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Normal to inverse transition in martian spinel: Understanding the interplay between chromium, vanadium, and iron valence state partitioning through a crystal-chemical lens

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Abstract

Spinel is a very important rock-forming mineral that is found in basalts from Earth, Mars, the Earth's Moon, and basaltic meteorites. Spinel can be used as a sensitive indicator of petrologic and geochemical processes that occur in its host rock. This paper highlights the role of increasing f_{O_2} (from IW-1 to FMQ+2) in converting a >90% normal spinel to an ~25% magnetite (inverse) spinel, the trajectory of $D_V^{spinel/melt}$ as it relates to the ratio of V^{3+}/V^{4+} in the melt, and the crystal chemical attributes of the spinel that control the intrinsic compatibility of both V^{3+} and V^{4+}. This work examines the nuances of the V partitioning and provides a crystal chemical basis for understanding Fe^{3+}, Cr, and V substitution into the octahedral sites of spinel. Understanding this interplay is critical for using spinels as both indicators of planetary parentage and reconstructing the redox history of magmatic systems on the terrestrial planets. Three potential examples for this use are provided. In addition, this work helps explain the ubiquitous miscibility gap between spinels with changing ülvospinel contents.

Keywords: Spinel, crystal chemistry, partitioning, vanadium, chromium, Invited Centennial article