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XANES measurements of Cr valence in olivine and their applications to planetary basalts

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Abstract

In this work we present a series of experiments that examine the relationship between oxygen fugacity and Cr valence ratio in olivine grown from a basaltic liquid. These experiments are specifically targeted for an olivine-rich martian basalt composition that was modeled after the bulk chemistry of the meteorite Yamato 980459 (i.e., Y-98). The chromium valence ratio in the olivine crystals was measured with X-ray absorption near edge spectroscopy (XANES) at the Advanced Photon Source, Argonne National Laboratory. Results from the XANES measurements indicate that the ratio of divalent to trivalent Cr in the olivine is not only systematically correlated with f_{O_2}, but is also reflective of the molar Cr^{3+}/Cr^{2+} in the silicate liquid from which it grew. In this way, measurements of Cr valence in olivine phenocrysts can yield important information about the oxygen fugacity and molar Cr^{3+}/Cr^{2+} of its parental liquid in the absence of a quenched melt phase. Although the results from the experiments presented in this work specifically apply to the Y-98 parental melt, the concepts and XANES analytical techniques discussed within the text present a novel, generalized methodology that may be applicable to any olivine-bearing basalt. Furthermore, the XANES-based measurements are made on a micrometer-scale, thus potential changes of the Cr^{3+}/Cr^{2+} in the melt during crystallization could be examined with a great deal of spatial detail.

Keywords: XANES, Cr valence, redox equilibria, martian basalts