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PRESSURE DEPENDENCE OF THE SPECIFIC

HEAT OF CeAl_3

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Abstract

The specific heat (C) of the heavy-fermion compound CeAl_3 has been measured between 0.3 and 20 K at pressures to 8.2 kbar. A very strong and non-linear dependence of C on pressure is observed. The maximum in C/T , which is a prominent feature of zero pressure measurements, disappears under pressure.

The specific heat of CeAl_3 has been measured under pressures (P) to 8.2 kbar between 0.35 and 20 K and the zero pressure measurements have been extended to 60 mK. There was no significant change in the zero pressure specific heat after cycling to the highest pressure. The magnitude of the effect of pressure is large and in agreement with previous experiments performed at $P = 0$ and 7 kbar above 1.5 K [1]. Our data at the lower pressures show that the P dependence is extremely non-linear. In particular, the maximum in C/T which seems to occur in the normal phase of non-magnetic heavy fermion compounds (HFC) [2,3] appears to be completely suppressed at a P of only 0.38 kbar. The results are shown in Figure 1, where an empirical $P^{1/6}$ pressure dependence of $[C/T]_{0.4\text{K}}$ is demonstrated in the inset (0.4 K is approximately the temperature of the zero-pressure maximum in C/T). The Gruneisen parameter $\partial \ln[C/T]_{0.4\text{K}} / \partial \ln V$, obtained by using the pressure dependence represented in Figure 1 and $K = 2.19 \times 10^{-3} \text{ kbar}^{-1}$ [6], varies from 360 at 0.1 kbar to 18 at 8 kbar. Another interesting point is that there is no pressure induced ordering (neither superconductivity nor magnetic ordering).

Pressure is a good variable for inducing a change from HFC to IVC (intermediate valence compound) behavior [4]. The Kondo temperature (T_K) in an HFC is drastically modified but there is a weaker pressure dependence of the IVC parameters because the increase of mixing reinforces the itinerant character of the f electrons and decreases the importance of correlations [5]. At $P = 0$ the temperature of the maximum in C/T has been taken as defining the temperature T^* where interactions between the heavy particles produce a coherent Kondo lattice [2,3]. As pressure data are limited to $T > T^*(0)$, the present results do not give a direct measure of $T^*(P)$ but the rapid change with pressure of C/T at $T > T^*(0)$ suggests a dramatic change in the interactions between particles. The values of $\gamma = [C/T]_{OK}$ have been obtained by extrapolation of the approximately linear C/T vs. T relation and are given in Table I together with the derived values of m^*/m and a Gruneisen coefficient $\Omega(m^*) = \partial \ln m^* / \partial \ln V$.

Attempts have been made to fit the specific heat using a free energy function $F = -kT \int_{-\infty}^{\infty} \rho(\epsilon) \ln \sum \exp(m\epsilon/kT) d\epsilon$, where the partition function is that of a collection of independent spins with $S_z = m$ subject to a distribution $\rho(\epsilon)$ of internal fields ϵ . This model with $\rho(\epsilon)$ taken as a

Lorentzian has been used to give a phenomenological representation of single-impurity Kondo systems [7]. We use here the sum of two Lorentzians of width Δ and centered at $\epsilon = \pm E_0$, which may represent a Kondo lattice with no dynamical interaction between particles [8]. At $P = 0$, it is impossible to obtain a good fit with constant values of Δ and E_0 , but an approximate fit can be obtained by using different values above and below 0.37 K. This temperature dependence of the parameters is in agreement with a recent theory of the Kondo lattice [9] and with experimental observations of changes in other variables like thermoelectric power [10].

The values of the parameters are given in Table II and reflect the necessity of a minimum in (temperature independent) $\rho(\epsilon)$ to represent the maximum in C/T . (Another approach to this problem is reported in another paper at this conference [11].) For $P \neq 0$, where the maximum in C/T is suppressed, approximate fits can be found with constant values of Δ and E_0 (also given in Table II). The resulting fits are shown in Figure 1 by the full lines. The difficulty in fitting the data above 2 K is due to the limitation in the model to a spin 1/2. The pressure mixing of the crystal field levels will be discussed in another paper.

Finally, the huge variation of C/T for a relatively small volume change ($\delta V/V \sim 1.6\%$ for $\delta P = 8$ kbar) contradicts the relatively weak variation of γ with the f atom distance deduced by the comparison of different lattices [12]. Clearly, the f atom distance is not an universal parameter for HFC's.

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Table I : Pressure dependence of the extrapolated value of C/T at 0K and of the corresponding effective mass normalized to the electron mass. The last column is the Gruneisen parameter $\Omega(m^*)$ interpolated between two pressure points.

P (kbar)	γ (mJ mole ⁻¹ K ⁻²)	m^*/m	$\Omega(m^*)$
0	1,164	291	
.38	1,024	256	168
2.2	838	209.5	56
4.75	657	164.5	47
8.2	549	137.5	26

Table II : Pressure dependence of the E_0 and Δ parameters of the two-Lorentzian model used for fitting the data.

P (kbar)	E_0 (K)	Δ (K)	$E_0 + \Delta$ (K)
0	2.7	1.5	4.2 (T < 0.37)
0	0	4.5	4.5 (T > 0.37)
0.38	4	6	10
2.2	4.7	7.6	12.3
4.75	6.5	8.1	14.6
8.2	8	10	18

Figure Caption

Figure 1 : Temperature dependence of C/T at various pressures and, represented by the full lines, the fits obtained with the parameters of Table II. The $p^{1/6}$ dependence of $[C/T]_{0.4K}$ is shown in the insert.

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Fig. 1

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