

Ni stable isotope fractionation during core crystallization

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As one of the most significant stages during planetary formation, core formation and crystallization usually cause important redistributions of siderophile elements and their isotope compositions. Core crystallization occurs with equilibrium processes between solid metal (sulfur-poor) and liquid metal (sulfur-rich) phases [1]. Ni is a major and siderophile element in planetary/asteroidal cores, and significant, large Ni stable isotope fractionations (~1‰) have been found in sulfides [2]. The stable isotopes of Ni may therefore provide a means of tracing core crystallization. However, due to lack of Ni isotope data of magmatic iron meteorites from a same group [3], we hope to reconstruct this process from high-temperature experiments.

Experimental samples of solid metal and liquid metal were produced at the Johns Hopkins University Applied Physics Lab, in a one-atmosphere vertical furnace at 1,260–1,470 °C for durations of 1–7 days [4]. Ni stable isotope measurements were performed at University of Bristol, using a double spike technique, with long-term $\delta^{60/58}\text{Ni}$ data reproducibility better than 0.03‰ (2SD). No Ni isotope differences ($-0.02 \pm 0.02\text{‰}$, 2SD) between solid metal and liquid metal were found for the samples that were conducted at 1,470 °C. However, at 1,260 °C, Ni isotopes are not equilibrated until seven days, which is not the case for Fe isotope system [4]. Isotopic fractionation between solid and liquid metal ($\Delta^{60/58}\text{Ni}_{\text{solid-liquid}} = 0.05 \pm 0.02\text{‰}$ 2SD, N = 6) was observed for experiments made at 1,260 – 1,380 °C.

These data suggest limited Ni stable isotope fractionation during asteroidal core crystallization. The relatively large $\delta^{60/58}\text{Ni}$ variation (~0.4‰) in iron meteorites [3] could be caused by other processes, e.g., Ni diffusion and kinetic isotope fractionation between kamacite and taenite. Similarly, Ni stable isotope variation in ureilites [5] and enstatite achondrites [6] cannot be caused by equilibrium Ni stable isotope fractionation between metal and sulfur-rich phases.

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