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Inferring iron oxide formation conditions on Mars from triple oxygen isotopes

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The presence of goethite (α-FeO(OH)), an iron oxide, on Mars was first inferred by the Mössbauer spectrometer on *Spirit* rover in Gusev crater and, more recently, conclusively detected by the CheMin X-ray diffractometer on *Curiosity* rover throughout the clay-sulfate transition in Gale crater [1, 2]. Moreover, iron oxides have also been identified petrographically in several Martian meteorites. The presence and relative abundances of iron oxides can be used to infer past environmental conditions and sedimentary processes on Mars (*e.g.*, oxidizing or reducing conditions, pH of aqueous environments, mineral formation temperatures, degree of chemical weathering). In this study we focus on: 1) the formation temperatures of Martian iron oxides, and 2) the pH of the fluid in which these minerals may have formed on Mars. Triple oxygen isotope analyses of iron oxides and coeval phases like clay or silica can be used in addition to the more common spectroscopic analyses to independently estimate environmental conditions experienced by Martian meteorites and return samples.

In this work, we will synthesize goethite across a range of near-neutral pHs and low temperatures, make triple oxygen isotope measurements of the iron oxide precipitates and solutions, and derive triple oxygen isotope fractionation factors and mass laws for the goethite-water system. The proposed work addresses knowledge gaps by synthesizing goethite at a series of incremental, near-neutral pHs to identify the degree of pH-dependence on goethite-water fractionation factors, potentially explaining the differences between the existent near-neutral pH data [3, 4], and expanding upon the only other near-neutral pH goethite-water fractionation factors, which are limited to measurements of 18O/16O, to include measurements of 17O/16O. Well-constrained fractionation factors and mass laws for components of Martian sediments are necessary to advance the interpretation of Earth-based laboratory analyses of Martian meteorites and would serve as preparation for analyses of returned Martian sediments or in situ rover- or lander-based measurements on Mars.

[1] Morris, R. V. et al. (2006), *JGR* 111.
[2] Rampe, E. B. et al. (2023), *LPSC* #1554.
[3] Galili, N. et al. (2019), *Science* 365, 469–473.
[4] Frierdich, A. J. et al. (2015), *GCA* 160, 38–54.