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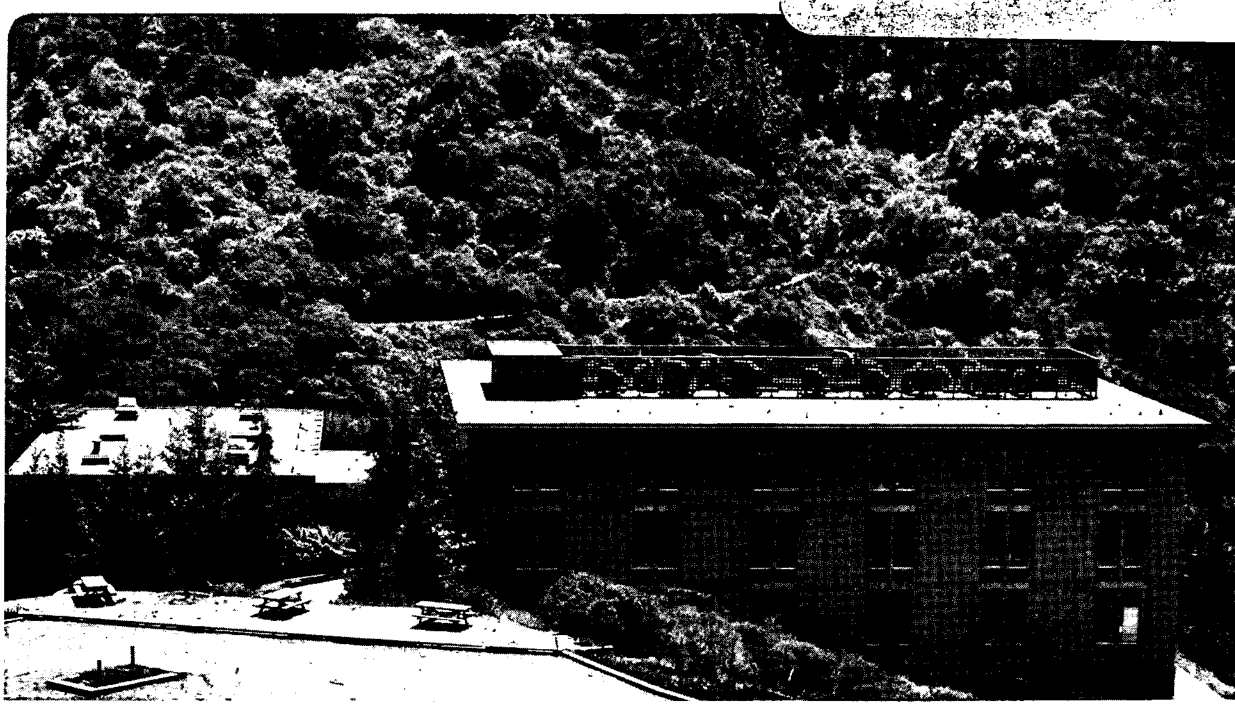
August 1985







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# SPECIFIC HEAT OF $CeAl_3$ BELOW 20K IN FIELDS TO 8T: EFFECT OF $CeAl_2$ AND/OR $Ce_3Al_{11}$ PHASES

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Four polycrystalline samples of $CeAl_3$ containing $CeAl_2$ and/or $Ce_3Al_{11}$ phases (2.6 to 13 wt.%) have been studied at $0.35<T<20K$ and $0<H<8T$. The specific heat for all samples agreed after correction for the impurities. The results below 1K are compared with the RLM using a T dependent Δ.

$CeAl_3$   Specific-Heat   Magnetism   Heavy-Fermion

PACS:   65.40-f   44.50.+f

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$CeAl_3$ melts incongruently and samples prepared from the stoichiometric melt contain $CeAl_2$ and $Ce_3Al_{11}$ impurities which can be reduced in concentration by annealing. Below 1K both $CeAl_2$ (antiferromagnetic: $T_N$=3.8K [1]) and $Ce_3Al_{11}$ (ferromagnetic: transitions at 3.2 and 6.2K [2]) have specific heats (C) which are negligible compared with that of $CeAl_3$, but C for $CeAl_3$ may be affected by strains due to the impurities. C *vs* T is plotted in Fig. 1 for four $CeAl_3$ samples. At H=0 the anomalies indicate varying amounts of $CeAl_2$ and/or $Ce_3Al_{11}$. The maxima due to transitions in the impurity phases are rounded and shifted to lower temperatures than in the pure components [1,2], showing that C of the host $CeAl_3$ and the impurities are not completely additive. Magnetic fields smooth the C *vs* T curves, masking impurity effects.

Sample G2 shows only $Ce_3Al_{11}$ impurity while N1 shows only $CeAl_2$. For these samples C was corrected for the impurity phases by a trial and error procedure (see Fig.2). First, a trial smooth curve, intended to represent C of the $CeAl_3$ content of the sample, was drawn. It joined the experimental curve at a temperature $T_1$ at which C of the impurity phase is negligible and was drawn parallel to the experimental curve at high temperatures where C is similar for all three phases. The entropy difference ($\Delta S$) between the trial and experimental curves was computed between $T_1$ and $T_2$, a temperature in the region in which the curves are parallel, and the wt.% impurity was calculated by comparison with the corresponding $\Delta S$ for the impurity in pure form. ($\Delta S$ was assumed to be the same for the impurity in pure and diluted forms, even though C is not.) The trial curve was progressively adjusted until the calculated wt.% impurity was consistent with its displacement from the experimental curve at high temperatures. In Fig.3, C vs T for G2 and N1, corrected to a mole of $CeAl_3$ by the above analysis, are plotted for 0 and 8T below 1K. For N2 (which contains both impurities, making the above analysis impractical) the 8T data were normalized to the data for G2 and N1 from $0.35K<T<1K$ to obtain a factor of 1.130. (G1 also contains both impurities estimated at 12.8 wt.%; however, extensive measurements in a field were not made.) At 8T all corrected data agree to ±0.5% in the range $0.35<T<1K$. At H=0 the agreement, using the same factors, varies from ±0.5% at 1K to ±3% at 0.35K. C vs H is plotted on isotherms in Fig.4. An interpretation of the near linear behavior of C vs H and the nearly T independent $(\partial C/\partial H)_T$ has been given elsewhere [3].

Figs. 3 and 4 show the close agreement of C for the different samples even though the impurities are different and their concentrations vary by a factor of 5.

Measurements on sample G2 have been extended, in zero field, to 0.06 K, and are qualitatively similar to several other recent measurements [4]. They are shown in Fig. 5 as C/T vs. T. The peak in C/T is not predicted by a single impurity description such as the resonant level model (RLM) [3]. Presumably it is due to development of coherence below 0.5K. It has been interpreted as due to a minimum in the density of states at the Fermi level [5]. However, as shown below, allowing the width Δ in the RLM to be T dependent can also lead to a peak in C/T. It is unclear whether development of coherence will affect the single impurity spin correlation time which is proportional to 1/Δ, but a new channel may open for losing local moment spin memory, which increases Δ, when coherence develops. The low-temperature spectral width determined by quasi-elastic neutron scattering [6], and thought by some to be proportional to Δ, may increase below 0.5K. To investigate the effect on C, we replace the T independent Δ in the RLM [3] by

$$\Delta(T)=\Delta_0[0.95+0.5(1-0.5/T)\tanh(0.6/T^2)]$$

where $\Delta_0$=4.5K. As shown in Fig.5, the RLM with its relatively weak T dependence of Δ-(see insert in Fig.5)-

fits all of the qualitative features of the data for $0.1<T<1K$, while the RLM with $\Delta_0$ fits the data above 0.5K.

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FIGURE CAPTIONS

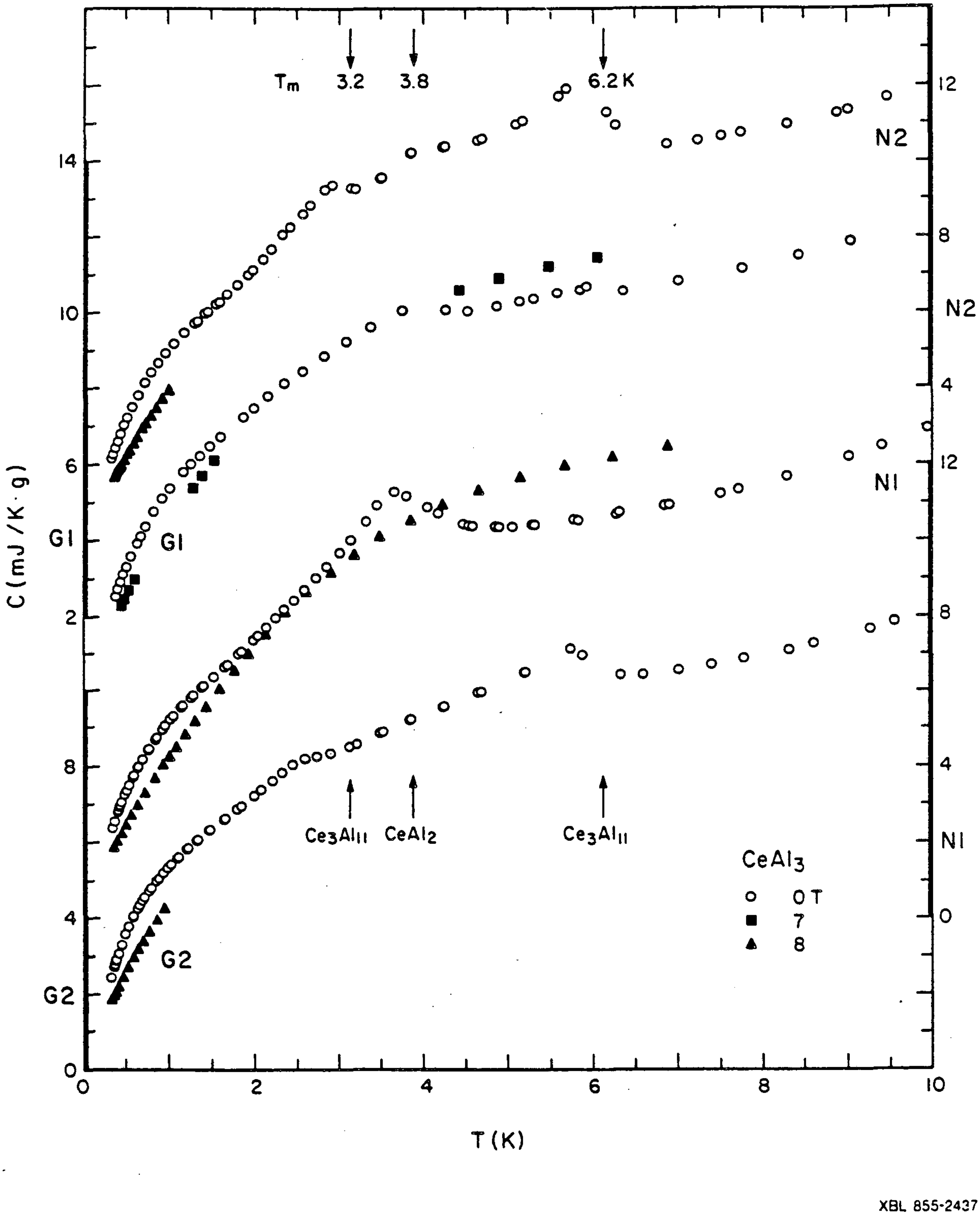
Fig.1. Specific heat for four contaminated $CeAl_3$ samples.

Fig.2. Anomalies in C for $CeAl_3$ due to $CeAl_2/Ce_3Al_{11}$ phases.

Fig.3. C for $CeAl_3$ after correction for impurity phases.

Fig.4. C vs H on isotherms after correction for impurities.

Fig.5. C/T vs T below 1K for $CeAl_3$.



Tm 3.2 3.8 6.2 K
N2
N2
N1
G1
G1
G2
G2
Ce3Al11 CeAl2 Ce3Al11
CeAl3
0 T
7
8
C (mJ / K·g)
T (K)
XBL 855-2437


Fig. 1

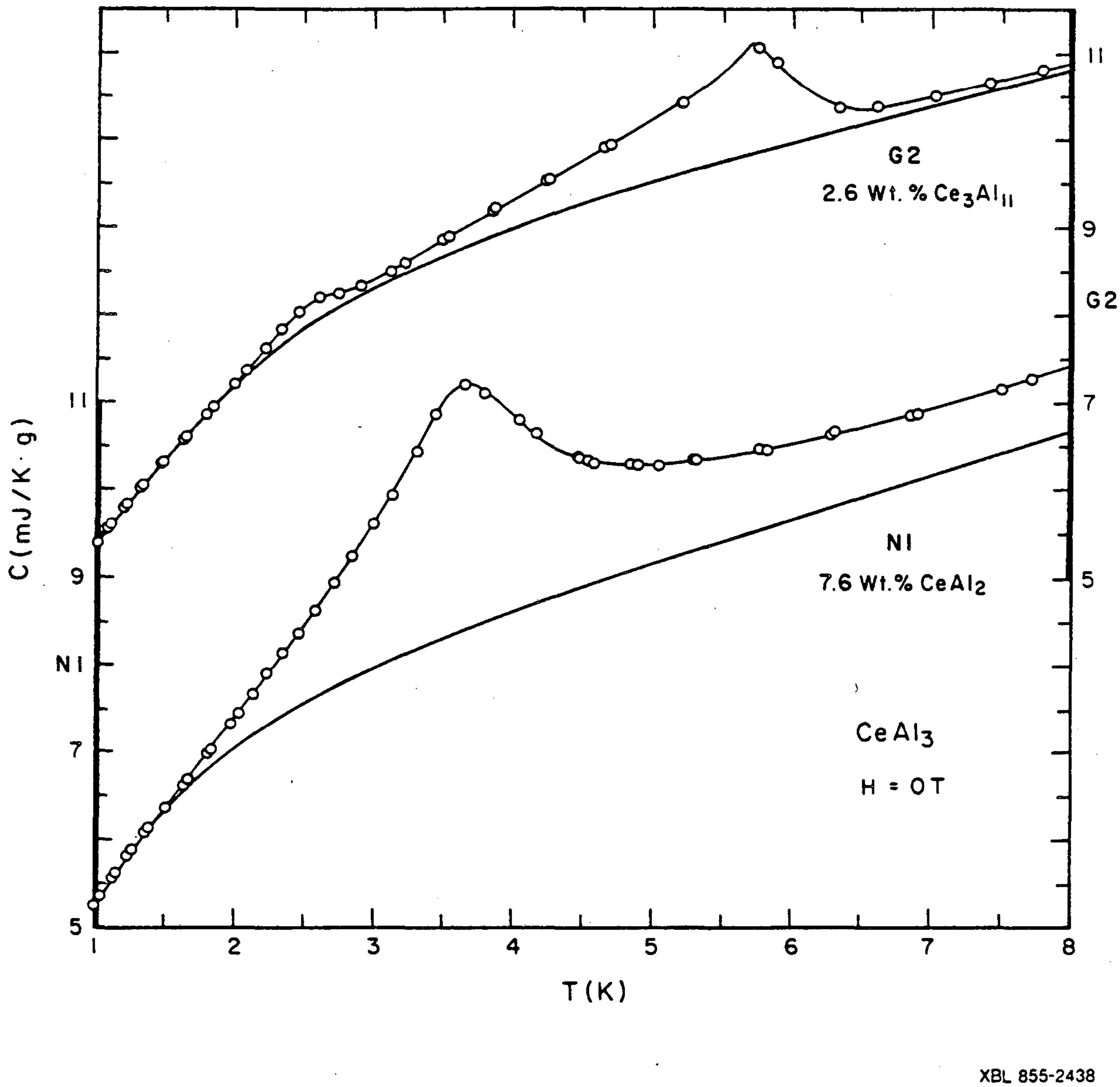
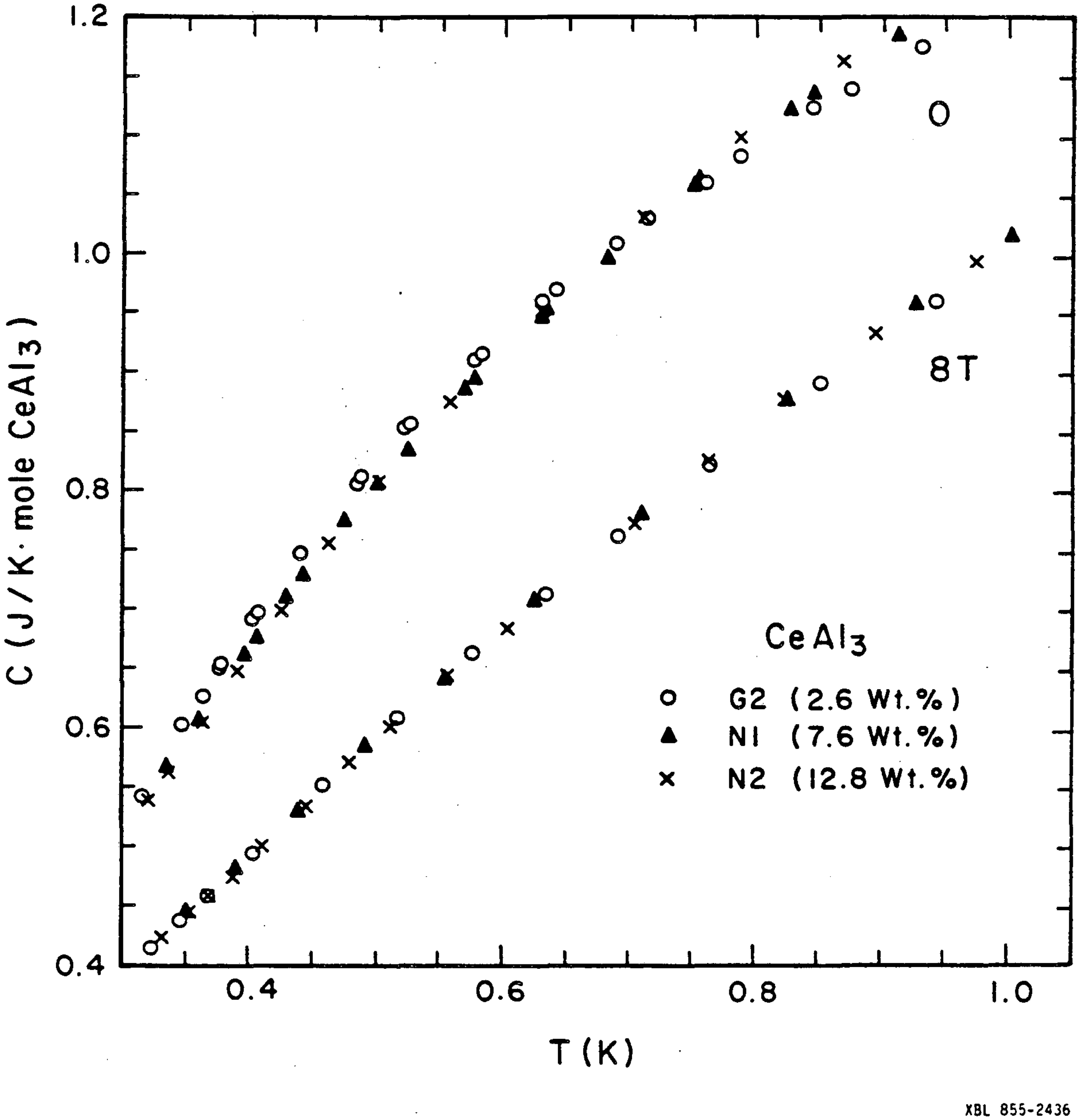

G2
2.6 Wt.% $Ce_3Al_{11}$
N1
7.6 Wt.% $CeAl_2$
$CeAl_3$
H = 0T
C (mJ/K·g)
T (K)
11
9
N1
7
5
1
2
3
4
5
6
7
8
11
9
G2
7
5
XBL 855-2438

Fig. 2



1.2
1.0
0.8
0.6
0.4
C (J / K · mole CeAl3)
0.4
0.6
0.8
1.0
T (K)
0
8T
CeAl3
G2 (2.6 Wt.%)
N1 (7.6 Wt.%)
N2 (12.8 Wt.%)
XBL 855-2436


Fig. 3

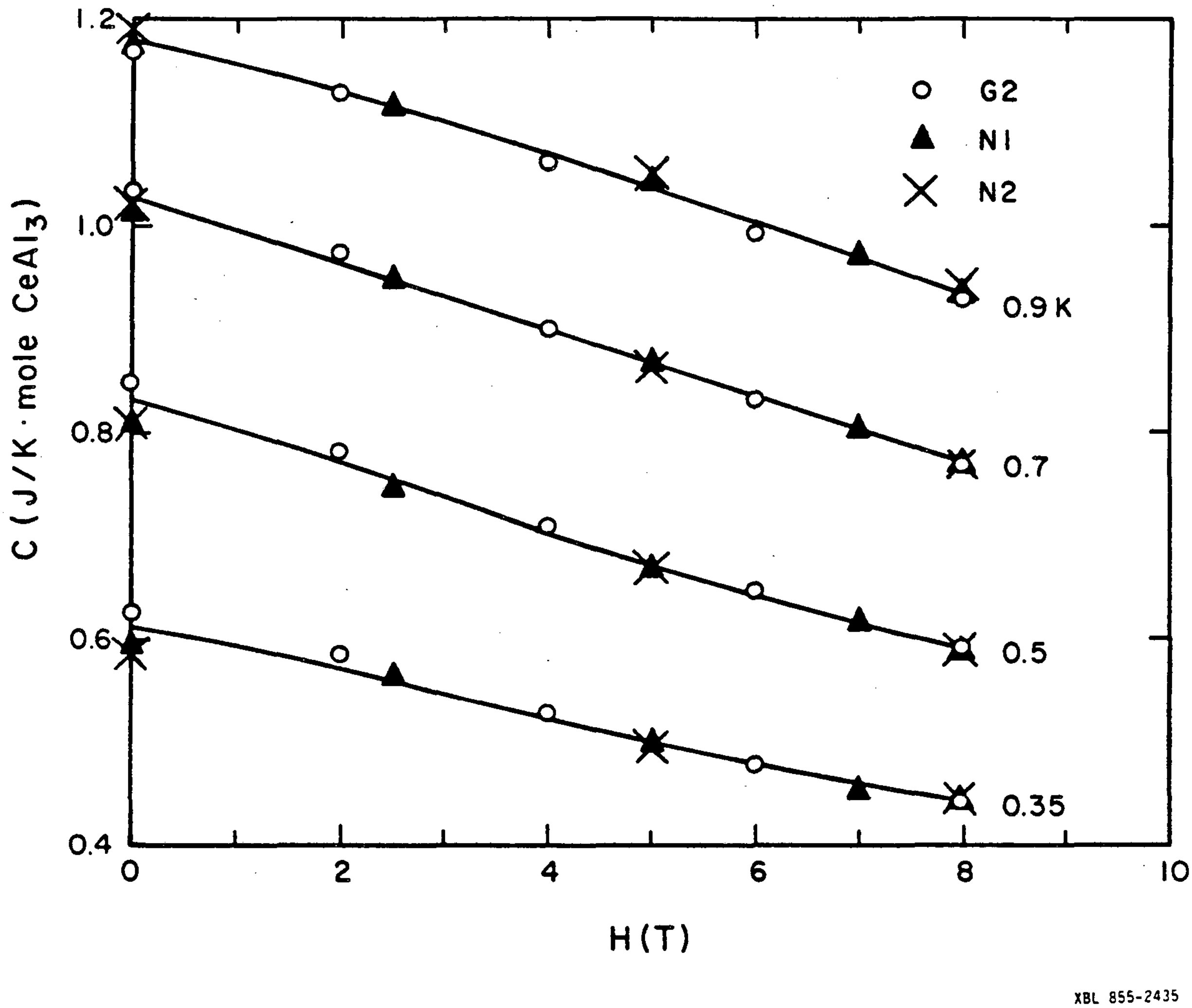
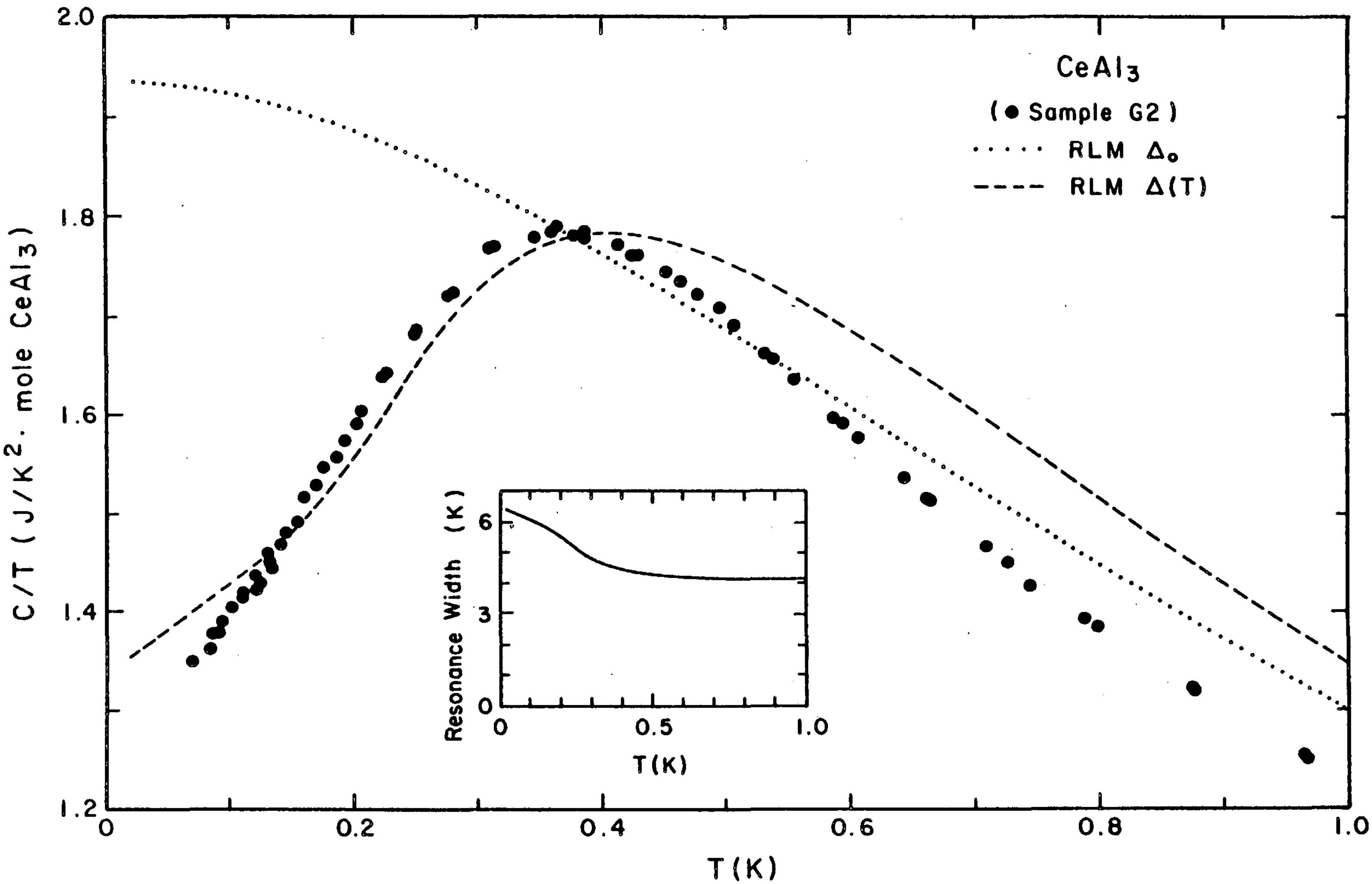

C (J/K · mole CeAl$_3$)
H(T)
G2
N1
N2
0.9 K
0.7
0.5
0.35
1.2
1.0
0.8
0.6
0.4
0
2
4
6
8
10
XBL 855-2435

Fig. 4




XBL 858-3598

Fig. 5

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