Thermodynamic Investigation of $PrOs_4Sb_{12}$ Crystals at Very Low Temperatures and High Magnetic Fields

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Introduction

The ground state of the first Pr-based heavy-fermion superconductor, $PrOs_4Sb_{12}$, is poorly understood. Different measurements provide conflicting insights into its state below 1 K. The heavy fermion behavior has been established by the specific heat above 1 K. The measured discontinuity in C/T at T_c (1.85 K) is 500-700 mJ/K^{2}mol, implying the electronic specific heat coefficient of order 500 mJ/K^{2}mol. However, the enhancement of the cyclotron mass, as measured by the de Haas-van Alphen technique below 600 mK and in magnetic fields greater than 5 T, is small, typical of transition metals. Thus either magnetic fields suppress the heavy fermion state or this state ceases at very low temperatures.

Results and Discussion

Low temperature, below 0.4 K, measurements of the electronic specific heat using the standard adiabatic technique were unreliable because of dominating and "slow" Sb quadrupolar nuclear heat capacity at low temperatures.

We have measured the electronic contribution to the specific heat directly by the relaxation method and using the fact that electronic relaxation time is proportional to the crystal mass while the nuclear contribution is of order of T_1, the spin-lattice relaxation time. Our investigation of several crystals, provided a clear evidence of a broad anomaly in the electronic specific heat at 0.4 K. The temperature of this anomaly is not affected by small magnetic fields.

Similarly, analysis of longitudinal magnetoresistance, investigated between 20 and 700 mK and in fields up to 18 T suggests a crossover behavior, with a crossover temperature 0.3 – 0.5 K.

Conclusions

We suggest there is a crossover behavior from the heavy fermion state at temperatures of order T_c to non-heavy fermion behavior at T=0 K. The crossover temperature, $T^* \approx 0.4$ K, is only weakly field-dependent. We also suggest that anomalies previously reported in the lower critical field, London penetration depth, and Sb-NQR are all related to the existence of this crossover temperature.

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