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Diffusive stable isotope fractionation during mineral dissolution

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I report diffusive fractionation of Mg isotopes in melt during anorthite dissolution in a haplobasalt melt. Mg isotope ratios are measured by SIMS at Caltech Microanalysis Center. The internal standard error of measured δ^{26}Mg/^{24}Mg ranges from 0.05‰ at 10 wt% MgO to 0.09‰ at 4 wt% MgO. However, the data scatter is larger than the internal standard error. The measured total δ^{26}Mg variation is about 3‰ when MgO concentration varies by a factor of about 3. The MgO concentration profile can be fit well using a constant effective binary diffusivity (D). The isotope profile can also be adequately fit using a constant D. However, the D value from fitting δ^{26}Mg profile is ~40% larger than that from fitting MgO profile. The difference may be due to either subtle compositional dependence of D, similar to the case of diffusive K isotope fractionation [1], or to significant scatter in the δ^{26}Mg data. The preliminary β value for Mg isotope diffusion assuming constant diffusivity is 0.079±0.006, in between previously reported β values of 0.05 for basalt-rhyolite diffusion couple [2] and 0.10 in albite-diopside diffusion couple [3] for Mg isotope diffusion.

The stable isotope ratio in the interface melt (δ_0) is not the ratio in equilibrium with the initial mineral, but is controlled by kinetics. The analytical solution for δ_0 in the interface melt is derived assuming constant diffusivity. δ_0 depends on five parameters: the initial isotope ratios in the mineral and melt, the β value, the ratio of the concentration of the element in the initial crystal to that in the initial melt, and the interface melt concentration (or the parameter of melt growth distance divided by $(Dt)^{1/2}$). If the initial δ_i value in the mineral is the same as that in the initial melt, then $(\delta_0\text{–}\delta_i)$ is roughly proportional to the β value, with more complicated relations to other parameters. The result can be used to estimate the expected isotope fractionation during mineral dissolution or growth in nature.

1. Zhang, 2022, EPSL, 581, 117405. 2. Richter et al., 2008, GCA, 72, 206-220. 3. Watkins et al., 2011, GCA, 75, 3103-3118.