Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.28315

Copper isotopic fractionation during the evaporation of CuS-bearing silicate melts: an experimental approach

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In the early Solar System, evaporation played a crucial role in the formation and evolution of the first solids (1) as well as planetary bodies (2). Significant depletions of volatile elements are often linked with mass-dependent isotope fractionation. However, the extent of isotopic fractionation is influenced by multiple factors, including melt composition, pressure, temperature, and redox state. In many cases, the specific effects of each parameter remain poorly understood, limiting the interpretation of isotopic data. For example, the reasons for the heavy Cu isotopes composition of lunar basalts compared to the Earth (≈+0.5‰, 3, 5) could result from evaporation during the Moon-forming impact, or its subsequent magmatic evolution (3, 4, 5). As such, it is essential to parametrize isotopic fractionation across a range of physical and chemical conditions.

In this study, we experimentally investigated Cu isotopic fractionation during evaporation from silicate melts containing CuS, providing a complementary dataset to previous CuO experiments (6). Under oxidizing conditions, we report an increase in δ^{65}Cu with temperature (1200–1500°C). On the contrary, in reducing environments, the range of δ^{65}Cu variations decreases as temperature increases. For instance, at **Δ**FMQ –6, δ^{65}Cu decreases from +4.73‰ at 1200°C to +1.42‰ at 1500°C. At 1200°C, decreasing the oxygen fugacity from **Δ**FMQ air to **Δ**FMQ –6 results in an increase in δ^{65}Cu from +0.39‰ to +4.73‰, whereas at 1500°C, δ^{65}Cu decreases. The decrease in δ^{65}Cu with increasing temperature suggests a stronger influence of diffusion-limited evaporation when oxidized species (CuO–CuS) dominate. This effect diminishes at lower fO_2 levels due to the presence of reduced Cu species. These results imply that following evaporation, δ^{65}Cu in the residual melt is expected to be heavier in oxidized environments (e.g., on Earth) compared to more reduced melts (e.g., on the Moon).

(1) Wai & Wasson, Nat. 282 (1979). (2) Dauphas et al., Planet. sci. j., 3 (2022). (3) Herzog et al., GCA 73 (2009). (4) Moynier et al., GCA 70 (2006). (5) Florin et al. MetSoc2024 abstract (2024). (6) Sossi et al. GCA (2019)