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

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Iron isotopes ($\delta^{57}\text{Fe}$) fractionate by Fe exchange in different valence states and bear witness to the redox history of early solar system bodies. Although $\delta^{57}\text{Fe}$ differences between terrestrial and Martian (SNC) basalts have been proposed [1], recent analytical advances and a refined $\delta^{57}\text{Fe}$ value for Earth’s mantle [2] call for a re-assessment of this difference. We report Fe isotope analyses of 17 Martian whole rocks and 5 mineral separates obtained in Canberra and Toulouse.

All Martian meteorites correlate with indices of magmatic differentiation. Nakhlites and evolved shergottites have $\delta^{57}\text{Fe}=0.05\pm0.03\%$, while the MgO-rich rocks are lighter ($\delta^{57}\text{Fe}=-0.01\pm0.02\%$). Lighter $\delta^{57}\text{Fe}$ of pyroxenes than whole-rock nakhlites causes a co-variation of $\delta^{57}\text{Fe}$ with $f_{\text{O}_2}$, where both increase in the melt as in terrestrial magmas.

If SNCs are representative of Martian magmatism, they are distinctly lighter than MORB. Extrapolation of the $\delta^{57}\text{Fe}$ SNC trend to a putative Martian mantle yields a value lighter than its terrestrial counterpart, but close to chondrites. If the Earth and Mars accreted from similar material, this disparity arose post-accretion (given the constancy of $\delta^{57}\text{Fe}$ in chondrites). As MORBs are more oxidised ($=\text{FMQ}$) than Martian shergottites (FMQ-2.5), a process that increased the $f_{\text{O}_2}$ and $\delta^{57}\text{Fe}$ of the BSE is required.

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