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Diffusive Mg isotope fractionation during mineral dissolution

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Diffusion can generate much larger isotope fractionation than equilibrium isotope fractionation. In addition, diffusive isotope fractionation in natural melts may be applied to infer cooling time scales, and to explore mineral dissolution and growth rates. We have been investigating diffusive Mg isotope fractionation during mineral dissolution in andesite, basalt, and Fe-free basalt using SIMS measurements at Caltech. The goals of the study are to (a) use mineral dissolution experiments to determine the beta factor in melts, and (b) evaluate the compositional dependence of beta for diffusive Mg isotope fractionation because literature data showed a large range of 0.045 to 0.10 [1-3]. In the investigation, measured Mg isotope diffusion profiles during anorthite dissolution can be modeled well, but those during olivine dissolution cannot be modeled well [4]. We suspected that the later was due to the large compositional variation along a diffusion profile during olivine dissolution, causing significant matrix effect. To examine this effect, “standard” glasses with compositions similar to those in points along diffusion profiles were synthesized with MgO powders from the same bottle (meaning the same Mg isotope ratio). The matrix effect is indeed significant and is shown in Fig. 1. After correction for the effect, the diffusion profile of Mg isotope ratios can be modeled well (Fig. 2). The new beta value is 0.077±0.002, greater than the previous value of 0.059±0.003 without matrix effect correction. Hence, the matrix effect is also significant in changing the beta value.

Combining the new result with previous results, the beta values for diffusive Mg isotope fractionation in andesite to basalt are 0.054 to 0.081 based on anorthite and olivine dissolution experiments, which lie within the literature values. The compositional dependence cannot be well resolved yet. Using a beta value of 0.065, a concentration contrast of 2.2 in a diffusion couple can generate 1‰ variation in $d^{26}Mg/^{24}Mg$, and a contrast of 10 can generate 3.5‰ variation in $d^{26}Mg/^{24}Mg$.

1. Richter et al., 2008, GCA, 72, 206-220.
2. Watkins et al., 2011, GCA, 75, 3103-3118.
3. Chopra et al., 2012, GCA, 88, 1-18.
4. Zhang, 2022, Goldschmidt Conf. abstract.