ABSENCE OF KONDO LATTICE COHERENCE EFFECTS IN Ce$_{0.6}$La$_{0.4}$Pb$_3$: A MAGNETIC FIELD STUDY

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Introduction

Lately, there has been renewed interest in the subject of the Kondo lattice and its relation to the single-impurity Kondo model. Nakatsuji et al.\textsuperscript{1} have proposed a two-fluid model that describes thermodynamic and transport properties of Ce$_x$La$_{1-x}$CoIn$_5$ by the superposition of a single-impurity part and a coherent heavy-fermion liquid part, the latter contribution proving to be overwhelmingly dominant for $x > 0.5$. This remarkable result requires re-examination of previous investigations concluding that single-impurity physics describes of a number of concentrated heavy fermions—particularly the alloy series Ce$_x$La$_{1-x}$Pb$_3$, for which the zero-field specific heat scales with $x$ for $0 < x \leq 0.6$, and the specific heat per Ce is accounted for quantitatively by the $S = \frac{1}{2}$ single-impurity Kondo model with an $x$-independent single-ion Kondo temperature $T_K$ (Ref. 2).

Experimental

Two polycrystalline samples of Ce$_{0.6}$La$_{0.4}$Pb$_3$ were synthesized independently. Because of the high vapor pressure of Pb, the starting material had additional Pb to compensate for vapor losses, and each sample was repeatedly arc melted and reweighed until the final stoichiometry was Ce$_{0.6}$La$_{0.4}$Pb$_3\pm0.01$. The samples were then annealed for two weeks at 600 ºC in the presence of additional free lead to minimize further Pb losses. The specific heat of Sample 1 was measured by the thermal relaxation method over temperatures $0.4 \leq T \leq 10$ K in magnetic fields $H = 0, 4, 8, 10,$ and $15$ T. Sample 2 was measured between 0.7 K and 4.2 K at zero field and 10 T to provide a basis for estimating the likely degree of sample dependence in the data.

Results and Conclusions

Both at 0 T and 10 T, the data for Samples 1 and 2 lie very close to one another, suggesting that they represent the intrinsic properties of Ce$_{0.6}$La$_{0.4}$Pb$_3$. After subtracting a lattice contribution, and taking into account a field-dependence of the effective $g$ factor resulting from mixing of Ce$^{3+}$ cubic crystalline electric field levels, we find that the excess specific heat $\Delta C$ between 1 K and 10 K is well described by the $S = \frac{1}{2}$ single-impurity Kondo model with just one adjustable parameter: the zero-field Kondo temperature, $T_K = 2.6 \pm 0.2$ K. In particular, the variation in the temperature and the height of the peak in $C$ vs. $T$ is captured with good accuracy. The greater width of the experimental peak may be attributable to the spread in effective $g$ factors arising from the distribution of angles between the magnetic field and the cubic crystal axes in our polycrystalline samples.

The agreement between the field dependence observed in the specific heat of Ce$_{0.6}$La$_{0.4}$Pb$_3$ and that predicted by the single-impurity Kondo model suggest that there is no significant coherence effect in the specific heat of this system, at least at temperatures of order the single-ion Kondo scale and higher. This provides a clear counter-example to the two-fluid model\textsuperscript{1} for Ce$_x$La$_{1-x}$CoIn$_5$, where coherence effects set in at temperatures more than an order of magnitude above $T_K$.

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References