Stable K isotope characteristics at mid-ocean ridge hydrothermal vents and their implications for the modern and ancient K cycle

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The potassium (K) cycle is related to silicate weathering and possible reverse weathering more directly than any other major cations in the ocean because K is mostly concentrated in silicates. The K cycle, therefore, has a significant bearing on Earth's climate over geological timescales. Stable K isotopes ($^{41}K/^{39}K$ or $\delta^{41}K$) provide a novel proxy for K cycling [1, 2], but a major unknown on this new isotope system is the influence of hydrothermal alteration that is known to be a major K sink at low temperatures and a major K source at high temperatures in the ocean.

Here we report $\delta^{41}K$ analyses of mid-ocean ridge (MOR) hydrothermal fluids collected from the Gorda Ridge and East Pacific Rise (EPR). Measured $\delta^{41}K$ ranges between the values of seawater and basalt. These variations are largely controlled by fluid–basalt interactions, although small K isotope fracitonation during phase separation may exist. Time-series samples from EPR show that fluid $\delta^{41}K$ can approach the seawater value immediately after a volcanic eruption that perturbed fluid chemistry, and return to pre-eruption values within ~2 years, providing an estimation for the timescale of water–rock interaction in the local vent system.

Fluid $\delta^{41}K$–$^{87}Sr/^{86}Sr$ systematics quantifies ~0.2-0.6‰ K isotope fractionation between basalt and fluid, with altered basalts having higher $\delta^{41}K$ values. Our results preclude hydrothermal alteration as the cause for the higher $\delta^{41}K$ value of seawater relative to the Bulk Silicate Earth, highlighting the potential significance of authigenic clay formation in the global K cycle. Applying K isotope fractionation constrained here to published ophiolite data [3] implies a considerably lower $\delta^{41}K$ value in the Ordovician seawater, possibly reflecting enhanced authigenic clay formation at that time.

[1] Li et al., *PNAS*, 2019; [2] Santiago Ramos et al., *GCA*, 2018; [3] Parendo et al., *PNAS*, 2017