance by monovalent cations, e.g. H^+, Na^+.

Yb as MgYbAlO$_4$ or Yb$_{4/3}$[vac]$_{2/3}$SiO$_4$, should show different diffusion rates. Yb associated with vacancies should diffuse at around the same rate as Fe-Mg or Mg tracer diffusion, analogous to, e.g., Cr^{3+}, whereas Yb charge-balanced by $^{IV}Al^{3+}$ may diffuse at a rate more comparable to Si tracer diffusion. This could explain the discrepancy between D$_{REE}$ as measured by Spandler and O'Neill [2] (faster diffusion) and Cherniak [3] (slower diffusion). The latter employed REE-aluminate garnet as a REE source for diffusion (high Al, high REE, encouraging Tschermak's substitution) where the former used a basalt with (relatively) low REE contents and relatively high aSiO$_2$, encouraging the vacancy mechanism. The applicability of the different D$_{REE}$ determinations will thus depend on the geological setting.

[1] Evans, O'Neill, & Tuff (2008), $Geochim.$ $Cosmochim.$ $Acta$ 72, 5708-5721. [2] Spandler & O'Neill (2010), $Contrib.$ $Min.$ $Petrol.$ 159, 791-818. [3] Cherniak (2010), $Am.$ $Min.$ 95, 362-368.