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Thermal equation of state of Fe_3O_4 magnetite up to 16 GPa and 1100 K

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Abstract

Fe_3O_4 magnetite is an important mineral commonly found in various geological settings, including the planet Mars, whose thermoelastic properties at high pressure and temperature are still poorly constrained. We performed X-ray diffraction measurements on natural magnetite using resistive-heated diamond-anvil cells up to 16 GPa and 1100 K. We fitted a thermal equation of state (EoS) to the collected data resulting in K_0 = 182(1) GPa, K'_0 = 4, θ_D = 660 K, γ = 1.8(1), and q = 2.7. Moreover, it was possible to explore the structural evolution of magnetite in detail using single-crystal measurements. Over the studied pressure and temperature range, we found no evidence of a transformation from an inverse to a normal spinel structure. The EoS parameters obtained in this study will be implemented into currently available databases for self-consistent thermodynamic modeling. In particular, our results are used to model and compare the sound wave velocities of a magnetite-bearing and magnetite-free martian upper mantle assemblage. We observe that the incorporation of magnetite reduces the sound wave velocities; however, the magnitude of the effect is below the current seismic detection limit of the InSight mission on Mars at the low abundance of magnetite expected in the martian mantle.

Keywords: Magnetite, thermal equation of state, X-ray diffraction, high-pressure, high-temperature