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THE LOW-TEMPERATURE SPECIFIC HEAT OF CeCu$_2$Ge$_2$

AT 0 AND 9.5 KBAR

by

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The Low-Temperature Specific Heat of CeCu$_2$Ge$_2$ at 0 and 9.5 kbar

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CeCu$_2$Ge$_2$ orders antiferromagnetically, $T_N$~4K, and $\gamma(T)$~200 mJ/K$^2$ mole near 0.5K and $P=0$. A pressure of 9.5 kbar has no measurable effect on $T_N$; reduces slightly the specific-heat anomaly at $T_N$; and reduces slightly $\gamma(T)$ below 0.7K. These effects of pressure are in striking contrast to the much stronger effects on other heavy-fermion compounds, e.g., CeAl$_3$, URu$_2$Si$_2$ and CeCu$_2$Si$_2$.

CeCu$_2$Ge$_2$ is isostructural with CeCu$_2$Si$_2$, the first heavy-fermion superconductor [1]. Although CeCu$_2$Ge$_2$ is not superconducting at zero pressure ($P$), it is superconducting for $P>70$ kbar [2]. Previous specific-heat ($C$) measurements [3] for $P=0$, 0.05$\leq T$$\leq$30K, and magnetic fields ($H$) to 8T, showed antiferromagnetic ordering at $T_N$=4.2K, and an anomaly in $C$ at 0.45K and $H=0$ that was interpreted as a maximum in $\gamma(T)$. The anomaly was suppressed, but not shifted in temperature, with increasing $H$ and disappeared at $H=8T$. This paper reports new data for $C$, 0.35$\leq T$$\leq$20K and $P=0$; and also data obtained at 9.5 kbar, the first for $P\neq0$. The $P=0$ data are in excellent agreement with the earlier work [3] suggesting that the features observed are intrinsic properties and not subject to the uncertainties related to sample dependence that are associated with some heavy-fermion compounds.

In Fig. 1, $C$ vs $T$, the solid line represents an estimate of the lattice specific heat ($C_\ell$) obtained for $T>14K$. The corresponding Debye temperature and $\gamma$ are ~240K and 10 mJ/K$^2$ mole, respectively. There are substantial uncertainties in these estimates, but it is clear that $C_\ell$ is a negligible contribution for $T<T_N$, and $\gamma$ is not large for $T>14K$. It follows that the quasiparticles acquire high mass only at lower temperatures.

Figure 2, a plot of $C/T$ vs $T$, shows the antiferromagnetic transition centered at $T_N$=4.3K, and the anomaly. Relative to the $P=0$ data, there are small decreases in $C/T$ just below $T_N$. 
and in the vicinity of 0.45K, but with no measurable change in $T_N$. The entropy ($S$) in Fig.
3 approaches $R\ln 2$ at higher temperatures consistent with a doublet ground state for Ce$^{3+}$.

To separate the 0.45K anomaly from that associated with antiferromagnetic ordering, the
procedure described in Ref. 3 was used: The low-temperature antiferromagnetic magnon
contribution, $\beta_3 T^3$, was derived from a plot of $C/T$ vs $T^2$, which is linear for $0.85 \leq T \leq 1.5$K.
Subtraction of that contribution, which is pressure independent, gives the "0.45K anomalies"
shown in Fig. 4. Both the position and magnitude of the maximum for $P=0$ are in good
agreement with those of Ref. 3. In 9.5 kbar, however, the maximum is shifted to 0.5K, and
reduced in magnitude for $T<0.7$K, by $\sim$30% at 0.35K.

The weak $P$ dependence of $C$ near $T_N$ is in sharp contrast to the relatively large change of
$C$ with $P$ for, e.g., URu$_2$Si$_2$ [4] for which $T_N=18$K. CeAl$_3$ also shows a maximum in $C/T$
near 0.4K, but it is rapidly suppressed with increasing pressure, disappearing completely for
$P<0.4$ kbar, and at $P=8.2$ kbar $C/T$ at 0.4K is reduced to less than one third of its $P=0$ value
[5]. CeCu$_2$Si$_2$ also shows a large change of $C$ with $P$ [6].

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REFERENCES

Figure 2

CeCu$_2$Ge$_2$

- $P=0$
- $+9.5$ kbar
FIGURE 3

S (J/K.mole)

CeCu$_2$Ge$_2$

P=0

T(K)

RLn2
CeCu$_2$Ge$_2$

$\Delta C/T$ (J/K$^2$.mole)

- $P = 0$
- + 9.5 kbar

FIGURE 4