

Rates and mechanism of Y, REE, and Cr diffusion in garnet

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ABSTRACT

Numerical simulation of the evolution of stranded diffusion profiles in partially resorbed garnet crystals from the aureole of the Makhavinekh Lake Pluton, Labrador, yields quantitative determinations of rates of diffusion of Y, rare earth elements (REEs), and Cr at ~700–900 °C, 0.53 GPa. Diffusion coefficients for these trivalent cations are 0.5–1.5 log₁₀ units smaller than those for major divalent cations measured in the same crystals, but diffusivities for trivalent cations are all equal to one another to within ±0.25 log₁₀ unit. Integration of these new data with previously published results resolves some prior inconsistencies, and defines the dependence of diffusivities for Y, the REEs, and Cr on temperature, pressure, and oxygen fugacity, while accounting for minor effects of ionic radius and host-crystal composition. Nd, Sm, and Eu—elements that are strongly depleted in rims of relict garnet crystals due to preferential partitioning out of garnet during resorption—evolve small but distinct maxima from initially nearly flat profiles; this “uphill diffusion” results from cross-coupling with Y and the other REEs, which are strongly concentrated in relict garnet rims by resorption. The weak dependence of diffusivity on ionic radius and host-crystal composition, the near-equivalence of diffusivities of Y+REEs with that of Cr, and the strong positive cross-coupling among Y+REEs are all explained by a diffusion mechanism that links the mobility of ^{viii}Y+REEs with that of ^{vi}Al; this is likely a consequence of the dominance of the menzerite-(Y) component as a means of incorporating Y+REEs in the garnet structure. However, the variety of possible substitution mechanisms that may enable Y+REE incorporation into garnet, and the degree to which each may be favored in different regimes of temperature, pressure, and oxygen fugacity, imply a potential for great complexity, as the net diffusional flux may result from the superposed effect of multiple diffusion mechanisms, each with different kinetics.

Keywords: Diffusion, garnet, rare earth elements, yttrium, chromium