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Theory of Field-Induced Phase Transition in $PrOs_4Sb_{12}$

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Recent experimental studies on $PrOs_4Sb_{12}$ have shown the existence of a field-induced ordered phase (FIOP) above 5T, which is neighboring with the known superconducting phase in the lower fields. As a first step to clarify the relation between these two phases we study in this work the origin and the nature of the FIOP theoretically.

Following Kohgi et al. we assume for the crystal-field level scheme the Γ_1-singlet ground state and the low-lying Γ_5 (or $\Gamma_4^{(2)}$) triplet states. Since the other levels are expected to be above 100K, it is reasonable to restrict the basis set to this singlet-triplet subspace. In analogy with dimer-spin systems we introduce a couple of $S = 1/2$ pseudo-spins, with which Γ_1 and Γ_5 are regarded as the total-spin-zero state and the spin-1 triplet. Using this representation we clarify a hidden symmetry in the local Hamiltnian and its relation with possible order parameters. It is shown that the Γ_5-type quadrupoles with three components are the promising candidate for the primary order parameter in FIOP. In the framework of mean-field theory we determine the stable component of the order parameters depending on the directions of the field. We found that the resulting phase diagram becomes weekly anisotropic reflecting the $O_h \to T_h$ symmetry breaking. Using the pseudo-spins the origin of the field-dependence of the primary and induced order parameters is discussed. In particular the tiny AF-magnetic moment in the quadrupolar phase is explained as a consequence of the cancellation of the two spins. These results are shown to be consistent with the available experimental results.

[1] M. Kohgi et al.: J. Phys. Soc. Jpn. **72** (2003) 1002.

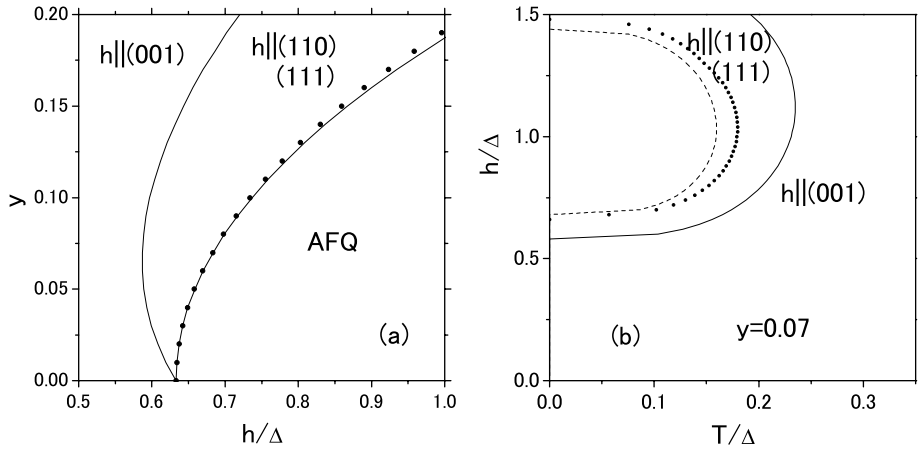

Figure 1: (a) The mean-field phase diagram for the T_h crystal field parameter (y) and the scaled magnetic field h/Δ, where Δ is the excitation energy between Γ_1 and Γ_5. (b) The mean-field phase diagram for the magnetic field and the scaled temperature (T).