Iron isotopes on Mars linked to the formation of the terrestrial planets

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Iron isotopes (δ^{57}Fe) fractionate during high-temperature processes through Fe exchange in different valence states and bear witness to the redox history of early solar system bodies. Although δ^{57}Fe differences between terrestrial and Martian (SNC meteorites) basalts have been proposed [1], recent analytical advances and a re-refined δ^{57}Fe value for Earth's mantle [2] call for a re-assessment of this difference. Here, we report Fe isotope analyses of 17 Martian whole rocks and 5 mineral separates obtained in Canberra and Toulouse using a high-precision technique.

While there are no differences detected between the depleted, intermediate and enriched shergottites, all Martian meteorites correlate with indices of magmatic differentiation. Nakhlites and evolved shergottites have δ^{57}Fe ≈ 0.05±0.03‰, while the MgO-rich rocks are lighter (δ^{57}Fe ≈ -0.01±0.02‰), Lighter δ^{57}Fe of pyroxenes than whole-rock nakhlites causes a co-variation of δ^{57}Fe with fO_2, where both increase in the melt in a manner analogous to evolving terrestrial magmas.

If SNCs are representative of Martian magmatism, Martian basalts are distinctly lighter than MORB. Extrapolation of the whole rock δ^{57}Fe SNC trend to a putative Martian mantle yields a value lighter than all estimates for its terrestrial counterpart, but close to chondrites. If the Earth and Mars accreted from similar material, and considering the constancy of δ^{57}Fe in chondrites, this disparity arose post-accretion. As MORB are more oxidised (~FMQ) than Martian shergottites (FMQ -2 to -3), a process that increased the fO_2 and δ^{57}Fe of the bulk silicate Earth is required.

Possible mechanisms include evaporation of light isotopes during a Moon-forming giant impact [1], addition of an oxidised ^{57}Fe-enriched impactor, or disproportionation and extraction of Fe^0 in equilibrium with perovskite with large $\Delta^{57}Fe_{mantle\text{-}core}$ [3,4], but not on the smaller body Mars [5].

[1] Poitrasson *et al* 2004, *EPSL,* **223,** 253-266 [2] Craddock and Dauphas, 2013, *EPSL*, **365**, 63-76 [3] Polyakov, 2009, *Science*, **323**, 912-914 [4] Williams *et al* 2012, *EPSL* **321-322**, 54-63 [5] Poitrasson *et al* 2009, *EPSL*, **278**, 376-385