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Iron isotope fractionation during planetary differentiation processes

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The Fe isotope composition of samples from various lunar reservoirs, Mars (SNC meteorites), HED parent body (eucrites), pallasites (metal and silicate) and the Earth's mantle were measured using high mass resolution MC-ICP-MS and Cu for mass bias correction. With this technique high precision measurements ($\approx$ 0.05‰ on δ^{56}Fe 2SD on replicate sample measurements) were performed, sufficient to resolve small variations between high temperature rocks and geochemical reservoirs formed during planetary differentiation.

The Fe isotope fractionation during planetary core formation can be confined to be $<$ 0.1‰ for δ^{56}Fe, as indicated by the indistinguishable Fe isotope composition of pallasite bulk metal (including sulfides and phosphides) and olivine separates. However, large fractionations ($\approx$ 0.5‰) were observed between different pallasite metal separates. These fractionations vary systematically with the amounts of troilite, schreibersite and taenite: Troilite generally has the lightest (δ^{56}Fe $\approx$ -0.25‰) and schreibersite the heaviest (δ^{56}Fe $\approx$ +0.2‰) Fe isotope composition. Therefore, these variations probably reflect Fe isotope fractionatation during exsolution of these phases rather than during silicate-metal separation.

In contrast, differentiation of the silicate portion of planets seems to fractionate Fe isotopes. Notably, igneous rocks (partial melts) are systematically isotopically heavier than their mantle protoliths. This is indicated by the mean of 11 terrestrial peridotite samples from different tectonic settings (δ^{56}Fe = +0.015 $\pm$ 0.018‰), which is sig-

nificantly lower than the mean of terrestrial basalts (δ^{56}Fe = +0.076 $\pm$ 0.029‰ 2SE). The peridotite mean is considered as the best estimate for δ^{56}Fe of the bulk silicate Earth and probably also of bulk Earth. The terrestrial basaltic mean is in good agreement with the mean of the lunar samples (δ^{56}Fe = +0.073 $\pm$ 0.019‰ 2SE), excluding the high-Ti basalts. The high-Ti basalts display the heaviest Fe isotope composition of all measured rocks (δ^{56}Fe $\approx$ +0.2‰). This is interpreted as a fingerprint of the lunar magma ocean, which produced a very heterogeneous mantle, including the ilmenite-rich source regions of these basalts.

Within uncertainties, samples from Mars (SNC meteorites), HED (eucrites) and the pallasites (average olivine + metal) have the same Fe isotope compositions as the Earth's mantle, which is indistinguishable from the standard IRMM-014. This indicates that the average solar system value should be very close to that of IRMM-014. However, Mars and the HED parent body might be slightly isotopically lighter than the Earth, the Moon and the pallasite parrent bodies, since their planetary mean is so far mainly based on basalts.