

Kinetic Fe and Mg isotope fractionation during rapid crystal growth in basaltic melt

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Rapid crystal growth can lead to disequilibrium uptake of growth-medium components, which raises the consideration of isotope mass effect in crystals that subject to this process. Here we report Fe and Mg isotope data on paired olivine grains and glassy matrix of quenched basaltic lava from the Lau back-arc basin. The results show significant $\Delta^{26}\text{Mg}_{\text{olivine-melt}}$ (-0.171‰~ -0.090‰) and resolvable $\Delta^{56}\text{Fe}_{\text{olivine-melt}}$ (-0.045‰~ -0.020‰). The quenched nature of the samples excludes Mg-Fe inter-diffusion after olivine crystallization, which, if any, would lead to higher $\Delta^{26}\text{Mg}_{\text{olivine-melt}}$ and lower $\Delta^{56}\text{Fe}_{\text{olivine-melt}}$ values. Given the theoretically limited equilibrium Mg isotope fractionation between olivine and melt, our observed isotopic fractionations most likely reflect a combination of both equilibrium and kinetic isotope effects during rapid crystal growth of olivine.

Two approaches [1, 2] are taken to simulate the kinetic Fe and Mg isotope fractionation observed in our studied samples and they give close results. The results show the kinetic effect accounts for -0.152‰~ -0.064‰ of the $\Delta^{26}\text{Mg}_{\text{olivine-melt}}$, which varies by individual samples. Hence, the equilibrium Mg isotope fractionation between olivine and melt ($\Delta^{26}\text{Mg}_{\text{olivine-melt}}$) can be constrained to be $-0.023 \pm 0.013\text{‰}$ at $\sim 1200^\circ\text{C}$. For iron isotopes, our simulation suggests that kinetic effect would induce $\Delta^{56}\text{Fe}_{\text{olivine-melt}}$ of only -0.001‰~ -0.003‰ in our samples, which is relatively negligible. Correspondingly, the equilibrium $\Delta^{56}\text{Fe}_{\text{olivine-melt}}$ is constrained to be $-0.029 \pm 0.012\text{‰}$ at $\sim 1200^\circ\text{C}$, which is in accordance with predicted values (-0.033‰) based on quantitative formula proposed in literatures [3, 4].

[1] Antonelli *et al.* (2019) *PNAS* **116**, 20315-20321. [2] Zhu *et al.* (2015) *Scientific Reports* **5**, 17561. [3] Dauphas *et al.* (2014) *EPSL* **398**, 127-140. [4] Sossi and O'Neill. (2017) *GCA* **196**, 121-143.