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Changes in physical properties of 4*C* pyrrhotite (Fe_7S_8) across the 32 K Besnus transition

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Abstract

Pyrrhotite, Fe_7S_8, is a common sulfide mineral in the Earth's crust and mantle, as well as in a range of meteorites and is of interest to a wide variety of disciplines including economic geology, geophysics, and material science. The 4*C* variety of pyrrhotite shows a dramatic change in magnetic properties at $T \approx 30$ K, known as the Besnus transition. Although this transition is frequently used to detect pyrrhotite in geologic samples, the underlying mechanism driving the transition has not yet been identified. This study presents a high-resolution view of the changes in heat capacity, magnetic, and electronic properties of a natural single crystal of nearly pure, monoclinic 4*C* pyrrhotite across the Besnus transition. Contrary to previous studies, *all* of these properties show clear evidence of the Besnus transition, specific heat, in particular, revealing a clear transition at 32 K, apparently of second-order nature. Small-angle neutron scattering data are also presented, demonstrating an unusual change in short-range magnetic scattering at the transition. Furthermore, a magnetic field dependence of the transition temperature can be seen in both induced magnetization and electrical resistivity. These new observations help narrow the possible nature of the phase transition, clearly showing that interactions between intergrown coexisting 4*C* and 5*C** superstructures, as suggested in some literature, are not necessary for the Besnus transition. In fact, the changes seen here in both the specific heat and the electronic transport properties are considerably larger than those seen in samples with intergrown superstructures. To further constrain the mechanism underlying the Besnus transition, we identify five separate potential models and evaluate them within the context of existing observations, thereby proposing experimental approaches that may help resolve ongoing ambiguities.

Keywords: Besnus transition, phase transition, magnetism, heat capacity, resistivity, sulfide, pyrrhotite