What is the Iron Isotopic Composition of the Bulk Moon?

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Large variations in Fe stable isotope ratios in planetary samples complicate efforts to estimate the composition of the bulk silicate portions of the terrestrial planets. Lunar basalts exhibit an exceptionally wide range in δ^{57}Fe. The primitive Apollo 15 green glasses have a near-chondritic δ^{57}Fe of -0.03 ± 0.05‰, whereas the more evolved low-Ti and high-Ti mare basalts have average δ^{57}Fe of 0.107 ± 0.031‰ and 0.266 ± 0.029‰, respectively [1, 2]. The similarity in δ^{57}Fe between mare basalts and MORBs [3], in addition to the near-chondritic δ^{57}Fe of shergottites and eucrites, has been used to argue that the Moon and Earth are isotopically heavy as a result of evaporation and condensation during the giant impact [1]. However, the roughly chondritic compositions of terrestrial peridotites suggest a chondritic Earth [4] and confound efforts to understand the δ^{57}Fe of the bulk silicate Moon (BSM) and infer processes than may have altered it.

Here we present the results of piston cylinder experiments designed to quantify equilibrium Fe isotope fractionations during the process of core formation. Our results show that the presence of Ni in planetary cores results in a fractionation of Fe isotopes between the mantle and core that scales with the Ni content of the core. The effect is similar to that of sulfur [5]. Assuming a Ni content of the lunar core equivalent to that of the average of magmatic Fe meteorites (8.4 wt. %, [6]) and a core-mantle equilibration temperature of ~1900 °C [7], we estimate the δ^{57}Fe of the BSM to be -0.06‰. This fractionation would increase and the mantle would become lighter, if there is S in the lunar core.

Our conclusion that the BSM is isotopically light suggests an even greater difference in δ^{57}Fe between the BSM and mare basalts than previously thought. This strongly suggests that silicate differentiation through LMO crystallization also results in Fe isotope fractionation, leading to increasingly heavy mantle source regions as the Moon solidifies, despite the lack of Fe^{3+} in lunar magmas. The broad correlation between TiO_2 content and δ^{57}Fe in mare basalts supports this conclusion.

[1] Poitrasson et al. (2004) *EPSL*, **223,** 253-266. [2] Weyer et al. (2005) *EPSL*, **240**, 251-264. [3] Teng et al. (2013) *GCA*, **107,** 12-26. [4] Craddock et al. (2013) *EPSL*, **365,** 63-76. [5] Shahar et al. (2015) *GCA*, **150**, 253-264. [6] Mittlefehldt et al. (1998) *Rev. Mineral.*, **36**, 4-01 – 4-195. [7] Righter and Drake (1996) *Icarus*, **124,** 513-529.