Two Diffusive Pathways for Argon in Quartz and Feldspar

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Quantifying both the diffusivity and solubility of noble gases within common crustal minerals is fundamental in geo- and thermo-chronology. Diffusivity controls the closure properties of a given mineral, while solubility (or more importantly, relative solubility: i.e. partitioning) controls the likelihood of excess Ar accumulation in a particular mineral [1]. Here, we present new data on both diffusion and partitioning of Ar within and between quartz, anorthite, and K-feldspar. Experiments were run at high temperatures (420-820 C) in a pressurized 1.6-1.7 Kbar pure argon atmosphere. The resulting diffusive uptake data, which for quartz were collected via both Rutherford Backscattering (as in [2]) and UV-laser depth profiling (as in [3]), indicate the presence of two apparent diffusion pathways within quartz, and likely within the feldspars as well. In quartz, one diffusion pathway (the crystal lattice) is characterized by low diffusivity (~10^{-18} to 10^{-17} cm^2/sec) with high apparent solubility (~1000-10000 ppmw Ar), whereas the second pathway (extended defects?) is characterized by faster effective diffusivity (~10^{-14} to 10^{-13} cm^2/sec) and results in a lower (time-dependent) effective bulk solubility (1-10 ppmw Ar). The feldspars (analyzed by UV-laser only) which show a deeply penetrating diffusive profile consistent with previous study [3], also show a comparatively high near surface solubility which would be consistent with a second slow diffusion pathway, analogous to quartz. Modeling of K-feldspar data yield a near-surface diffusivity about 100x slower, and a solubility about 100x greater, than the deeply penetrating profile. We interpret these two diffusion pathways in quartz as 1. slow lattice diffusion with relatively high solubility, and 2. rapid “fast path” diffusion creating a low, ultimately time-dependent, effective bulk solubility. The same could be proposed for the feldspars. Comparison of the total argon content within the near surface lattice and the deeply penetrating fast-paths reveals that the lattice dominates the total Ar budget, so lattice solubilities should control the effective partitioning between these minerals in most systems. The quartz lattice partitions Ar over the K-feldspar lattice by a factor of ~10.

References

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