LBL--28747

DE90 011602

MAGNETIC FIELD DEPENDENCE OF THE SPECIFIC HEAT OF HEAVY-FERMION $YbCu_{4.5}$

A. Amato, R. A. Fisher, N. E. Phillips, D. Jaccard* and E. Walker*

Materials and Chemical Sciences Division,
Lawrence Berkeley Laboratory
and
Department of Chemistry,
University of California,
Berkeley, California 94720, USA

and

**Département de Physique de la Matière Condensée,*
Université de Genève, CH-1211 Genève, Switzerland

March 1990

This work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Materials Sciences Division of the U.S. Department Energy under contract DE-AC03-76SF00098. Additional support for A.A. was provided by a grant from the Swiss National Science Foundation.

MAGNETIC FIELD DEPENDENCE OF THE SPECIFIC HEAT OF HEAVY-FERMION $YbCu_{4.5}$

A. AMATO, R.A. FISHER, N.E. PHILLIPS, D. JACCARD* and E. WALKER*

Materials and Chemical Sciences Division,
Lawrence Berkeley Laboratory, Berkeley, CA 94720, USA
*Département de Physique de la Matière Condensée,
Université de Genève, CH-1211 Genève, Switzerland

The specific heat of a polycrystalline sample of $YbCu_{4.5}$ has been measured between 0.3 and 20K in magnetic fields to 7T. At zero field a minimum in C/T is observed near 11K. Below that temperature C/T increases and below 0.5K exhibits an upturn ascribed to a hyperfine contribution. The increase in C/T below 11K is reduced by a factor 1.5 for H=7T, whereas the hyperfine term is enhanced due to the contribution of the ^{63}Cu and ^{65}Cu nuclei.

The hybridization of f electrons with the conduction band, in rare-earth and actinide based compounds, leads to various kind of phenomena. The most interesting one is probably the occurrence of an unusually large value of the coefficient (γ) of the linear term in the specific heat at low temperature for some compounds known as heavy-fermion compounds (HFC). To date, due to the difficulty of preparing good quality samples, the class of ytterbium-based HFC has not received as much attention as the cerium and uranium-based HFC. We report here on specific heat (C) measurements on a high purity polycrystalline sample of $YbCu_{4.5}$ between 0.3 and 20K in magnetic fields (H) to 7T.

Stoichiometric amounts of 3N ytterbium and 5N copper were melted by resistive heating in a tantalum tube with both ends sealed with an electron gun and squeezed in high-current clamps. Three passes through a high frequency vertical zone melting furnace were then made. Due to the thermal gradients in this process migration of Yb was observed throughout the sample. Nevertheless, we found that about half of the sample was a pure $YbCu_{4.5}$ phase as shown by metallography, X-ray diffraction and energy dispersive electron micro-probe analysis.

Fig. 1 shows the temperature dependence of C/T in magnetic fields. The points below 0.7K are well represented by the sum of a hyperfine contribution, $A(H)T^{-2}$, and γT, and were analyzed on that basis.The dashed lines at low temperature represent C/T after subtraction of $A(H)T^{-2}$. Unlike previous data (1-3) limited to T>1.3K and measurements of non-zone refined samples, the present data do not show any anomaly at 2.2K, where the main parasitic phase, Yb_2O_3, orders antiferromagnetically, emphasizing the good quality of the sample. The behavior of C/T is similar to that reported for non-magnetic cerium-based

HFC, such as $CeCu_6$, with different temperature dependencies in two regions of temperature: (i) above 12K, one observes the usual decrease with decreasing T; (ii) Below 10K, C/T exhibits an enormous increase ascribed to the formation of a resonance at the Fermi level due to the Kondo interaction between 4f and conduction electrons. The extrapolated value of $\gamma \sim 635$ mJ/K^{2}mole is, to our knowledge, the largest among non-magnetic ytterbium-based HFC. As a first approximation, by applying the theory of dilute Kondo systems (4) our results lead to an estimation of the Kondo temperature $T_K \sim 9$K. This value roughly corresponds to the temperature at which the electrical resistivity and the thermoelectric power reach their extrema (1).

The field dependence of the extrapolated values of γ are plotted in Fig. 2. Applying a magnetic field results in a rapid decrease of C/T reflecting the progressive cancellation of the Kondo interaction (intrasite) and of possible magnetic correlations between two next neighbor rare-earth atoms (intersite). However, the absence of saturation in the decrease of γ indicates only a partial destruction of the magnetic interactions in a magnetic field of 7T and is therefore consistent with the estimated value of the energy scale of the Kondo interaction (T_K). A regime where the magnetic interactions have completely collapsed can be expected only at higher field, at which the Zeeman energy becomes larger than the energy scales of the intrasite and intersite magnetic interactions.

The field dependence of the coefficient of the T^2 term is plotted in fig. 3. The error bars represent the change in A(H) from the best-fit value that would increase the rms deviations by 20%. The uncertainty in the coefficient A(H) reflects the large value of the electronic term compared with the hyperfine contribution in the temperature range of the fit. At H = 0,

the coefficient A=850 μJK/mole probably arises mainly from pure quadrupolar splitting of ^{173}Yb. However, preliminary Mössbauer measurements (5), showed the presence of two different Yb sites with equal occupancy, leading to a quadrupolar contribution to the coefficient A of 320 μJK/mole. (The remaining part might possibly be ascribed to the quadrupolar splitting of ^{63}Cu and ^{65}Cu). For $0<H\leq 7T$, the contribution to A of ^{171}Yb and ^{173}Yb nuclei can be calculated to be negligible and the hyperfine contribution of ^{63}Cu and ^{65}Cu should be dominant. However, in this case also, the values of A are about 2.6 times greater than expected.

Acknowledgements

This work was supported by the Director, Office of Basic Energy Sciences, Division of Materials Sciences of the U.S. Department of Energy under Contract DE-AC03-76SF00098. Additional support for A.A. was provided by a grant from the Swiss National Science Foundation.

References

(1) D. Jaccard, A. Junod and J. Sierro, Helv. Phys. Acta. 53 (1980) 583.

(2) N. Sato, H. Abe, M. Kontani, S. Yamagata, K. Adachi and T. Komatsubara, Physica B to be published.

(3) Z. Fisk, J.D. Thompson and H.R. Ott, J. Magn. Magn. Mat. 76&77 (1988) 637.

(4) V.T. Rajan, Phys. Rev. Lett. 51 (1983) 308.

(5) F. Bonville, private communication.

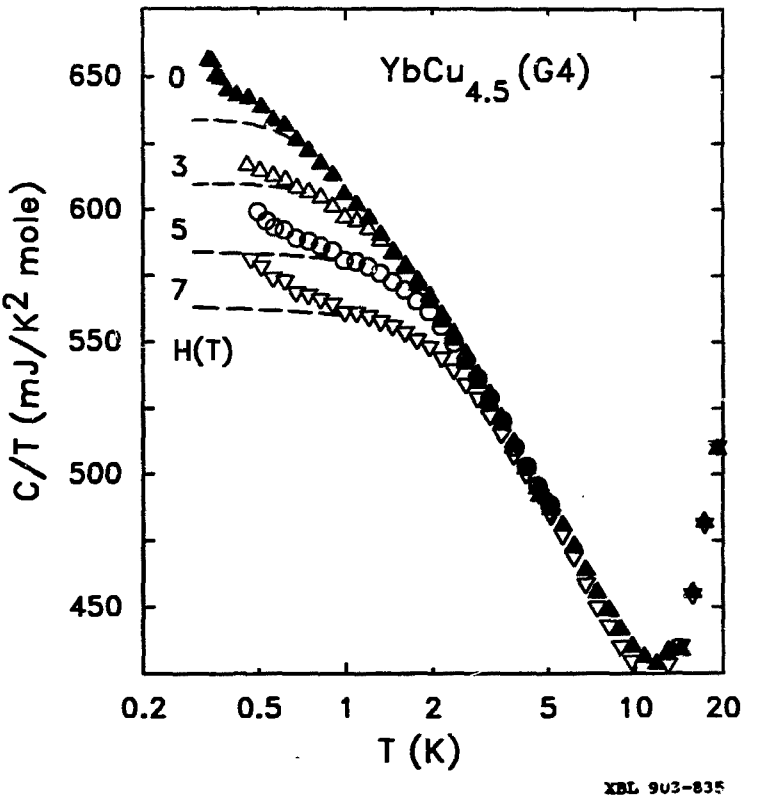

FIGURE 1

Field dependence of C/T. The dashed lines show C/T after subtraction of a hyperfine contribution.

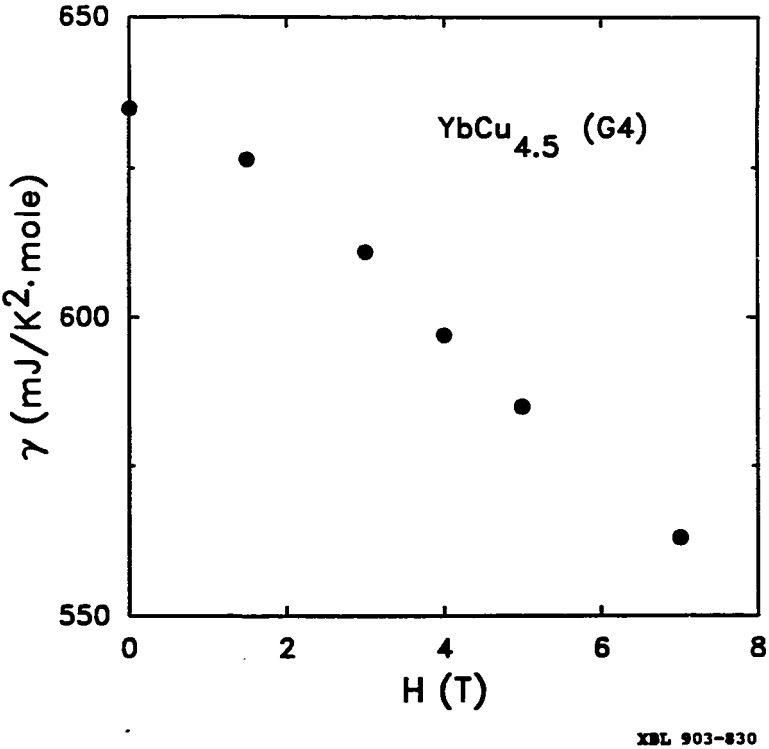

FIGURE 2

Field dependence of the extrapolated values of γ, after subtraction of a hyperfine contribution from C.

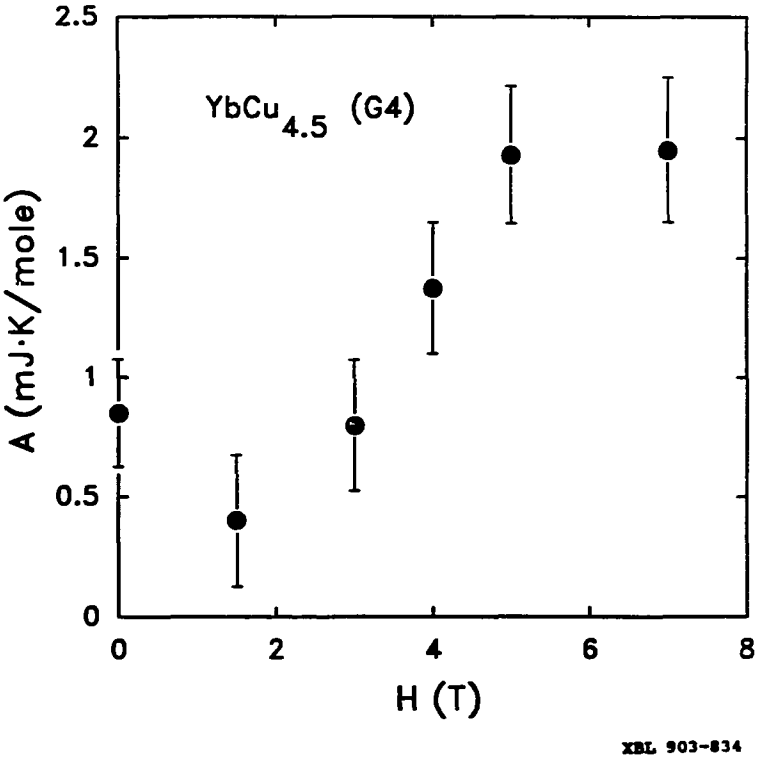

FIGURE 3

Field dependence of the coefficient A(H) of the hyperfine contribution $C_N = A(H)/T^2$.