

Diffusive isotope fractionation in silicate melts

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Diffusive isotope fractionation in silicate melts is able to generate much greater variation in stable isotope ratios than equilibrium isotope fractionation [1-7 and references therein]. Diffusive isotope fractionation is due to slower motion of the heavier isotope (isotope 2) compared to the lighter isotope (isotope 1). An empirical parameter b is used to quantify the diffusivity difference: $D_2/D_1 = (m_1/m_2)^b$.

I will present my group's recent and ongoing work in diffusive isotope fractionation in silicate melts. The magnitude and hence the resolvability of such fractionation depend on the initial concentration contrast, which is used to choose the most appropriate samples for a given study.

Diffusive K isotope fractionation was investigated using diffusion couple experiments in molten basalt [5]. The inferred b value at 1350°C and 1 GPa is 0.108 and 0.090 in Si-K and Mg-K interdiffusion experiments, respectively. Diffusive Ti isotope fractionation was investigated using diffusion couple experiments in molten Fe-free basalts [7]. The inferred b value at 1500°C and 1 GPa is 0.0318 in Ti-Mg interdiffusion experiment. Diffusive Mg isotope fractionation is investigated using mineral dissolution experiments in basalt and andesite (Zhang and Bai, submitted). The inferred b value is 0.052 to 0.077.

Reported b values so far are all based on isotope ratio profiles because diffusivities for individual isotope species do not have high enough precision to resolve the b value. Nonetheless, for diffusive H isotope fractionation, it is possible to resolve the difference of H_2 and D_2 diffusivity in silica glass owing to high precision in determined diffusivity [8-10]. The estimated b value ranges from 0.29 to 0.47. Figure 1 summarizes the available b values, related to relative diffusivity. Its significance will be discussed.

Reference: [1] Richter et al., 1999, GCA, 63, 2853; [2] Watkins et al., 2017, RiMG, 82, 82; [3] Fortin et al., 2017, EPSL, 480, 45; [4] Holycross et al., 2018, GPL, 6, 39; [5] Zhang, 2022, EPSL, 581, 117405; [6] Ni, Shahr, 2023, EPSL, 624, 118459; [7] Zhou et al., 2025, EPSL, 651, 119176; [8] Lee, 1963, JCP, 38, 448; [9] Shelby, 1977, JAP, 48, 3387; [10] Shang et al., 2009, GCA, 73, 5435.

