

Ab initio study of structural, elastic and thermodynamic properties of Fe₃S at high pressure: Implications for planetary cores

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Abstract

Using density functional theory electronic structure calculations, the equation of state, thermodynamic and elastic properties, and sound wave velocities of Fe₃S at pressures up to 250 GPa have been determined. Fe₃S is found to be ferromagnetic at ambient conditions but becomes non-magnetic at pressures above 50 GPa. This magnetic transition changes the c/a ratio leading to more isotropic compressibility, and discontinuities in elastic constants and isotropic sound velocities. Thermal expansion, heat capacity, and Grüneisen parameters are calculated at high pressures and elevated temperatures using the quasiharmonic approximation. We estimate Fe-Fe and Fe-S force constants, which vary with Fe environment, as well as the ⁵⁶Fe/⁵⁴Fe equilibrium reduced partition function in Fe₃S and compare these results with recently reported experimental values. Finally, our calculations under the conditions of the Earth's inner core allow us to estimate a S content of 2.7 wt% S, assuming the only components of the inner core are Fe and Fe₃S, a linear variation of elastic properties between end-members Fe and Fe₃S, and that Fe₃S is kinetically stable. Possible consequences for the core-mantle boundary of Mars are also discussed.

Keywords

Fe₃S, First-principles calculations, High pressure, Thermodynamic properties