

Experimental investigation of F and Cl partitioning between apatite and Fe-rich basaltic melt at 0 GPa and 950–1050 °C: Evidence for steric controls on apatite-melt exchange equilibria in OH-poor apatite

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ABSTRACT

Apatite-melt partitioning experiments were conducted in a Deltech vertical-quench 1-bar furnace at 0 GPa and 950–1050 °C using an Fe-rich basaltic starting composition. Each experiment had a unique F:Cl ratio to assess the partitioning of F and Cl between apatite and melt, and the oxygen fugacity of all experiments was between IW and IW-1. Apatite-melt partitioning of F and Cl along the F-Cl binary join is investigated in particular to assess the effect of non-ideal mixing of apatite X-site components. The quenched melt and apatite from each experiment were analyzed by electron probe microanalysis. Several of our experiments exhibited evidence of silicate liquid immiscibility (SLI), so we also evaluated the effect of SLI on the partitioning of F and Cl between apatite and melt in those experiments. The F-Cl exchange equilibria between apatite and melt were variable with $K_{\text{F,Cl}}^{\text{Ap-melt}}$ values in the range of 0.08–0.21 across the F-Cl join. The $K_{\text{F,Cl}}^{\text{Ap-melt}}$ values decreased with decreasing F in apatite and melt. Notably, we did not observe evidence that SLI has a first-order effect on the behavior of F and Cl partitioning between apatite and melt. The observed drop in $K_{\text{F,Cl}}^{\text{Ap-melt}}$ values with decreasing F abundance in melt and apatite indicate that F becomes more compatible in apatite than Cl as there is less F in the system under nominally anhydrous conditions. This behavior can be explained by the presence of an off-mirror F site in F-Cl apatite that only F can occupy, and this F site is required to stabilize the apatite structure in OH-poor systems. These results demonstrate a link between atomic arrangements of apatite X-site components, the thermodynamic mixing properties of apatite X-site components, and the values of apatite-melt exchange equilibria for apatite X-site components. These results also indicate that Cl-rich apatites [i.e., Cl > 0.1 structural formula units (sfu) of apatite X-site] with compositions near the F-Cl binary join (i.e., <0.12 sfu from the F-Cl binary join), even if formed from H₂O-bearing natural systems, should not be used for apatite-based melt-hygrometry.

Keywords: Hygrometry, Moon, Mars, water, phosphate, silicate liquid immiscibility, merrillite, electron microprobe