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Isotopic fractionation during multi-stage core formation

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During the process of planetary differentiation and core formation, the elemental and isotopic composition of the bulk silicate Earth (BSE) is established. The depletion of moderately siderophile elements (e.g. Fe, Ni, Si, S) in the BSE relative to chondrites may be explained by metal-silicate equilibration during core formation, but it remains unclear whether this process is also responsible for terrestrial isotopic anomalies. Notably, the Fe isotopic composition of terrestrial rocks is heavy with respect to their likely chondritic progenitors (e.g. [1]; [2]). Understanding the isotopic behavior of moderately siderophile elements during metal-silicate equilibration is essential to further constrain the timeline and processes of terrestrial planet formation. Experimental studies of isotopic fractionation at relevant temperatures and pressures yield contradictory conclusions about the effect of core formation on terrestrial isotopic composition (e.g. [3]; [4]). However, prior studies rely on single stage core formation models that are unphysical, requiring the entire core to equilibrate with the entire mantle at mid-mantle pressures and temperatures. Furthermore, such models struggle to reproduce the abundances of the moderately siderophile elements and are inconsistent with astrophysical models of planet formation. To address this deficiency, we present a coupled model of astrophysical N-body accretion and core-mantle differentiation to investigate the effects of core formation on bulk planetary isotopic composition. We use a model capable of tracing isotopic composition throughout a scenario of multi-stage core formation in terrestrial planets. In particular, our model tracks the evolution of notable stable isotopic species Fe, Ni, and Si, using experimentally derived or otherwise theoretically calculated isotopic fractionation factors. Preliminary results show that repeated core formation events may cumulatively increase net isotopic fractionation enough to explain terrestrial isotopic anomalies. Our model shows that in addition to reproducing bulk terrestrial chemistry, a multi-stage core formation scenario is a potential explanation for BSE isotopic signatures.

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