

Fluorine partitioning between quadrilateral clinopyroxenes and melt

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ABSTRACT

Concentrations of fluorine and chlorine were measured in glasses (quenched melts) and coexisting clinopyroxene, orthopyroxene, olivine, and plagioclase in run products of experiments previously used to measure sulfur partitioning between these phases. The partitioning of F between clinopyroxene and silicate melt was determined in 13 experiments at a variety of pressures, temperatures, and melt compositions ranging from basaltic to dacitic (49 to 66 wt% SiO₂) at 0.8 to 1.2 GPa and 1000 to 1240 °C, at hydrous and anhydrous conditions. Additionally, we determined the crystal-melt partitioning of F for 4 experiments with plagioclase, 2 with orthopyroxene, and 1 with olivine. Although Cl was also measured in the experiments, the concentrations in the crystals are close to background concentration levels. The partition coefficients of fluorine between clinopyroxene and melt varied from ~0.09 to 0.29 and were linearly dependent upon the concentration of aluminum in the octahedral M1 site of clinopyroxene. Similar relationships are seen when our results are combined with previous measurements of the fluorine partition coefficient between clinopyroxene and melt, but each study shows its own unique correlation between the F partition coefficient and Al^{M1}. These dissimilarities in correlations with Al^{M1} are attributed to differing analytical protocols used in the various studies. However, the combined data set demonstrates a linear correlation with Al^{M1}, the inverse of the NBO/T ratio of the melt (T/NBO), pressure and temperature, which can be described as:

$$\ln(D_F^{Cpx/L}) = (0.2298 \pm 0.04847)(T/NBO) - (1.029 \pm 0.8045)(Al^{M1}) - (3889 \pm 1803)(1/T) - (0.5472 \pm 0.1084)(P) + 0.5871 \pm 1.304,$$

where each uncertainty is 1 standard error in the fit (as calculated by the R-project software), T is in K, and P is in GPa. Although this relationship reproduces 81% of the partitioning data to within 25% (relative), the different linear trends of the partition coefficient, $D_F^{Cpx/L}$ vs. Al^{M1} from different laboratories suggest the need for additional investigations and development of clinopyroxene standards with certified fluorine compositions. Nevertheless, we conclude that the self-consistency of each study indicates that F partition coefficients determined using one protocol can be applied to minerals or glasses analyzed using the same protocol and ion microprobe to better understand the storage and transport of fluorine in magmatic systems.

Keywords: Mineral/melt partitioning, fluorine, chlorine, silicate melt, clinopyroxene partition coefficient; Experimental Halogens in Honor of Jim Webster