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Oxidation state of iron and Fe-Mg partitioning between olivine and basaltic martian melts

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Abstract

We performed a series of experiments at 1 atm pressure and temperatures of 1300–1500 °C to determine the effect of oxygen fugacity on the oxidation state of Fe in a synthetic martian basalt. Ferric-ferrous ratios were determined on the quenched glasses using Mössbauer spectroscopy. Following the conventional doublet assignments in the spectrum, we obtain a $Fe^{3+}/\Sigma Fe$ value of 0.19 at 1450 °C and an oxygen fugacity corresponding to the QFM buffer. If we apply the Berry et al. (2018) assignments the calculated $Fe^{3+}/\Sigma Fe$ drops to 0.09, and the slope of $\log(X^{melt}_{FeO1.5}/X^{melt}_{FeO})$ vs. $\log(f_{O_2})$ changes from 0.18 to 0.26.

Combining oxidation state data together with results of one additional olivine-bearing experiment to determine the appropriate value(s) for the olivine (Ol)-liquid (liq) exchange coefficient, $K_{D,Fe^{2+}\text{-}Mg} = (FeO/MgO)^{Ol}/(FeO/MgO)^{liq}$ (by weight), suggests a $K_{D,Fe^{2+}\text{-}Mg}$ of 0.388 ± 0.006 (uncertainty is one median absolute deviation) using the traditional interpretation of Mössbauer spectroscopy and a value of 0.345 ± 0.005 following the Mössbauer spectra approach of Berry et al. (2018).

We used our value of $K_{D,Fe^{2+}\text{-}Mg}$ to test whether any of the olivine-bearing shergottites represent liquids. For each meteorite, we assumed a liquid composition equal to that of the bulk and then compared that liquid to the most Mg-rich olivine reported. Applying a $K_{D,Fe^{2+}\text{-}Mg}$ of ~0.36 leads to the possibility that bulk Yamato 980459, NWA 5789, NWA 2990, Tissint, and EETA 79001 (lithology A) represent liquids.

Keywords: Olivine-phyric shergottites, Fe^{2+}-Mg partitioning, olivine, basalt, Mars