Title
Pressure Dependence of the Specific Heat of Heavy-Fermion YbCu{sub 4.5}

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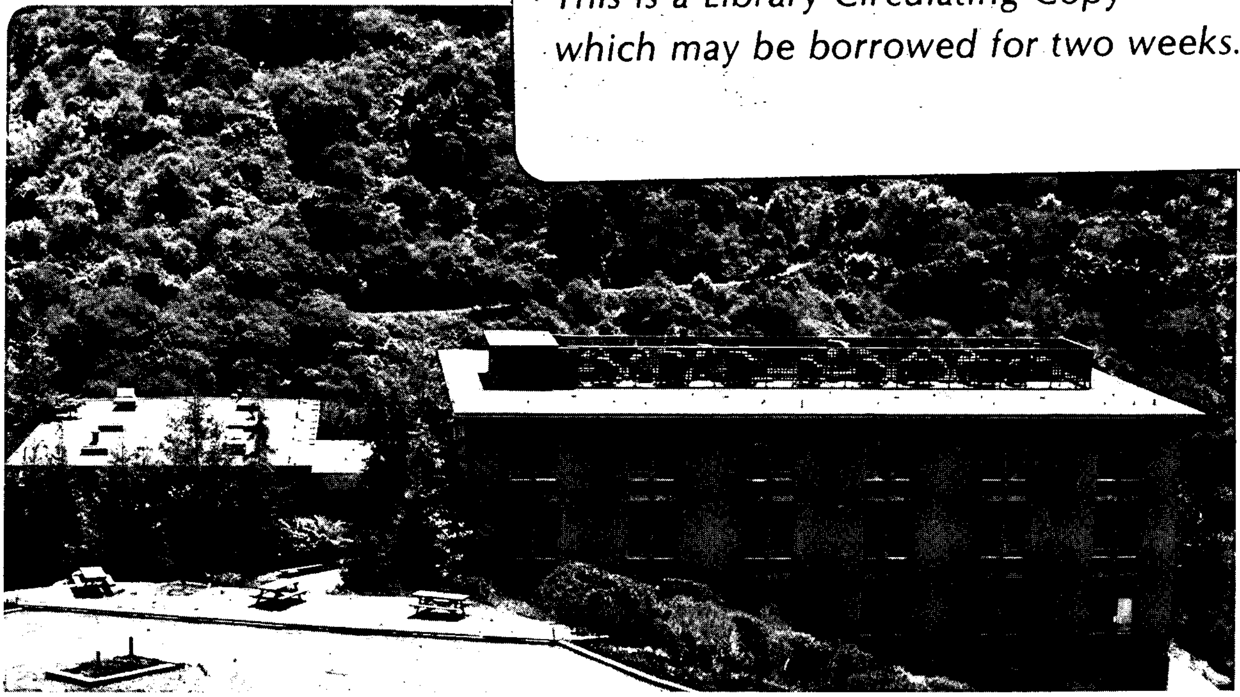

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PRESSURE DEPENDENCE OF THE SPECIFIC HEAT OF HEAVY-FERMION $YbCu_{4.5}$

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The specific heat of a polycrystalline sample of $YbCu_{4.5}$ has been measured between 0.3 and 20K at pressures to 8.2 kbar. Unlike cerium-based heavy-fermion compounds, an increase of C/T is observed with increasing pressure, with the linear term enhanced by about 16% at 8.2 kbar. Above 7K, $(\partial C/\partial P)_T$ is negative. The nuclear contribution observed at $P=0$ is increased by roughly a factor of two at 8.2 kbar.

Due to the high sensitivity to pressure of the 4f and 5f electrons, the heavy-fermion compounds (HFC), in which the hybridization of the f electrons with the conduction band plays the key role in the phenomenon, represent an interesting field for measurements of the pressure dependence of the physical properties. We report here on specific heat (C) measurements on a high purity polycrystalline sample of $YbCu_{4.5}$ between 0.3 and 20K as a function of pressure (P) to 8.2 kbar.

$YbCu_{4.5}$ can be categorized as a HFC that does not undergo a transition to either a magnetically ordered or a superconducting state to the lowest temperatures at which it has been studied ($T \approx 300$mK). Magnetic measurements below room temperature (1,2) suggest that ytterbium is close to the trivalent state ($4f^{13}$) with an effective moment $\mu = 4.22\mu_B$ which is near the value for a free trivalent ion $\mu = 4.54\mu_B$.

Details of the preparation and characterization of the sample are given in Ref. 3. Fig. 1 shows the temperature dependence of C/T under pressure. The precision of the measurements is such that the uncertainty in C for the sample is about 0.4% at the lowest temperatures, increasing to about 6% at 20K. At $P=0$, C/T exhibits a minimum near 11K. Below 10K, one observes a dramatic increase with decreasing T reflecting the formation of a narrow resonance due to the Kondo interaction between 4f and conduction electrons. The points below 0.7K are well represented by the sum of a hyperfine contribution, AT^{-2}, and γT. They were analyzed on that basis to obtain $\gamma(P)$ and A(P). $A(0) \approx 850\,\mu$JK/mole, which is at least in part due to the quadrupole splitting of ^{173}Yb nuclei (3,4), and a possible contribution from ^{63}Cu and ^{65}Cu. There are two temperature regions that differ in the pressure dependence of C: (i) above about 7K $(\partial C/\partial P)_T$ is predominantly negative; (ii)

Below 7K a rapid increase of C with increasing P is observed. The extrapolated values of the coefficient of the electronic term of the specific heat (γ), as a function of P, are plotted in Fig. 2. In the pressure range investigated γ is linear in P, $\gamma(P)=637+12.6P$ mJ/K^{2}mole. A similar behavior of $\gamma(P)$ has been found in the intermediate valence compound YbCuAl (5) and is in sharp contrast with the usual decrease in $\gamma(P)$ observed in non-magnetic uranium or cerium-based HFC, such as $CeCu_6$ -- see Fig. 2.

The cerium (or uranium) compounds lose their localized magnetic moments under pressure because the single $4f^1$ (or $5f^1$) electron is squeezed out of the f-shell. Thus a gradual transition is observed from a heavy-fermion state to a valence fluctuating state and a decrease of γ occurs. On the other hand, for ytterbium compounds the pressure stabilizes the trivalent state ($4f^{13}$) and, therefore, the localized magnetic moment. One can thus expect to observe the development, or the strengthening, of heavy-fermion behavior through the application of pressure. The present data, like the systematic decrease under pressure of the temperature (T_M) at which the electrical resistivity is maximum (7), with T_M presumably related to the energy scale (T_K) of the intrasite Kondo interactions, are in agreement with this simple viewpoint. Whereas there are qualitative similarities between the effects of the pressure and the magnetic field (H) on the specific heat for cerium-based HFC (namely a similar decrease), the responses of the ytterbium-based HFC to the action of P and H are opposite (3) emphasizing the different effects of the pressure (modifying the occupancy of the 4f-shell) and of the magnetic field (locking the spin-flip processes).

Fig. 3 is a plot of the pressure dependence of the coefficient of the T^{-2} term of the high temperature limit of the nuclear contribution. At $P=8.2$ kbar A is enhanced by roughly a factor of two, describing, presumably, an increase of the electrical field gradient at the ^{173}Yb, ^{63}Cu and ^{65}Cu sites.

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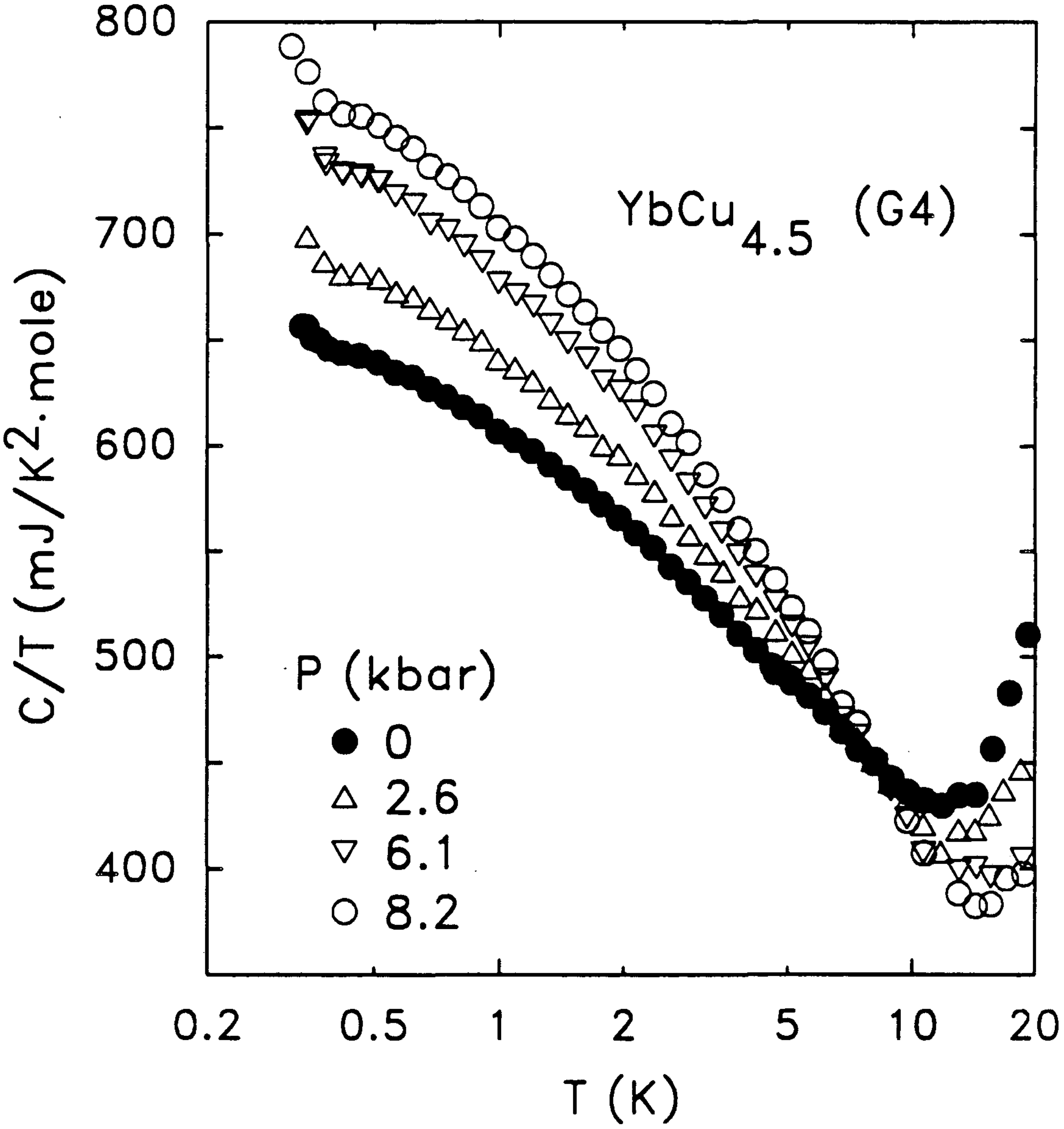

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FIGURE 1

Pressure dependence of C/T for $YbCu_{4.5}$

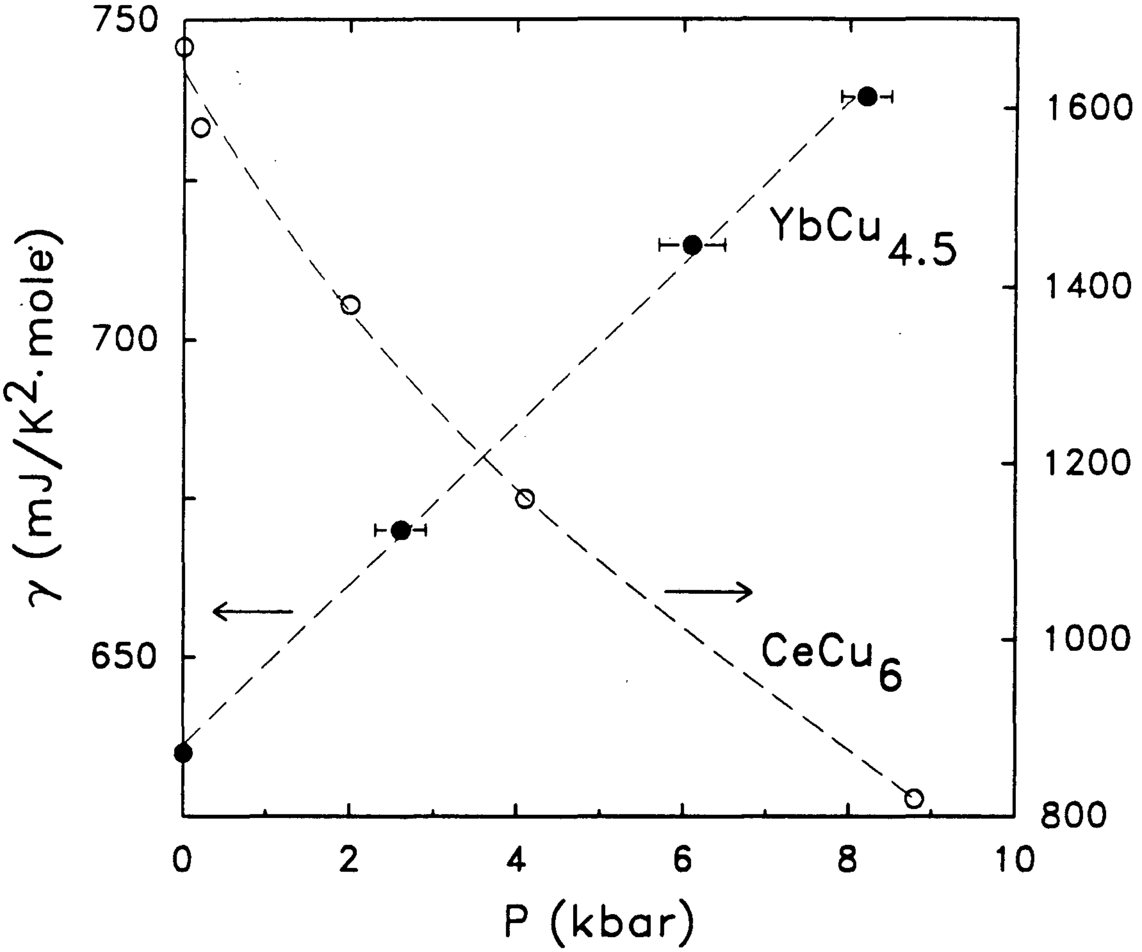

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FIGURE 2

Pressure dependence of the extrapolated value of γ for $YbCu_{4.5}$ after subtraction of a nuclear contribution from C. Data for $CeCu_6$ (Ref.6) are plotted for comparison.

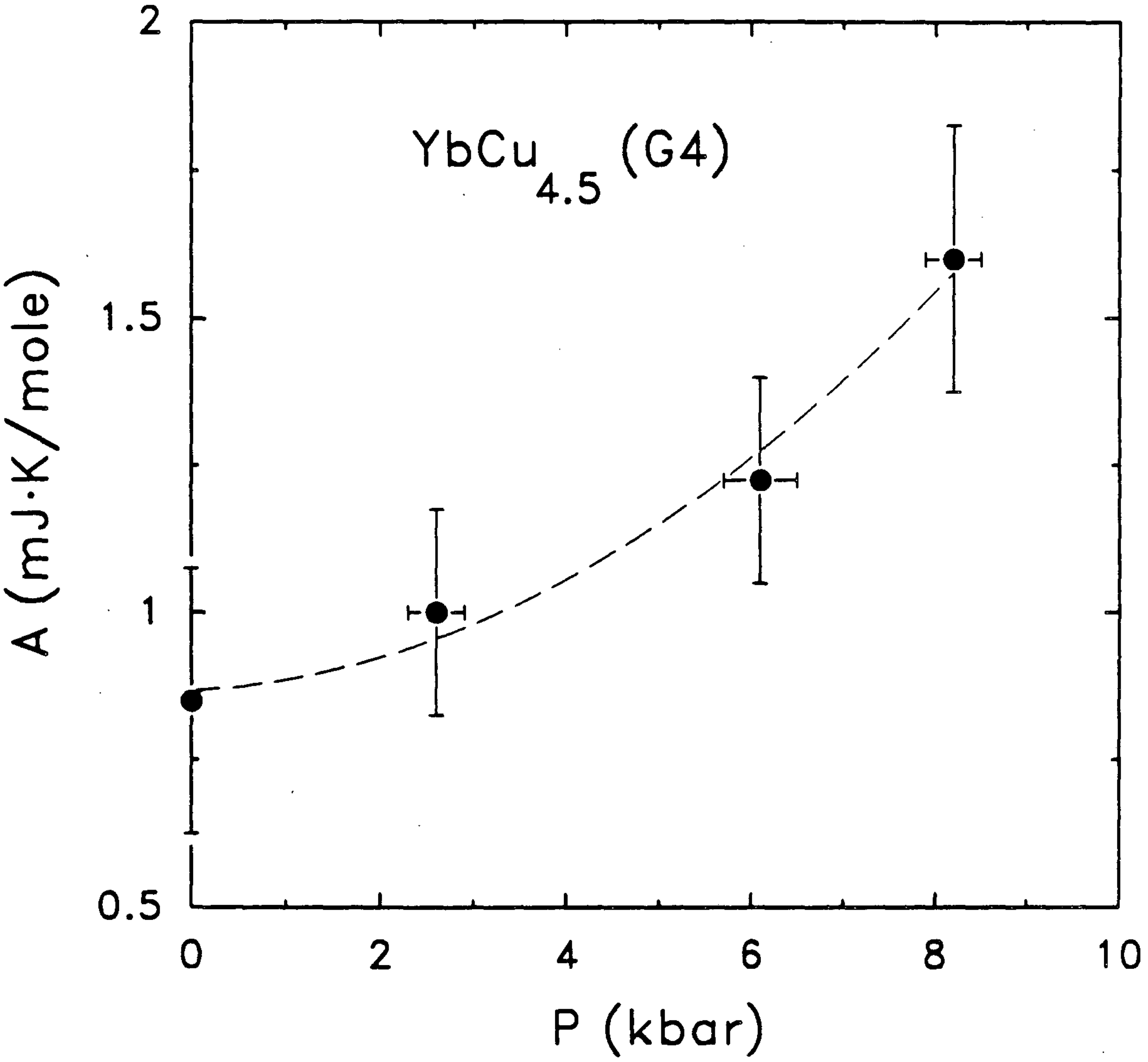

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FIGURE 3

Pressure dependence of the coefficient A of the nuclear contribution.

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