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Copper Isotope Fractionation by Diffusion in Basaltic Melts

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Since the advancement in precise Cu isotope analysis about 20 years ago, various types of geological and planetary samples have been investigated for their Cu isotopic compositions. These studies found that Cu isotopes show limited equilibrium fractionation at magmatic temperatures. For example, mid-ocean ridge basalts, ocean island basalts, komatiites, and peridotites all have similar Cu isotopic compositions with an average d^{65}Cu of 0.07‰. In contrast, natural samples that experienced kinetic processes (e.g. lunar samples, trinitite glasses, and tektites) show Cu isotope fractionation as high as 12.5‰, making it especially important to understand how Cu isotopes are fractionated by kinetic processes, such as evaporation and diffusion.

Diffusion can cause isotopic fractionation because lighter isotopes of an element diffuse faster than its heavier isotopes. More quantitatively, the diffusivities of two isotopes of an element are related to their masses via: $D_i/D_j = (m_j/m_i)^{\beta}$, where D_i, D_j, m_i, and m_j are the diffusivities and molecular masses of the two isotopes respectively, and β is an empirical factor. Understanding how diffusion fractionates Cu isotopes in silicate melts relies heavily on knowledge of the β factor.

In this study, Cu isotope profiles in diffusion couple experiments are measured to determine the β factor for Cu in basaltic melts. A micromill loaded with tungsten-carbide drill bits was used to sample the experimental product at different distances from the diffusion couple interface. The sampled glass powders were dissolved and Cu was purified using Bio-Rad columns loaded with AG1-X8 resin. The purified Cu cut was then measured for its isotopic composition using a Nu Plasma II at the Carnegie Institution for Science.

Based on the measured Cu isotope profiles of two Cu diffusion couple experiments at 1314 and 1397ºC, similar β factors of 0.177 and 0.157 are obtained. These are the first experimental data on the β factor for Cu in silicate melts and are crucial for understanding Cu isotope fractionation in kinetic processes. For example, during planetesimal evaporation in the early stages of Earth formation or tektite formation, significant Cu isotope fractionation could occur simply due to diffusive transport of Cu to the melt surface.