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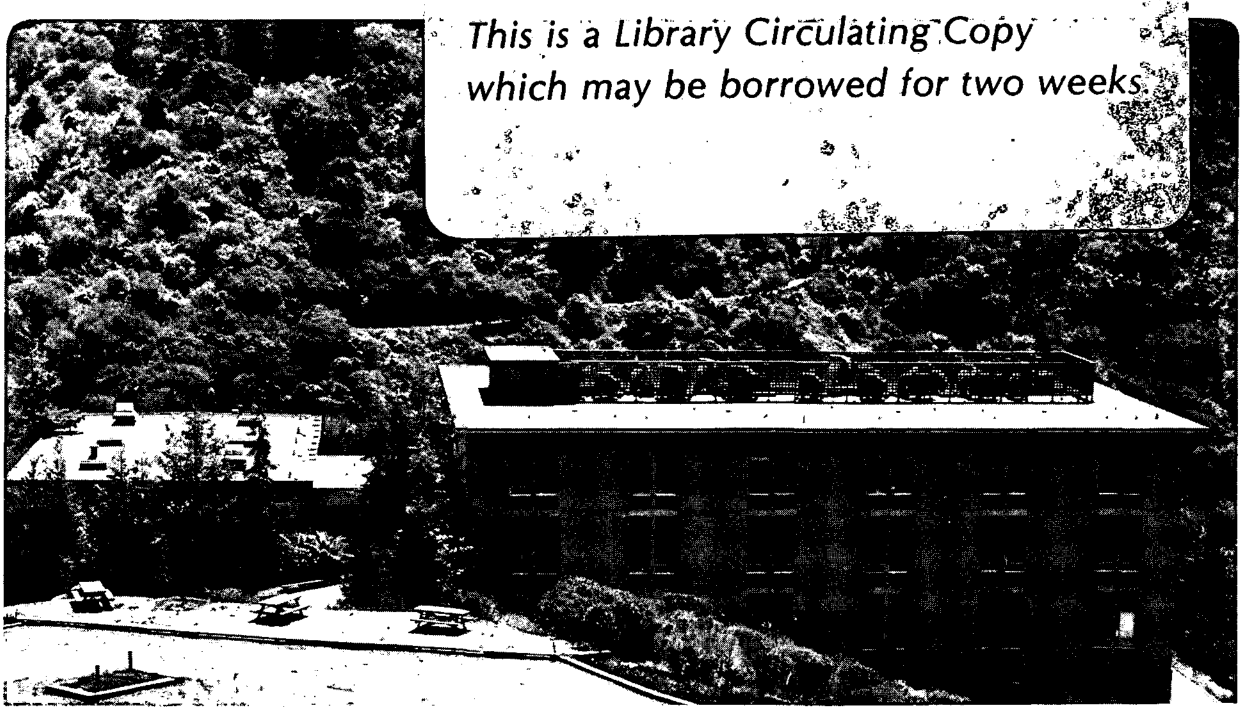

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The specific heat, C, of a single crystal of $CeCu_6$ has been measured between 0.06 and 20K to pressures, P, of 8.8 kbar, and between 0.3 and 20K in magnetic fields, H, to 7.5T. At zero H and P, a minimum in C/T is observed near 8K. Below that temperature C/T increases, and below 1K is linear in T, C/T=1.67-0.67T J/mole K^2. No maximum in C/T is found. This increase in C/T is reduced by a factor of three at 8.8 kbar and virtually completely suppressed for H = 7.5T along the [001] axis. With H ∥ [100] and [010] axes the effect on C is small.

$CeCu_6$ is an example of a heavy-fermion compound, HFC, that does not undergo a transition to either a superconducting or magnetically ordered state above 60mK [1-4]. In this respect it is similar to $CeAl_3$ [5]. Measurement of the pressure dependence of the properties of such an HFC is of particular interest because the 4 f-electrons, which play a central role in the phenomena, are very pressure sensitive and large effects can be observed at modest P without the complications of ordering. Properties of materials as a function of P provide an additional dimension for comparison with theoretical models, and also provide a sound basis for correlating various properties, since only one simple parameter, the volume, V, is changed. The response of C to H for an HFC is not as simple as that of C to P. However, measurements of C in large H can produce a high degree of magnetic polarization leading to a state in which interactions between particles are dominated by the interaction with the magnetic field.

At zero P and H we have measured C for two single crystal samples of $CeCu_6$ -- G1, unannealed and G2, annealed. The results are shown in Fig. 1. Sample G2 had a residual resistivity, $\rho(0)$, which was one-half that of sample G1 which had $\rho(0) = 4\mu\Omega$cm along the [001] axis. Both samples have essentially identical C as shown in the lower insert of Fig. 1. In contrast to $CeAl_3$ [2], there is no maximum in C/T for $CeCu_6$ to 0.06K. Below 1K, C/T is linear in temperature: C/T = 1.67 - 0.67T J/mole K^2 (see insert at the top of Fig. 1). (To our knowledge, this value of γ, 1.67, is the largest known.) The absence of a maximum in C/T agrees with two previous results [1,2] but not with another [3].

A sample similar to G2 was measured to pressures of 8.8 kbar in the range $0.06<T<20$K. The results are plotted as C/T vs T in Fig. 2. The linearity of C/T with T below 1K holds to the highest P, as shown in the insert to Fig. 2. Values of $\gamma(P)$ and a(P) are listed in Fig. 2. At 8.8 kbar, γ is decreased by a factor of two and a by a factor of six. There is a substantial non-linearity in the pressure dependence of C, and to show more clearly the relationship between C(P) at different P, smoothed representations of [C(P)-C(0)]/T are plotted vs T in Fig. 3. Error bars represent the indicated percentage of the total measured C including that of the pressure cell. Precision of the measurements is such that the uncertainty in C for the sample is about 0.1% of the total. As illustrated in Fig. 3, there are three regions of pressure dependence:

1) below 2K, where $(\partial C/\partial P)_T$ is predominantly negative; 2) between 2 and 10K, where it is positive; and 3) above 10K, where it is again negative. Smoothed values of the Gruneisen parameter for C is defined as $\Gamma_C \equiv -(\partial \ln C/\partial \ln V)_T = \kappa^{-1}(\partial \ln C/\partial P)_T$ where κ is the compressibility, as listed in Table I.

C(P) can be compared to $\rho(P)$, where ρ is the resistivity, by using the approximate empirical rule $\gamma \propto T_M^{-1}$, where T_M is the maximum in ρ vs T [6]. For $CeCu_6$ $\gamma(0)/\gamma(9\ \text{kbar}) = 2.0$ and $T_M(9\ \text{kbar})/T_M(0) = 2.2$ [7]. Both γ and T_M probably depend in a complex way on the interplay between the interactions related to characteristic temperatures T^* (intersite interactions between f-electrons) and T_K (Kondo-like interactions of f-electrons and the conduction band). However, the correlation between γ and T_M seems to indicate the existence of a scaling relation involving these characteristic temperatures.

The specific heat for sample G1 was measured in magnetic fields to 7.5T for $0.3<T<20K$ and H ∥ [001], [010] and [100], respectively. Fig. 4 shows the results plotted as C/T vs T. For H ∥ [100] and [010] the effect of H is small. With H ∥ [001] there is a large effect on C, with 7.5T nearly completely suppressing the increase of C/T for $0.3<T<8K$. As shown in the insert of Fig. 4, C/T has an initial quadratic H-dependence: $C(H)/T = C(0)/T - \alpha H^2$. For $H<4.5T$ a broad maximum develops in C/T. The occurrence of a maximum at high H can be explained by the strong polarization of a narrow band with Zeeman decoupling between spin-up and spin-down bands.

There are interesting qualitative similarities between the effects of P and H on C for $CeCu_6$. (The effect of 5T ∥ [001] is strikingly similar to that of 8.8 kbar.) While these similarities are suggestive, they occur in a temperature region where C is presumably dominated by intersite interactions on a Kondo lattice, and no simple rationale has been recognized for them. $CeAl_3$ shows the same effect of P and H on C; however, by contrast, UBe_{13} and UPt_3, while exhibiting a strong dependence of C on P, have only a weak dependence of C on H at any temperature [8].

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* Work at Berkeley supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Materials Sciences Division of the U.S. Department of Energy under Contract Number DE-AC03-76SF00098.

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Table I. Γ_C for $CeCu_6$. ($\kappa=1.1\times10^{-3}$ kbar^{-1}[9].)

T(K) P(kbar)	0	0.5	1	1.5	2	5	10	20
0	-115	-52	0	20	40	-8	-56	-90
1	-88	-54	-19	0	10	4	-28	-72
3	-73	-60	-41	-23	-13	14	-4	-54
5	-68	-60	-46	-31	-18	12	6	-37
7	-66	-57	-48	-35	-20	5	12	-17
9	-63	-55	-50	-38	-22	0	18	0

FIGURE CAPTIONS

Fig. 1. C/T vs log T for $CeCu_6$.

Fig. 2. C/T vs log T for $CeCu_6$ at constant P.

Fig. 3. [C(P)-C(0)]/T vs T at constant P.

Fig. 4. C/T vs log T at constant H.

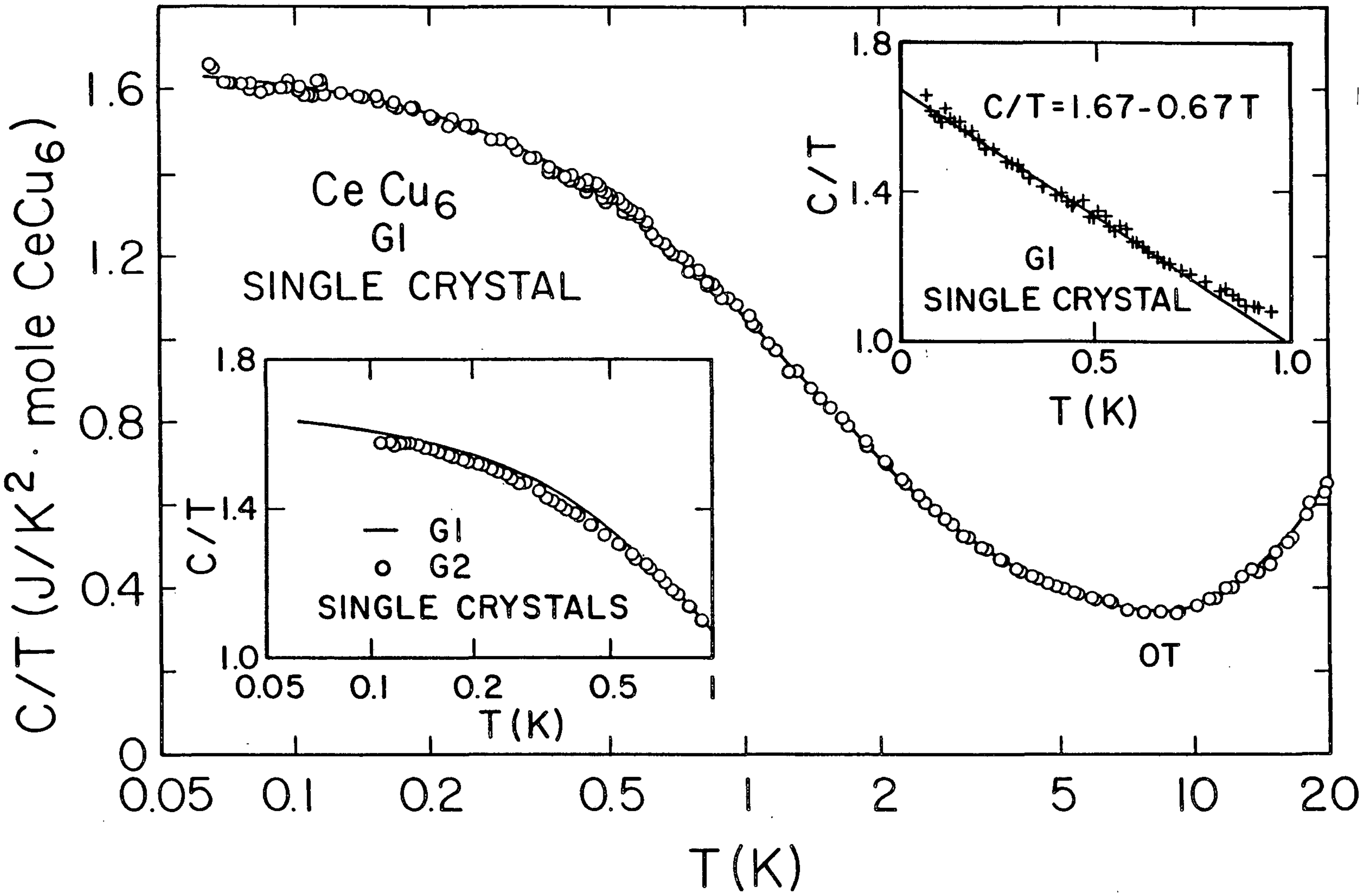
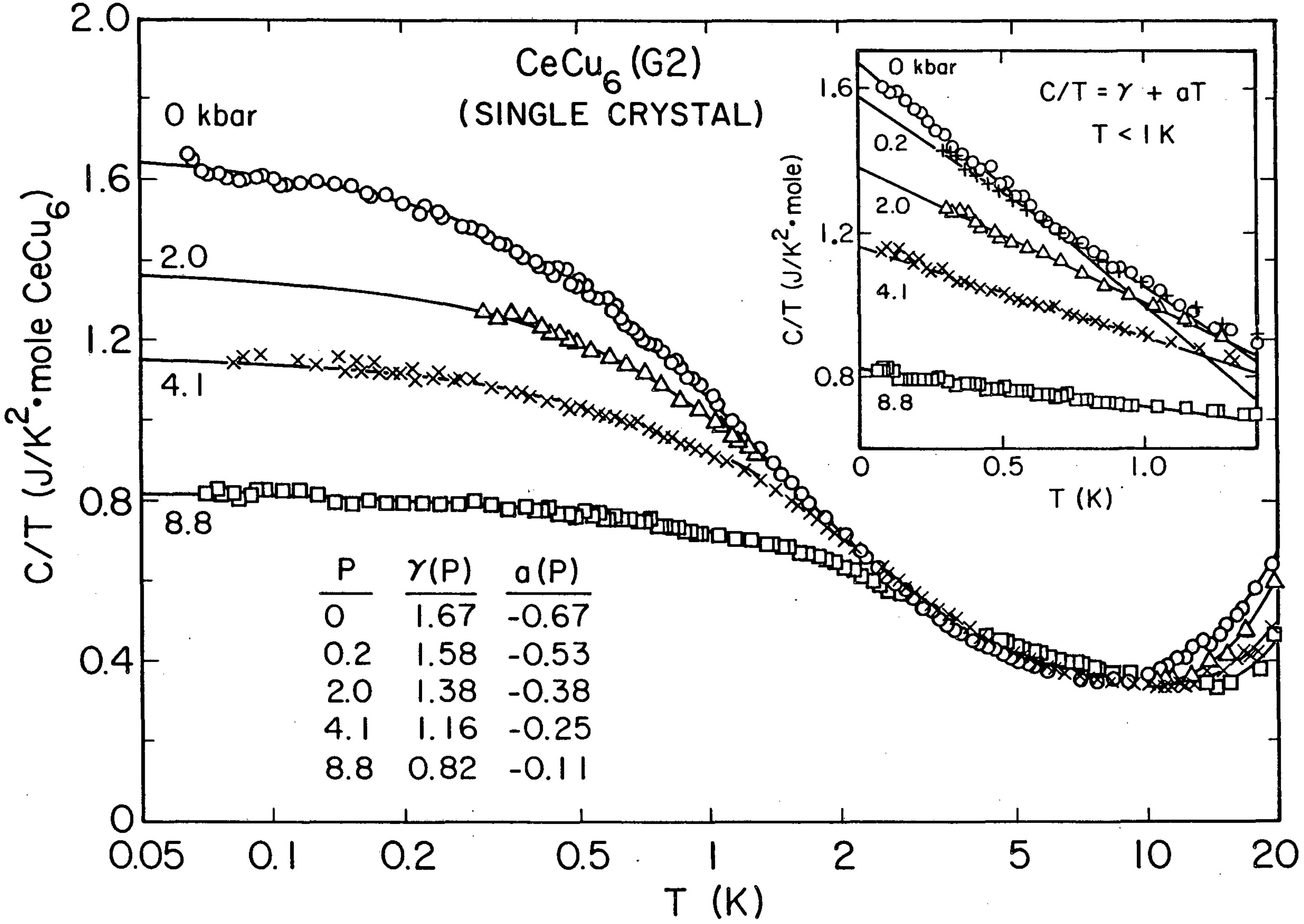

C/T (J/K^2 · mole CeCu$_6$)
1.6
1.2
0.8
0.4
0
0.05
0.1
0.2
0.5
1
2
5
10
20
T(K)
Ce Cu$_6$
G1
SINGLE CRYSTAL
0T
C/T
1.8
1.4
1.0
0.05
0.1
0.2
0.5
1
T(K)
— G1
o G2
SINGLE CRYSTALS
C/T
1.8
1.4
1.0
0
0.5
1.0
T (K)
C/T=1.67-0.67T
G1
SINGLE CRYSTAL

FIGURE 1



P	γ(P)	a(P)
0	1.67	-0.67
0.2	1.58	-0.53
2.0	1.38	-0.38
4.1	1.16	-0.25
8.8	0.82	-0.11

FIGURE 2

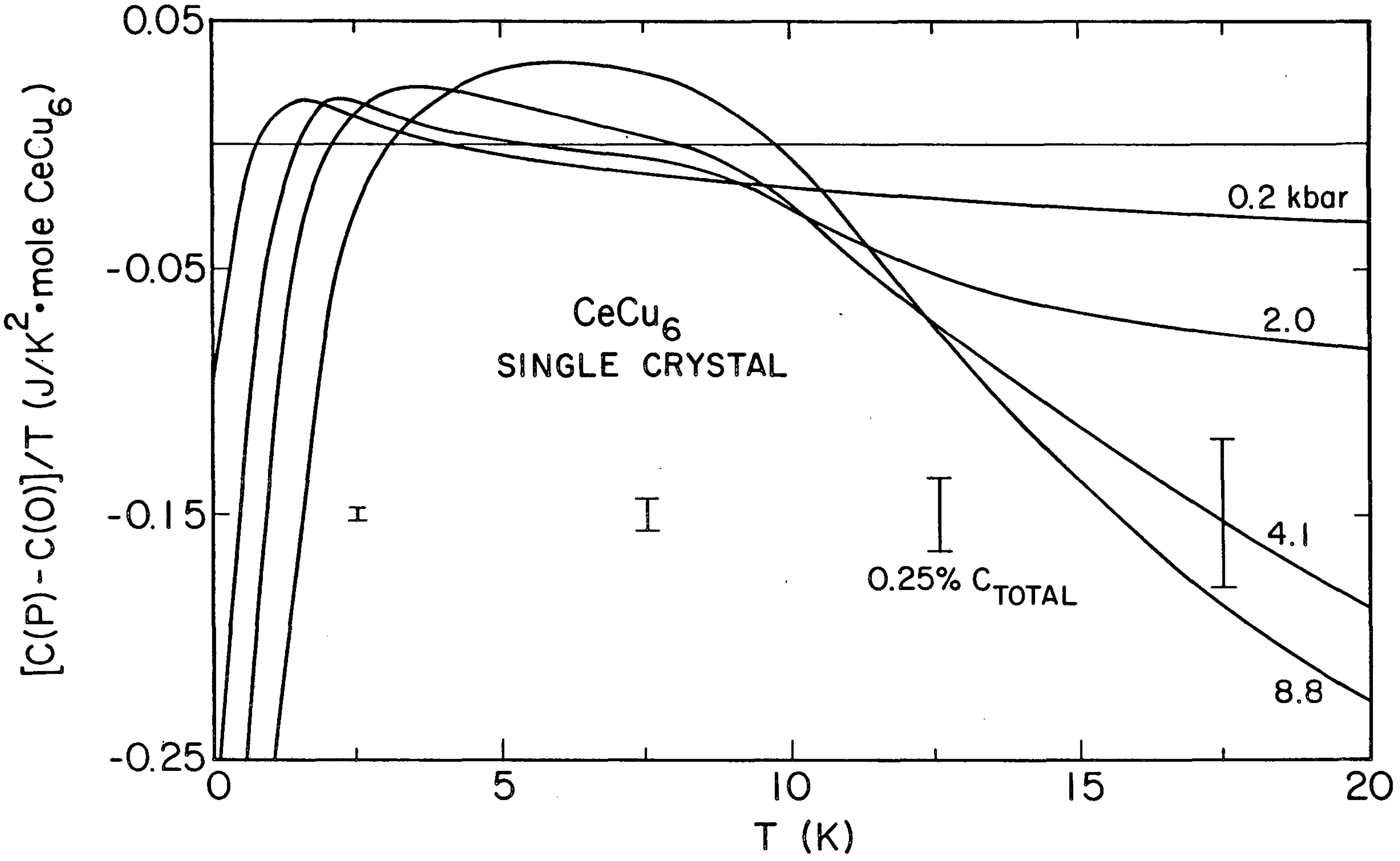

0.05
-0.05
-0.15
-0.25
0
5
10
15
20
T (K)
[C(P) - C(O)]/T (J/K^2•mole CeCu$_6$)
CeCu$_6$
SINGLE CRYSTAL
0.2 kbar
2.0
4.1
8.8
0.25% C$_{TOTAL}$

FIGURE 3

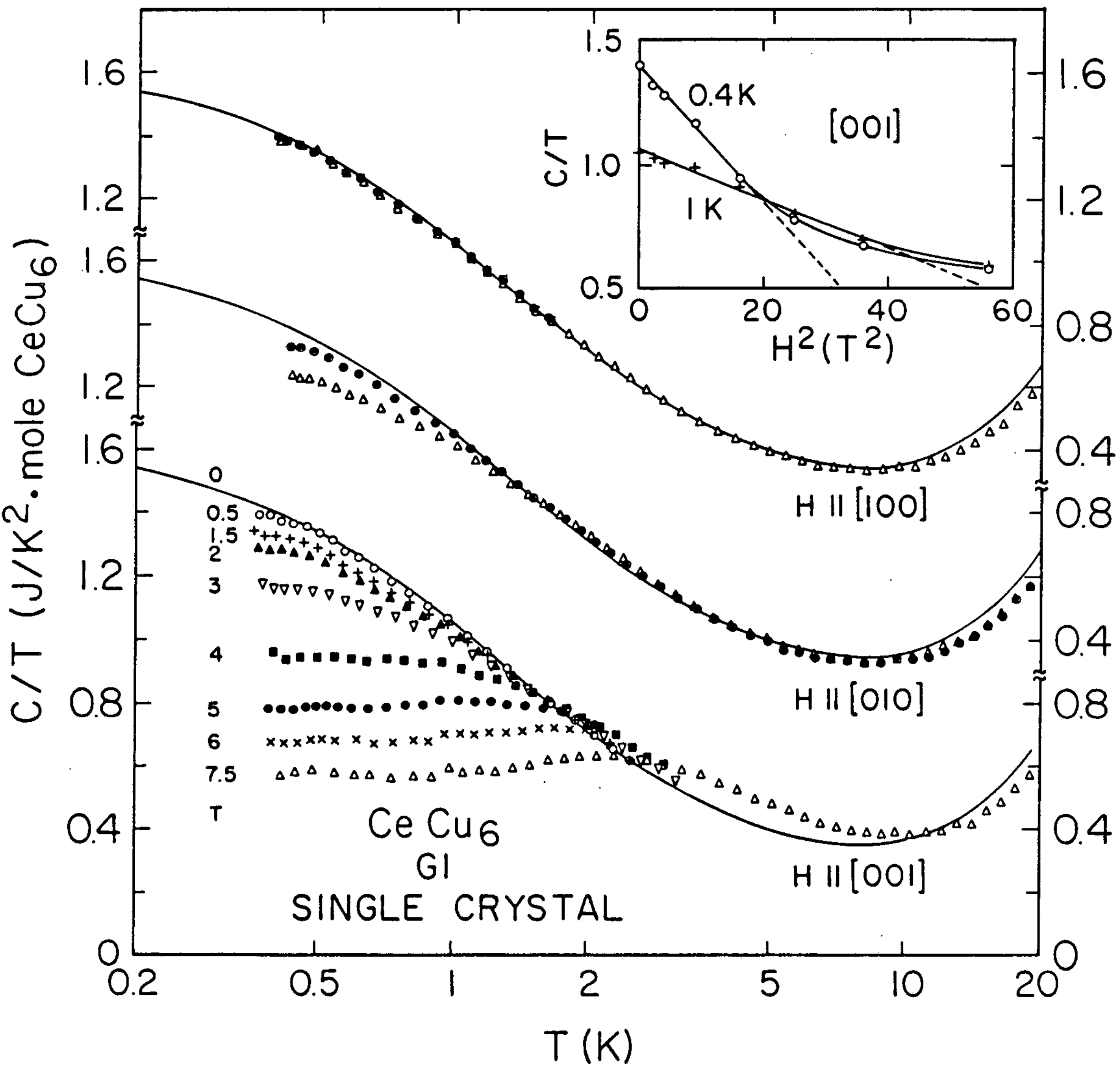

C/T (J/K^2· mole CeCu$_6$)
T (K)
0.2
0.5
1
2
5
10
20
0
0.4
0.8
1.2
1.6
H ∥ [100]
H ∥ [010]
H ∥ [001]
0
0.5
1.5
2
3
4
5
6
7.5
T
Ce Cu$_6$
G1
SINGLE CRYSTAL
C/T
1.5
1.0
0.5
0.4K
1K
[001]
0
20
40
60
H^2(T^2)

FIGURE 4

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