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Melting temperature depression due to the electronic spin transition of iron

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Abstract

The electronic spin transition of iron has been shown to strongly affect many thermoelastic properties of the host mineral. However, the response of melting temperatures to the spin transition remains largely unexplored. Here, we study the melting of lower mantle minerals, ferropericlase and bridgmanite, using Lindemann's Law. This empirical law predicts a negligible melting temperature depression for Earth-relevant bridgmanite but a substantial depression for Earth-relevant ferropericlase across the spin transition of iron, consistent with extant experimental results. This melting depression can be explained within the framework of Lindemann's Law for a Debye-like solid. The transition of iron from high- to low-spin configuration reduces the molar volume and the bulk modulus of the crystal, leading to a decrease in Debye frequency and consequently lowering the melting temperature. Thermodynamically, the melting depression likely derives from a more negative Margules parameter for a liquid mixture of high- and low-spin end-members as compared to that of a solid mixture. This melting depression across the spin transition of iron may be the process responsible for the formation of a deep molten layer during the crystallization of a magma ocean in the past, and a reduced viscosity layer at present.

Keywords: Melting, spin transition, ferropericlase, bridgmanite, lower mantle