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SPECIAL COLLECTION: APATITE: A COMMON MINERAL, UNCOMMONLY VERSATILE

Experimental investigation of F, Cl, and OH partitioning between apatite and Fe-rich basaltic melt at 1.0–1.2 GPa and 950–1000 °C†

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Abstract

Apatite-melt partitioning experiments were conducted in a piston-cylinder press at 1.0–1.2 GPa and 950–1000 °C using an Fe-rich basaltic starting composition and an oxygen fugacity within the range of ΔIW-1 to ΔIW+2. Each experiment had a unique F:Cl:OH ratio to assess the partitioning as a function of the volatile content of apatite and melt. The quenched melt and apatite were analyzed by electron probe microanalysis and secondary ion mass spectrometry techniques. The mineral-melt partition coefficients (*D* values) determined in this study are as follows: $D_{F}^{Ap\text{-}Melt} = 4.4–19$, $D_{Cl}^{Ap\text{-}Melt} = 1.1–5$, $D_{OH}^{Ap\text{-}Melt} = 0.07–0.24$. This large range in values indicates that a linear relationship does not exist between the concentrations of F, Cl, or OH in apatite and F, Cl, or OH in melt, respectively. This non-Nernstian behavior is a direct consequence of F, Cl, and OH being essential structural constituents in apatite and minor to trace components in the melt. Therefore mineral-melt *D* values for F, Cl, and OH in apatite should not be used to directly determine the volatile abundances of coexisting silicate melts. However, the apatite-melt *D* values for F, Cl, and OH are necessarily interdependent given that F, Cl, and OH all mix on the same crystallographic site in apatite. Consequently, we examined the ratio of *D* values (exchange coefficients) for each volatile pair (OH-F, Cl-F, and OH-Cl) and observed that they display much less variability: $K_{d_{Cl\text{-}F}}^{Ap\text{-}Melt} = 0.21 \pm 0.03$, $K_{d_{OH\text{-}F}}^{Ap\text{-}Melt} = 0.014 \pm 0.002$, and $K_{d_{OH\text{-}Cl}}^{Ap\text{-}Melt} = 0.06 \pm 0.02$. However, variations with apatite composition, specifically when mole fractions of F in the apatite X-site were low ($X_F < 0.18$), were observed and warrant additional study. To implement the exchange coefficient to determine the H_2O content of a silicate melt at the time of apatite crystallization (apatite-based melt hygrometry), the H_2O abundance of the apatite, an apatite-melt exchange K_d that includes OH (either OH-F or OH-Cl), and the abundance of F or Cl in the apatite and F or Cl in the melt at the time of apatite crystallization are needed (F if using the OH-F K_d and Cl if using the OH-Cl K_d). To determine the H_2O content of the parental melt, the F or Cl abundance of the parental melt is needed in place of the F or Cl abundance of the melt at the time of apatite crystallization. Importantly, however, exchange coefficients may vary as a function of temperature, pressure, melt composition, apatite composition, and/or oxygen fugacity, so the combined effects of these parameters must be investigated further before exchange coefficients are applied broadly to determine volatile abundances of coexisting melt from apatite volatile abundances.

Keywords: Lunar water, water on Mars, QUE 94201, phosphates, piston cylinder