American Mineralogist, Volume 103, pages 839–847, 2018

Al diffusion in quartz

Nicholas D. Tailby[1,2,3,*,†], Daniele J. Cherniak[2], and E. Bruce Watson[2,3]

[1]Department of Earth and Planetary Sciences, American Museum of Natural History, Central Park West at 79th Street, New York, New York 10024-5192, U.S.A.
[2]Department of Earth and Environmental Sciences, Science Center 1W19, Rensselaer Polytechnic Institute, 110 8th Street, Troy, New York 12180, U.S.A.
[3]New York Center for Astrobiology, Rensselaer Polytechnic Institute, 110 8th Street, Troy, New York 12180, U.S.A.

Abstract

Aluminum diffusion in synthetic and natural quartz was characterized under anhydrous conditions at 1 atm and temperatures from 700 to 950 °C. Experiments were carried out on polished quartz slabs immersed in fine-grained powder of spodumene or K-feldspar. Diffusion profiles were measured using Nuclear Reaction Analysis (NRA) and yield the following Arrhenius parameters: $D_{Al} = 2.48 \times 10^{-11} \exp(-199 \pm 10\ \text{kJ/mol}/\text{R}T)\ \text{m}^2\text{s}^{-1}$, where $\log D_0 = -10.6 \pm 0.55$.

The diffusivity of Al through the quartz lattice is sufficiently slow (e.g., akin to Ti) that diffusive modification or loss of Al in magmatic or metamorphic quartz is unlikely in all but the most extreme temperature-time conditions seen in natural systems. In other words, core to rim Al zonation produced during crystal fractionation from a granitoid, or metamorphic overgrowths on quartz during metamorphism, are likely to be preserved at the crystal scale but may show some diffusive relaxation at sub-micrometers to tens of micrometers in scale. The similar diffusivities of Al and Ti also suggest that diffusive modification of Al/Ti is highly unlikely to occur at all but the smallest length scales (e.g., sub-micrometers to tens of micrometers). These observations indicate that the two most abundant impurities in quartz (Al and Ti) are likely to record primary information regarding the crystallization conditions in most geological environments.

Keywords: Quartz, diffusion, Al, Ti, trace element, granite, nuclear reaction analysis, Arrhenius parameters; Mechanisms, Rates, and Timescales of Geochemical Transport Processes in the Crust and Mantle