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Low-T Properties of $PrMg_3$ with the Cubic Γ_3 Ground State

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An intermetallic compound $PrMg_3$ with the cubic Fe_3Al-type structure, in which Pr^{3+} occupies the cubic site, was reported in previous studies as a Γ_3 ground-state (GS) system with the crystalline-electric-field (CEF) level scheme of Γ_3(0 K)-Γ_4(56 K)-Γ_1(135 K)-Γ_5(183 K)[1]. The cubic Γ_3 is a non-magnetic, non-Kramers doublet, which has no magnetic dipoles but electric quadrupoles (O_{20}, O_{22}) and a magnetic octupole (T_{xyz}).

We have investigated the low-T properties of $PrMg_3$ on single crystals by the magnetic susceptibility $\chi(T)$ and the specific heat $C_{\rm P}(T)$[2]. $\chi(T)$ increases monotonically with decreasing T below room T and tends to saturate below $\sim$20 K, suggesting basically Van-Vleck-like behavior at low T. $C_{\rm P,PrMg3}(T)$ exhibits no anomaly down to 0.54 K that suggests a phase transition. As shown in Fig. 1, The $4f$ contribution $C_{4f}(T)$ has a huge broad anomaly with a peak $\sim$1.8 J/mol K at 0.9 K and a large $C_{4f}(T)/T$=2.8 J/mol K^2 at 0.54 K. No apparent NFL behavior was observed in $C_{4f}(T)$ down to 0.54 K. Weak $H_{\rm ext}$-dependence of the $C_{4f}(T)$ anomaly even under $H_{\rm ext}$=9 T//[001] suggests its basically nonmagnetic origin. $S_{4f}(T)$, the $4f$ contribution to the entropy, approaches Rln 2 around $\sim$5 K, where it increases slowly. Therefore, it can be concluded from the basically Van-Vleck-like $\chi(T)$ and the low-T $C_{4f}(T)$ anomaly that the CEF GS is the Γ_3 doublet. This conclusion is consistent with the CEF level scheme deduced from the neutron measurement. Then, the observed low-T $C_{4f}(T)$ anomaly is reasonably ascribed to the GS Γ_3 multipole degrees of freedom. The anomaly, however, is not described as a collection of the 2-ch. Kondo impurities, as can be seen in Fig. 1. Rather, it is more similar to that for the 1-ch. Kondo model with $T_{\rm K,1-ch}$=1.3 K, including its weak $H_{\rm ext}$-dependence. The low-T $C_{4f}(T)$ anomaly suggests that the Γ_3 multipole degrees of freedom are quenched by forming a strongly correlated electronic state through the $c-f$ hybridization.

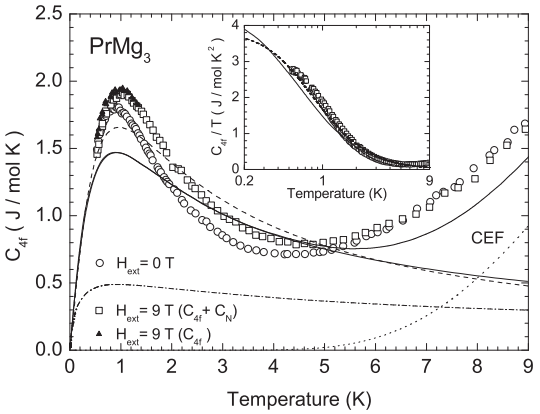

Figure 1: The low-T part of $C_{4f}(T)$ of a single crystal of $PrMg_3$ for $H_{\rm ext}$=0 T (circles) and 9 T//[001] (squares). The dot-dashed line and the thin solid line represent the specific heat of the 2-ch. ($T_{\rm K,2-ch}$=1.5 K) and 1-ch. ($T_{\rm K,1-ch}$=1.3 K) impurity Kondo model. The dotted line is the calculated Schottky contribution from the CEF excited states. The thick solid line corresponds to the sum of the 1-ch. Kondo and the CEF-excited-states contributions.

(1) R. M. Galera *et al.*, J.Magn. & Magn. Mater. **23** (1981) 317.
(2) H. Tanida *et al.*, to be published in J. Phys. Soc. Jpn. (2006) July.