Title

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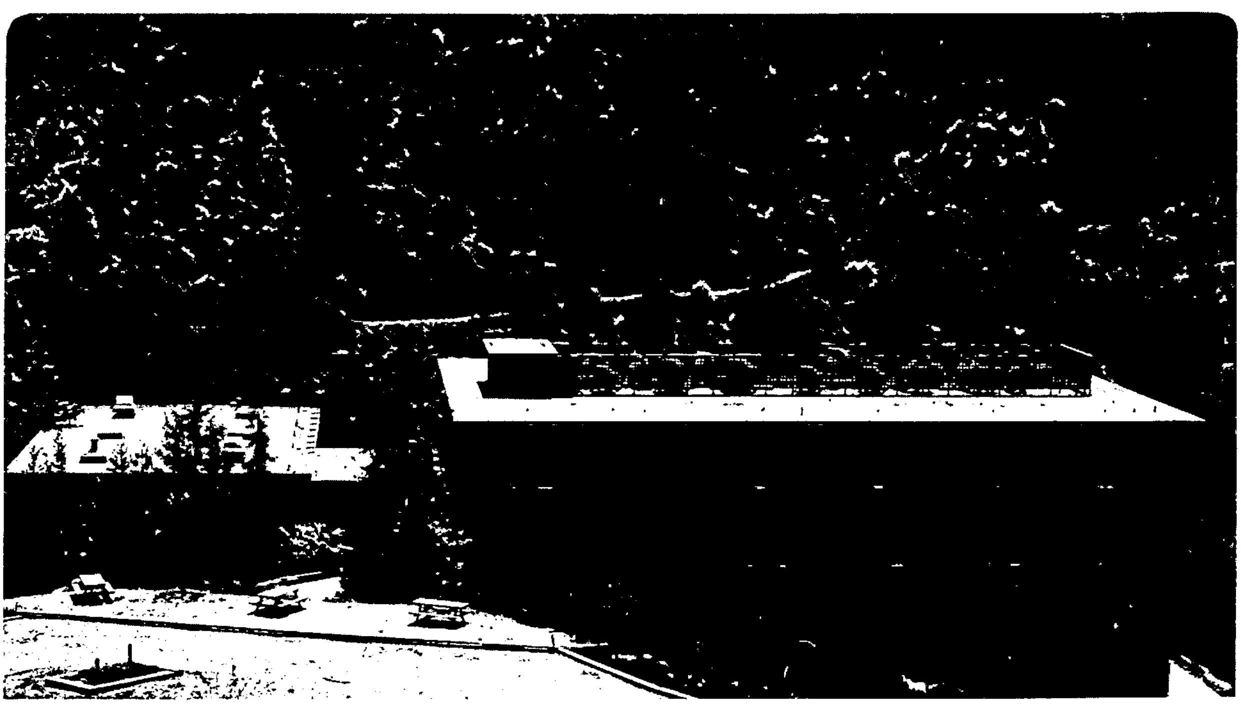

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SPECIFIC HEAT OF HIGH-T_c $YBa_2(Cu_{3-x}M_x)O_7$ WITH M=Cr OR Zn

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The effects of substitution of Cr and Zn for Cu in YBCO have been studied calorimetrically and by magnetic measurements. There is a qualitative correlation between the suppression of the superconducting transition and an increase in the concentration of localized moments in both cases.

T_c for $YBa_2Cu_3O_7$ (YBCO) decreases when 3-d elements are substituted for Cu. Zn probably randomly occupies both chain and plane sites,[1] while Cr probably substitutes only in chain sites.[2] Table 1 lists derived properties, and Ref. 3 gives references to previous measurements of specific heat (C) on doped YBCO.

Figure 1 shows T_c(onset), ΔT_c and $-4\pi\chi_v$ determined from field-cooled susceptibility (χ) measurements. The localized moment fraction [$n_i(\chi)$] was determined from a fit of χ above T_c by a Curie-Weiss law with S=1/2 and g=2. C data for H=0 are plotted in Fig. 2, and fitted by: $C=A_{-2}T^{-2}+\gamma(0)T+B_3T^3+B_5T^5$. The H=0 C/T upturns (probably caused by the onset of magnetic ordering of localized moments) become Schottky anomalies in 7T as shown in Fig. 3. The localized moment fraction [$n_i(C)$] was evaluated from the entropy associated with the anomaly, with S=1/2. $n_i(\chi)$ is always greater than $n_i(C)$ which implies some entropy loss for T>30K. C/T near T_c is displayed in Fig. 4, where the solid line represents the normal state C from a harmonic lattice fit[4] to C data above T_c.

As x increases, for both Cr- and Zn-doping, T_c, $-4\pi\chi_v$, $\Delta C(T_c)/T_c$, γ and $d\gamma/dH$ <u>decrease</u>; ΔT_c, $n_i(C)$, $\gamma(0)$ and B_5 <u>increase</u>; and $n_i(\chi)$ and A_{-2}(H=0) <u>increase</u>, but not monotonically in the case of Zn-doping. (Any simple relation between $n_i(C)$, $n_i(\chi)$ and the superconducting transition is presumably obscured by variations in the amounts of magnetic impurity phases.) B_3 increases for Cr-doping and decreases for Zn- doping. The A_{-2}(7T) term is from hyperfine interactions for Cu, which for increasing x approach the theoretical 0.47, perhaps because of decreasing relaxation times associated with in- creasing localized moments induced by doping.

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TABLE 1. Properties of $YBa_2(Cu_{3-x}M_x)O_7$ for M=Cr or Zn. Units are mJ, K, mole and T, and % is mole% referred to a formula unit.

	Cr: $dT_c/dx\% = -0.5$			Zn: $dT_c/dx\% = -1.1$		
x%	0	1.5	4.0	0	3.0	15
T_c(onset)	92	91	90	91	89	75
ΔT_c	5	6	13	3	4	17
$-4\pi\chi_v$	0.50	0.11	0.08	0.17	0.17	0.05
$n_i(\chi)\%$	2.7	7.6	7.8	3.7	2.2	10.1
$n_i(C)\%$	0.35	0.75	1.4	0.48	0.60	0.89
A_{-2}(H=0)	45	97	207	58	34	109
A_{-2}(7T)	0.20	0.25	0.32	0.25	0.36	0.45
$B_3 x10^1$	2.64	3.10	3.11	2.68	2.10	2.01
$B_5 x10^3$	1.1	1.2	1.4	1.1	1.6	1.9
Θ_0	457	434	433	455	494	500
$\gamma(0)$	7.0	8.8	9.5	8.6	11	23
$\Delta C(T_c)/T_c$	47	27	0	39	26	0
$\gamma(\beta=1.43)$	33	19	0	27	18	0
$d\gamma/dH$	0.17	0.17	0.16	0.16	0.14	0

FIGURE CAPTIONS

1. Meissner fraction vs T for $YBa_2(Cu_{3-x}Cr_x)O_7$.

2. C/T vs T^2 in the low-temperature region.

3. C minus hyperfine, electronic and lattice terms.

4. Effect of Cr-doping on $\Delta C(T_c)/T_c$.

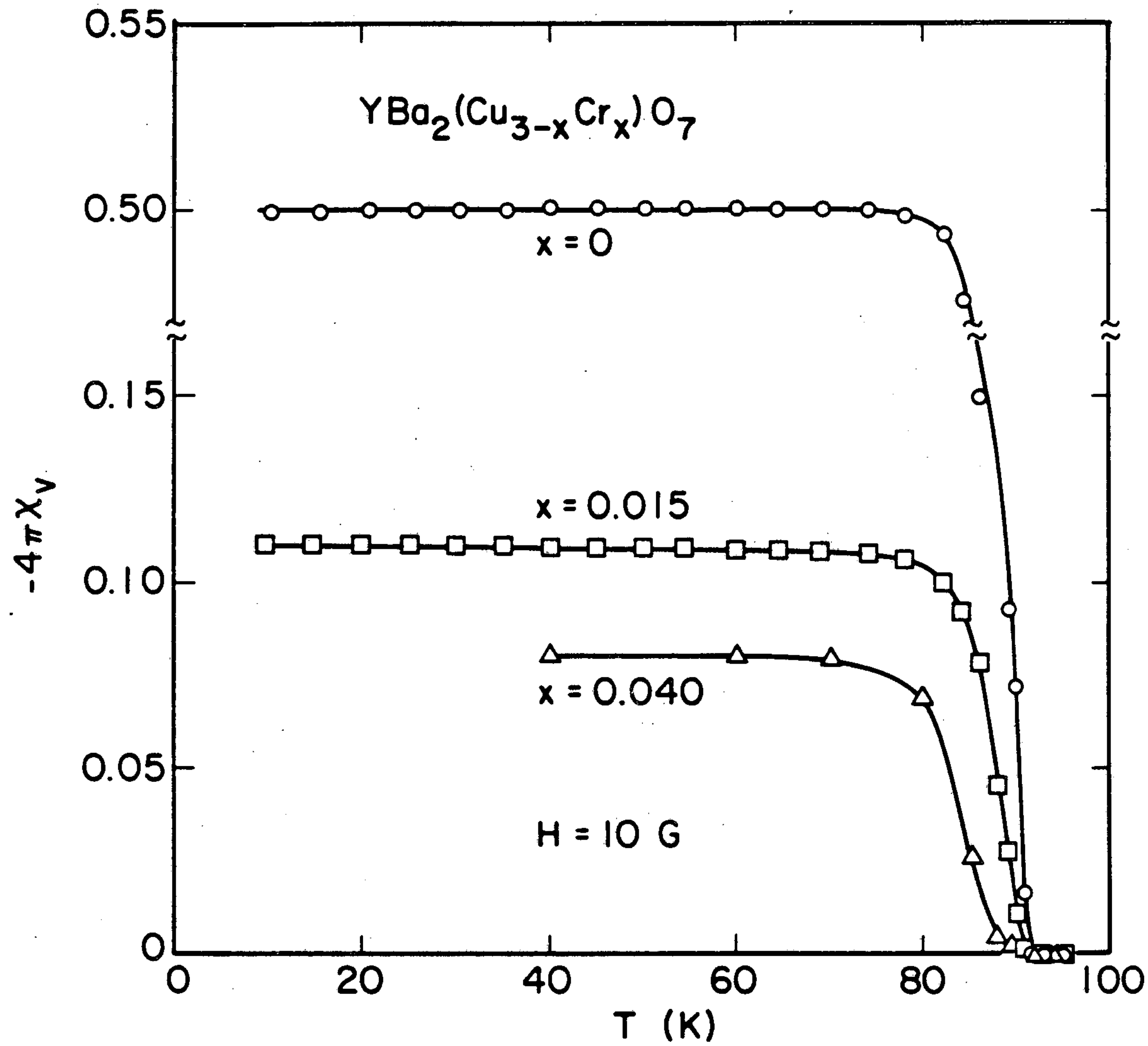

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Fig. 1

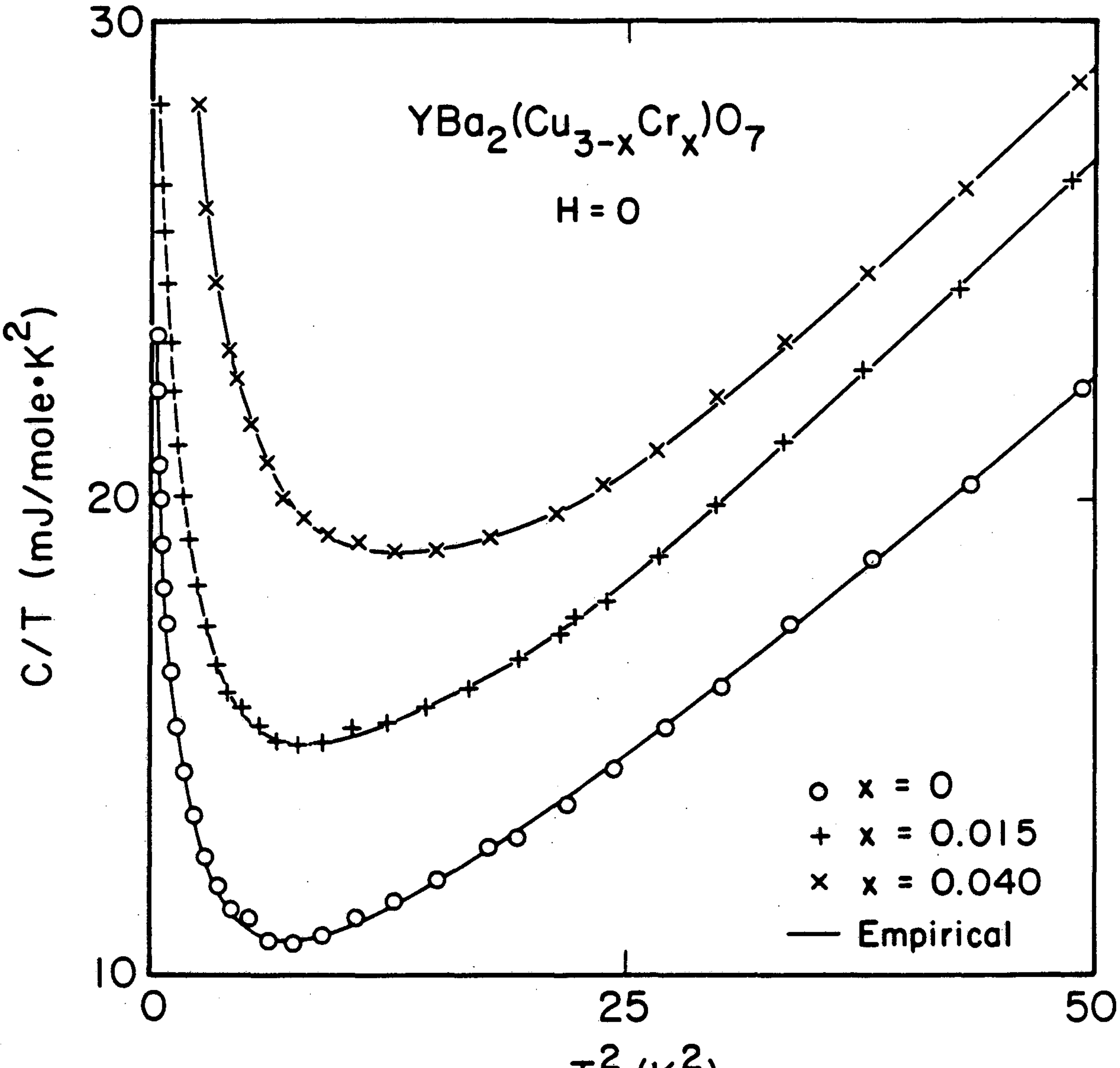

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Fig. 2

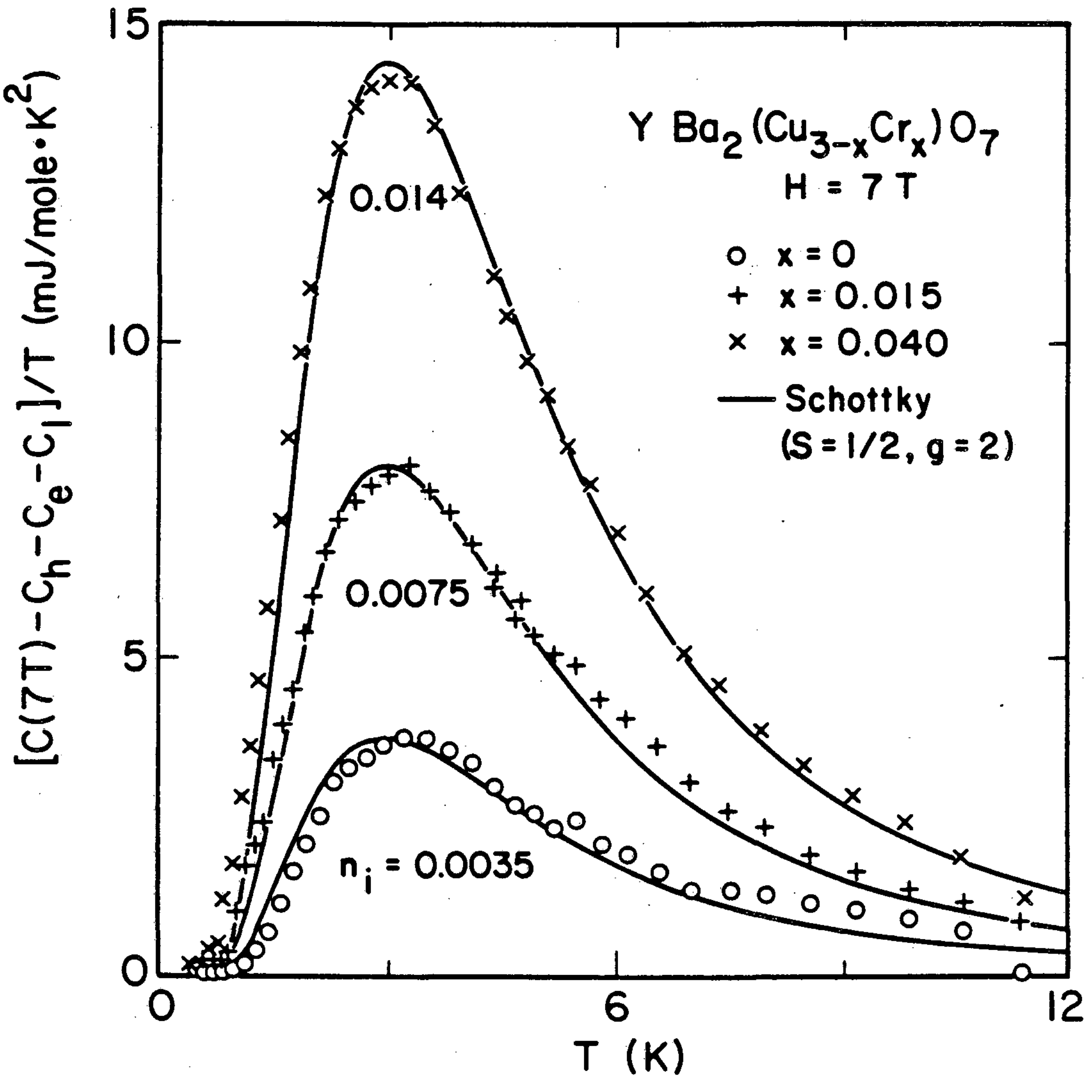

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Fig. 3

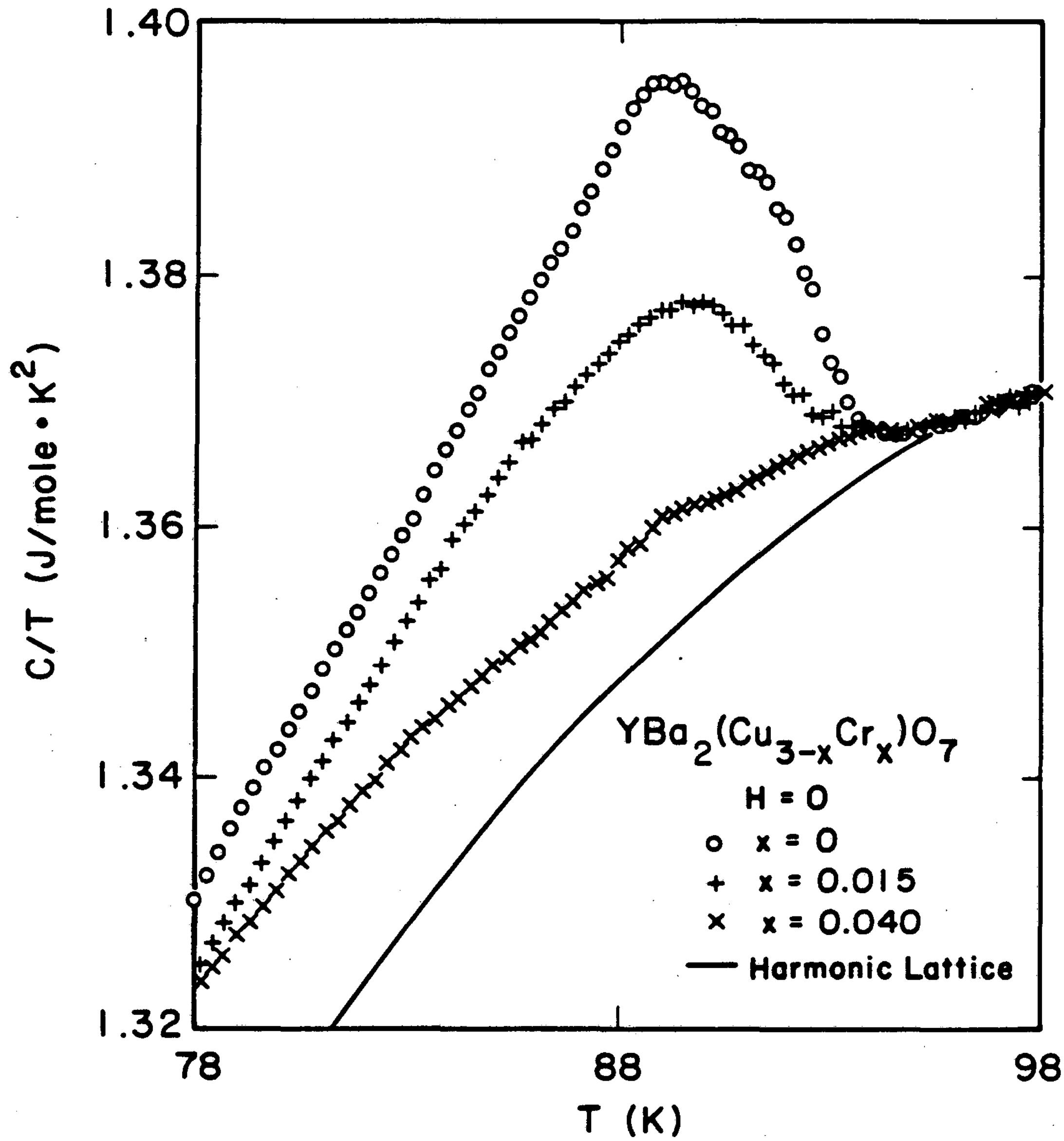

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Fig. 4

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Lattice and Electronic Specific Heat of $YBa_2Cu_3O_7$

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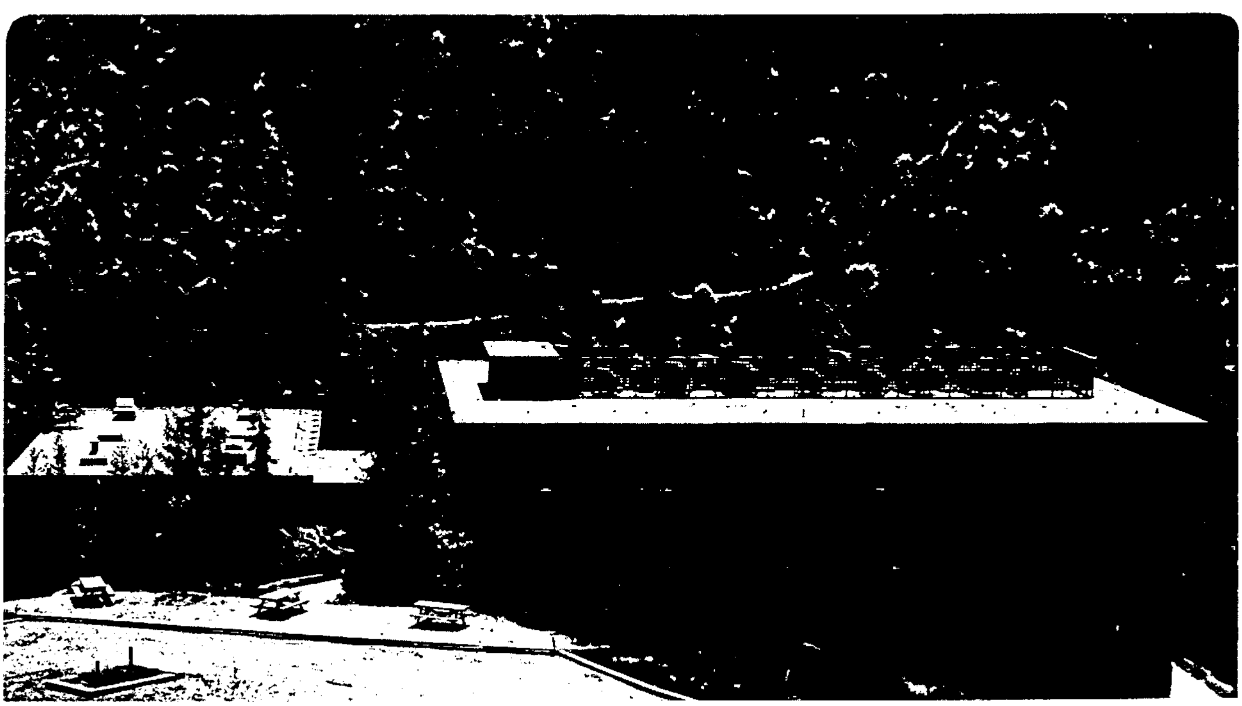

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LATTICE AND ELECTRONIC SPECIFIC HEAT OF $YBa_2Cu_3O_7$*

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We report specific heat measurements on $YBa_2Cu_3O_7$ (YBCO) from 78 to 284K. The higher temperature data are well-represented as the sum of a term proportional to T and a harmonic lattice contribution. These data show no evidence of an anomaly in the temperature region 200-230K. The data near T_c are consistent with the specific heat of a BCS superconductor that has a contribution from 3-dimensional Gaussian fluctuations.

Specific heat (C) measurements on a 1.9g YBCO sample prepared by the citrate pyrolysis method have been made from 78 to 284K both by conventional heat pulse (HP) techniques and by a continuous heating (CH) method. Fig. 1a shows a plot of every other HP point as well as a curve that represents a fit to all of the data above 110K by the sum of a term proportional to temperature and a harmonic lattice contribution.[1]

A partial motivation for making these measurements was to seek evidence for a specific heat anomaly reported at ~215K.[2] In Fig. 1b the HP data between 200 and 230K are shown along with a fit to the data obtained by including all points above 110K except for those between 200 and 230K. As Fig. 1b indicates, the results show that any anomaly in the specific heat of this sample is substantially smaller than that reported earlier. The CH data have less scatter but slightly larger systematic uncertainties, and also fail to show anomalous behavior in this temperature region.

Fig. 2a shows both the HP and some of the CH data in the vicinity of T_c (89.4K). Well away from the peak, the two sets of measurements agree to ~0.1%. However, near the peak the CH data (heating rate ~6.5 mK/sec) show a marked rounding. It is possible that this rounding is evidence of long relaxation effects near T_c, but further experimental work is necessary before such a conclusion can be made with confidence. Fig. 2b shows the HP data along with an extrapolation of the fit made to the data above 110K. This fitted curve, when extended to 60K, and when corrected by a BCS electronic specific heat contribution[1], passes through specific heat data obtained on a 20 g sample made from the same batch of material as the 1.9 g sample.

Figure 3 is a plot of C/T vs. T, where $\Delta C = C(\text{measured}) - C(\text{fit})$. The continuous curve in Fig. 3 represents a BCS superconductor with $T_c = 89.38$K; $\gamma = 41$ mJ/mole K^2; and with an added 3D Gaussian fluctuation contribution $C(\text{fluctuation}) = A^{\pm}/|T/T_c - 1|^{1/2}$. The values of A^+ ($T>T_c$) and A^-($T<T_c$) are 0.51 and 0.24 J/mole K, respectively. The ratio A^+/A^- is similar to that reported[3] for a YBCO single crystal, but the values of A^+ and A^- are larger, corresponding approximately to the difference in the values of $\Delta C(T_c)$ and, presumably, to differences in the fractions of the samples that are superconducting.

It is interesting to note that the width of the transition in this polycrystalline sample can be accounted for entirely by fluctuation effects -- sample inhomogeneity does not appear to make a significant contribution.

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FIGURE CAPTIONS

FIGURE 1. a) Molar specific heat of YBCO between 78 and 284K. The smooth curve is a fit to the data. b) Enlarged view of the data between 200-230K. See text for discussion.

FIGURE 2. a) C/T vs. T near T_c for both heat pulse (+) and continuous heating (0) data. b) Heat pulse data and extrapolation of the fit to the higher temperature data.

FIGURE 3. {C(measured)-C(fit)}/T near T_c. The curve represents the sum of BCS and 3D Gaussian fluctuation contributions.

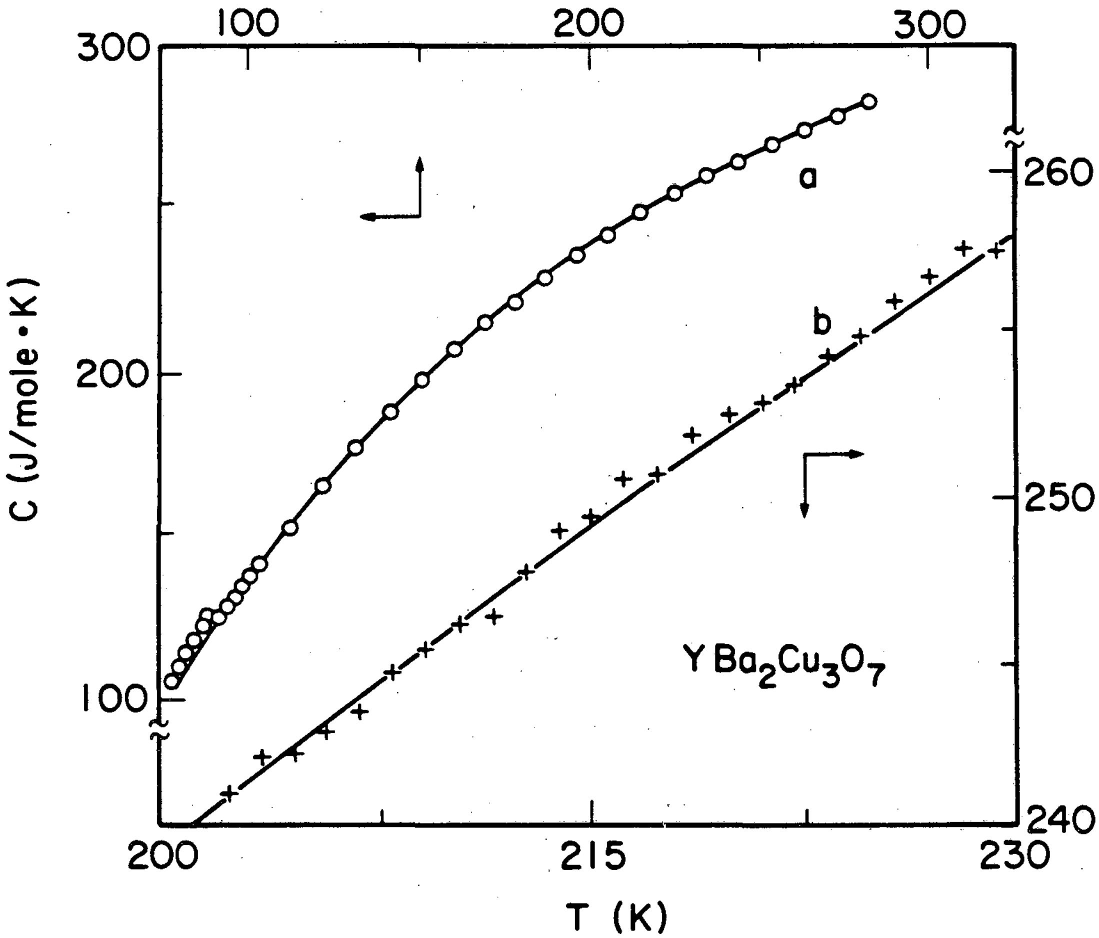

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Fig. 1

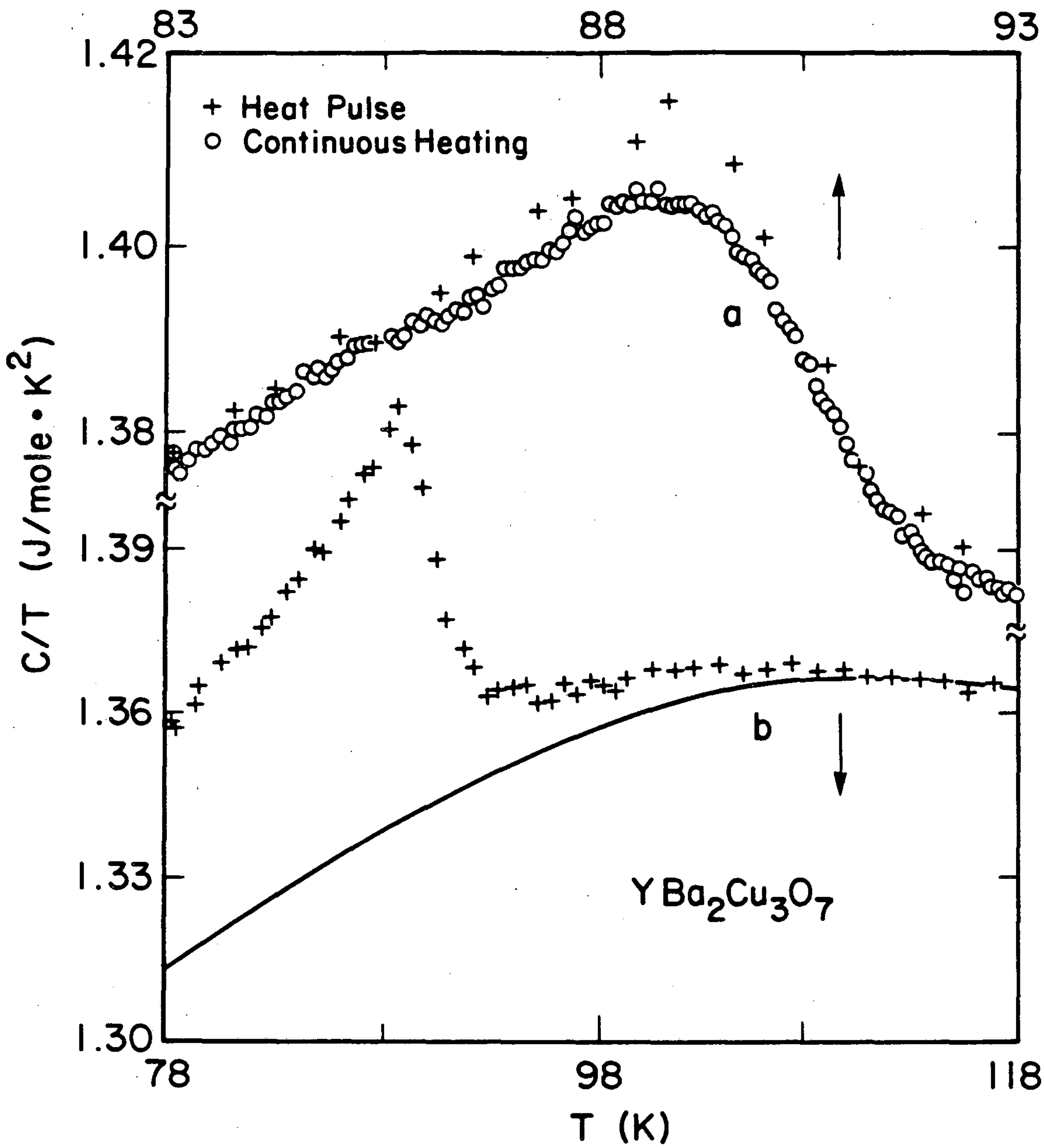

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Fig. 2

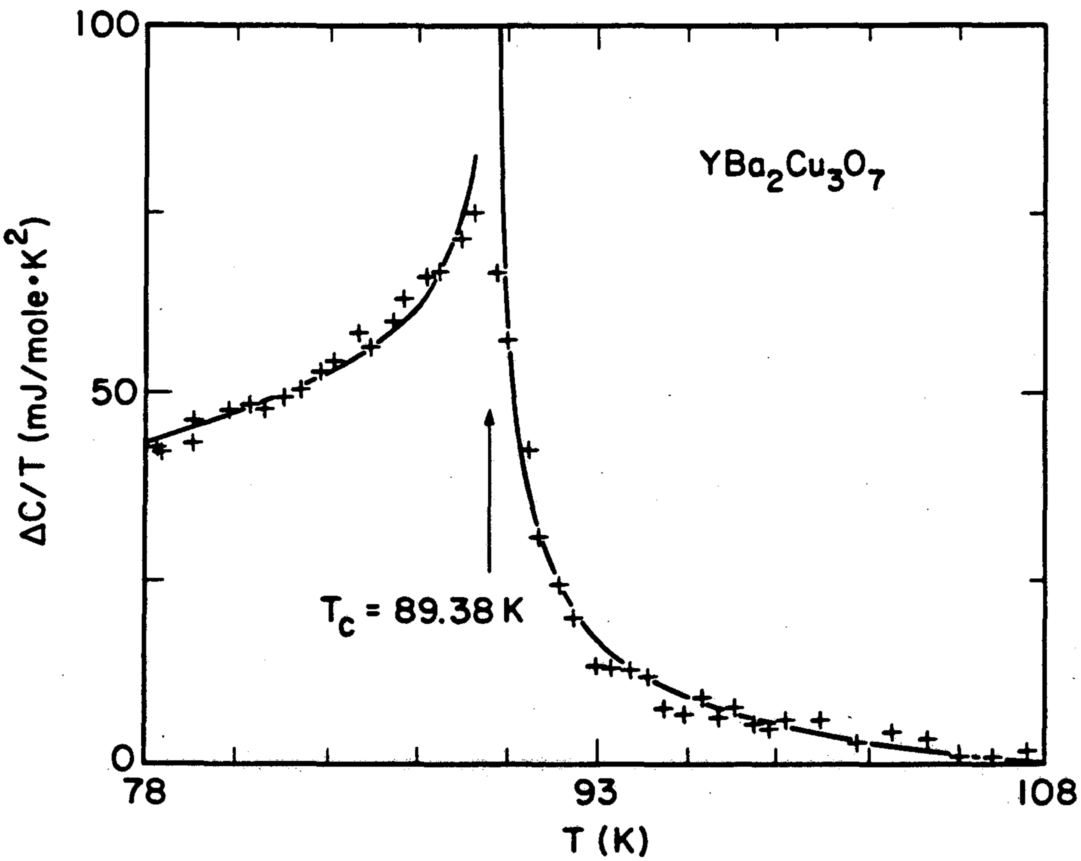

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Fig. 3

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