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March 1990

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SPECIFIC HEAT OF $(Y_{1-x}Pr_x)Ba_2Cu_3O_7$; MAGNETIC ORDERING; MAGNETIC HYPERFINE FIELDS

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SPECIFIC HEAT OF $(Y_{1-x}Pr_x)Ba_2Cu_3O_7$: MAGNETIC ORDERING; MAGNETIC HYPERFINE FIELDS

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The specific heat of $(Y_{1-x}Pr_x)Ba_2Cu_3O_7$ has been measured for $x=0$, 0.1, 0.2 and 0.3, $0.3 \leq T \leq 120$K and $H=0$ and 7T. The coefficient of the linear term is $\gamma \approx 200$ mJ/mole Pr·K^2. The Pr ions are characterized by a previously unrecognized <u>low-temperature</u> ordering, and an effective hyperfine field that is enhanced by an applied field.

$(Y_{1-x}Pr_x)Ba_2Cu_3O_7$ has the orthorhombic structure, but is superconducting only for $x \lesssim 0.6$, with $T_c(x)$ following the Abrikosov-Gorkov relation for pair breaking by magnetic moments (1,2). Earlier measurements of the specific heat (C) were interpreted as showing very high values of the coefficient (γ) of the "linear" term γT, reaching, in the case of high values of x, $\gamma \approx 750$ mJ/mole Pr$\cdot K^2$ (3-5). As reported here, extension of the measurements to lower temperatures and to magnetic fields has shown that magnetic ordering contributed to C in the temperature interval in which γ was determined, and the values of γ that appear to be relevant to the conduction electron system are, although still high, substantially lower. The measurements also give values of the effective hyperfine field (H_h) at the Pr nuclei.

In Fig. 1 ($x=0$ and 0.3) magnetic ordering for $x=0.3$ is evident from the broad Schottky-like anomalies near 1 and 5K, respectively, for $H=0$ and 7T. The low temperature upturns in C/T are indicative of hyperfine contributions, primarily from ^{141}Pr. Although Meissner effect measurements showed a transition to the superconducting state at $T_c \approx 42$K (2), no obvious discontinuity was observed in C.

A least-squares fit of the 7-T data by $C(7T)=D(7T)T^{-2}+\gamma(7T)T$, shown in Fig. 2, gives $\gamma(7T)=9.0$, 32, 47 and 66 mJ/mole$\cdot K^2$ and $D(7T)=0.26$, 9.4, 15.7 and 29.7 mJ$\cdot$K/mole for $x=0$, 0.1, 0.2 and 0.3, respectively, and $H_h(7T)=100\pm5T$. The values of $\gamma(7T)$ are well represented by $\gamma(7T)=9+200x$ mJ/mole$\cdot K^2$; determination of $\gamma(0)$ is precluded by the Schottky anomalies except for $x=0$, in which case $\gamma(0)=7.6$ mJ/mole$\cdot K^2$.

The values $H_h(H)$ derived from D(H), are shown for $x=0.3$ in Fig. 3. The zero-field value is 44T, and there is a strong non-linear enhancement with increasing H. $H_h(7T)$ is essentially independent of x; the field dependence was not determined for other values of x. At least qualitatively, H_h(7T) is consistent with either a Pr^{4+}, $J_z = \pm 1/2$ ground state and low-lying states of higher J_z, or a Pr^{3+} singlet ground state with exchange-induced mixing of higher states.

Figure 4 shows the magnetic ordering and electronic contributions to C for x=0.3, obtained by subtracting the hyperfine contribution and (for the "background" contribution) the total specific heat for x=0. The upper horizontal line is the value of γ(7T) determined below 1K, and the lower horizontal line represents the high-temperature limiting value. The temperature dependence of the electronic contribution, represented in the low- and high-temperature limits by these lines, is indeed reminescent of the heavy-fermion behavior that was suggested (6) on the basis of high γ values. The small feature near 42K may be associated with the transition to the superconducting state. The entropies associated with the magnetic ordering anomalies are (½)Rln2, based on moles of Pr. The same values were obtained for x=0.1 and 0.2.The insert to Fig. 4 illustrates the origin of higher γ values when the usual C/T vs T^2 plot is used without taking account of the magnetic ordering. Fig. 5 shows the anomaly in C/T near T_c=86K for x=0.1 which is very much attenuated compared with those observed for x=0.

The work at LBL was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Materials Sciences Division of the U.S. Dept. of Energy under contract DE-AC03-76SF00098, and at LLNL and Davis under the auspices of the U.S. Dept. of Energy under contract W-7405-ENG-48. Additional support for A.A. was provided by a grant from the Swiss National Science Foundation.

References

(1) A. Kebede et al., J. Magn. Magn. Mat. 76&77 (1988) 619.

(2) J.L. Peng et al., Phys. Rev. B40 (1989) 4517.

(3) A. Kebede et al., Phys Rev. B40 (1989) 4453.

(4) S. Ghamaty et al., to be published.

(5) N. Sankar et al., Solid State Commun. 67 (1988) 391.

(6) C.S. Jee et al., Solid State Commun. 69 (1989) 379.

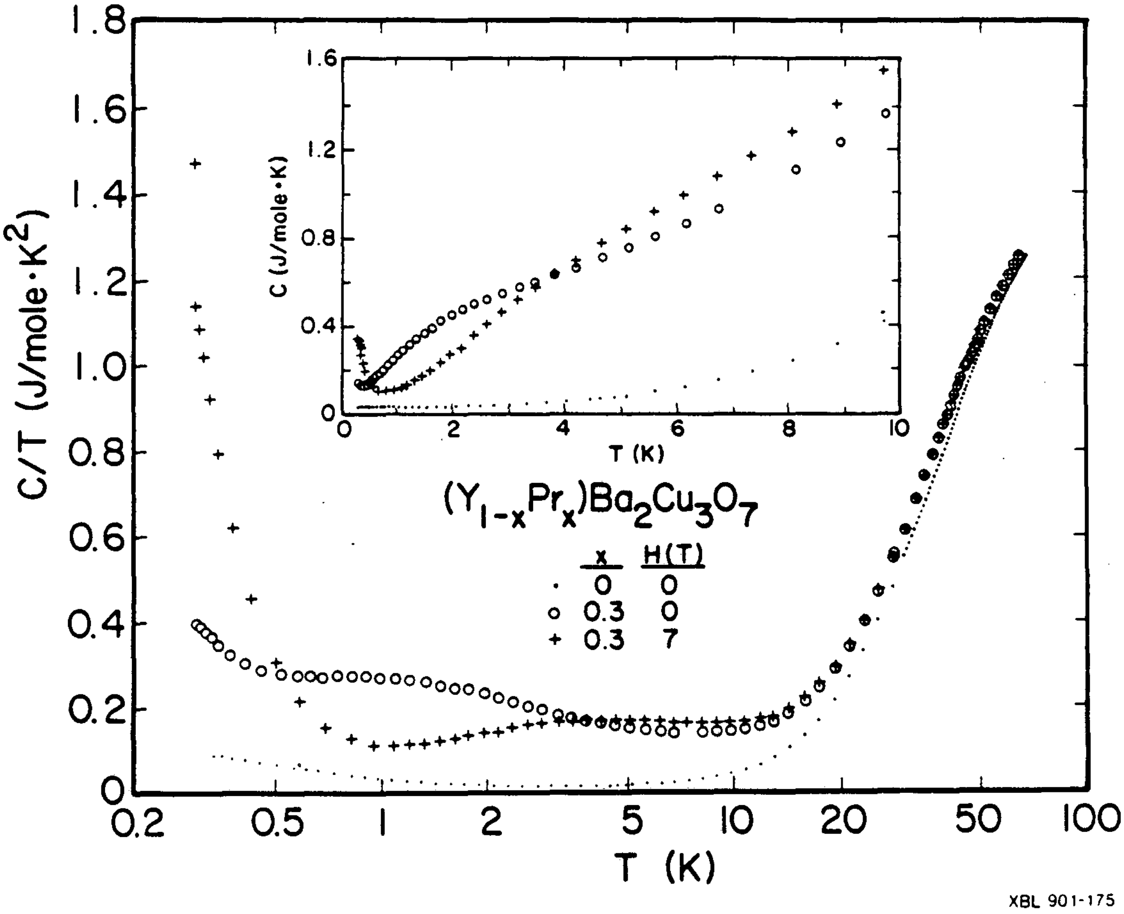

FIGURE 1

C/T vs T for x=0 and 0.3

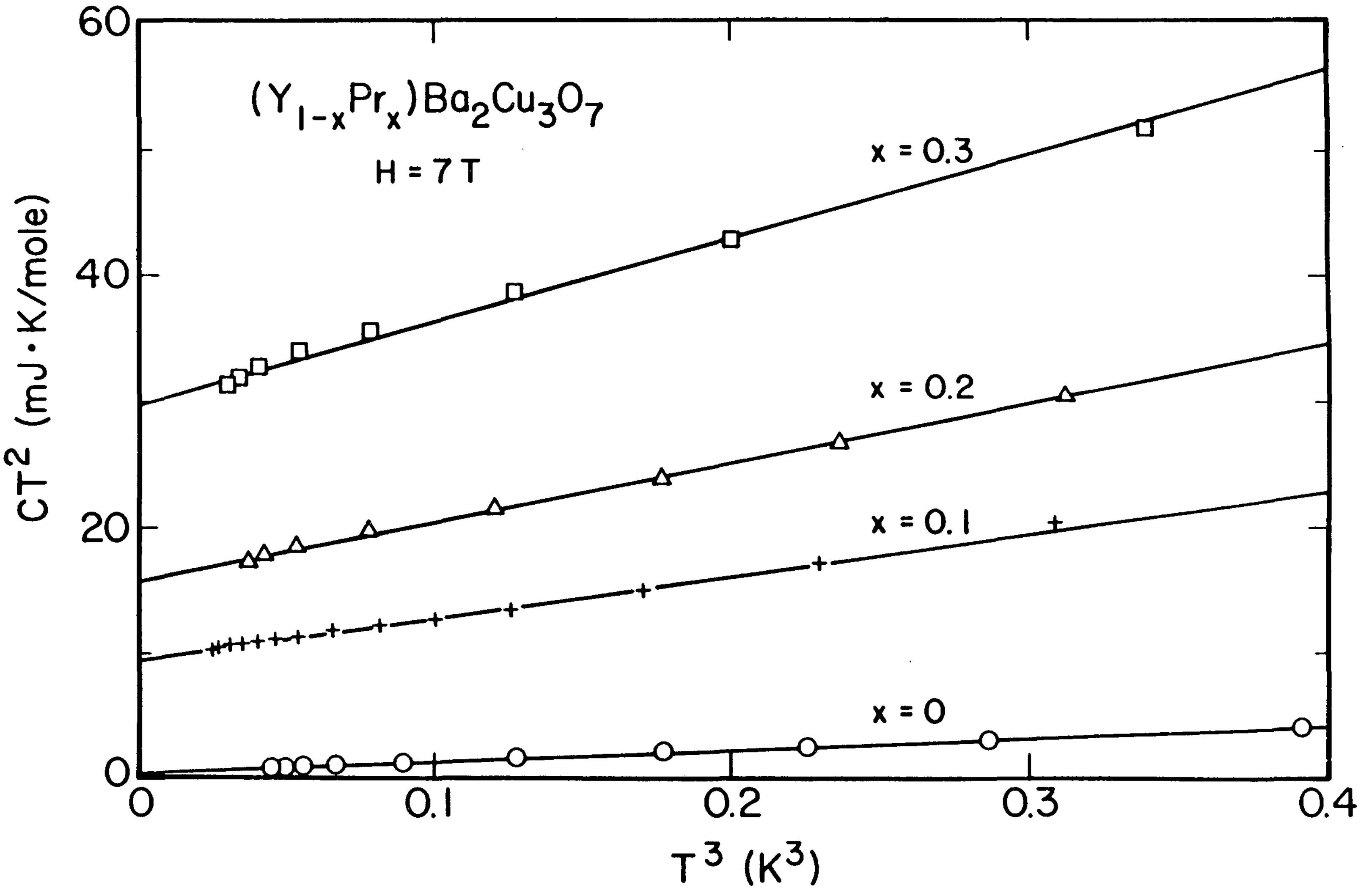

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FIGURE 2

CT^2 vs T^3 for x=0, 0.1, 0.2 and 0.3.

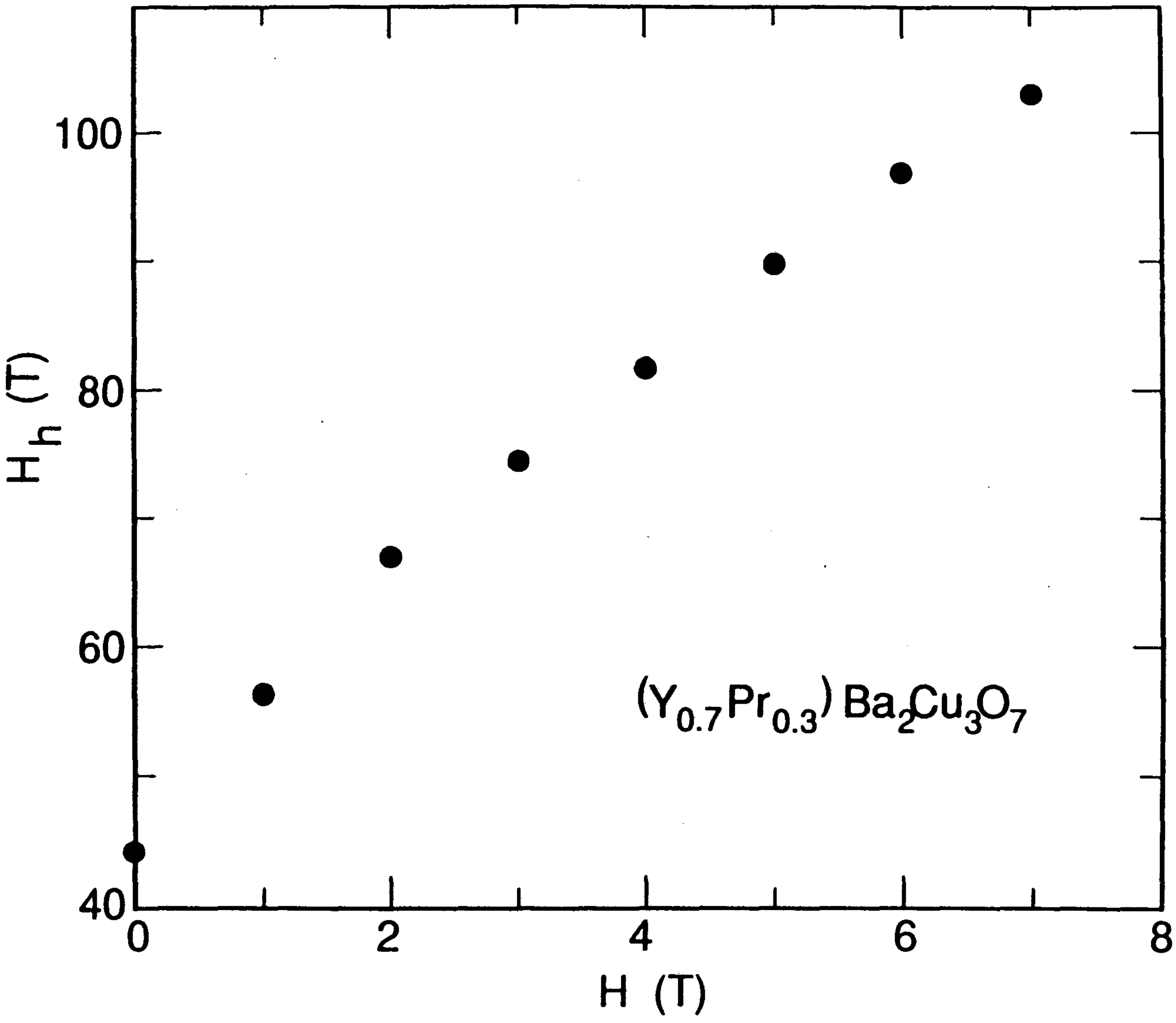

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FIGURE 3

H_h vs H for x=0.3

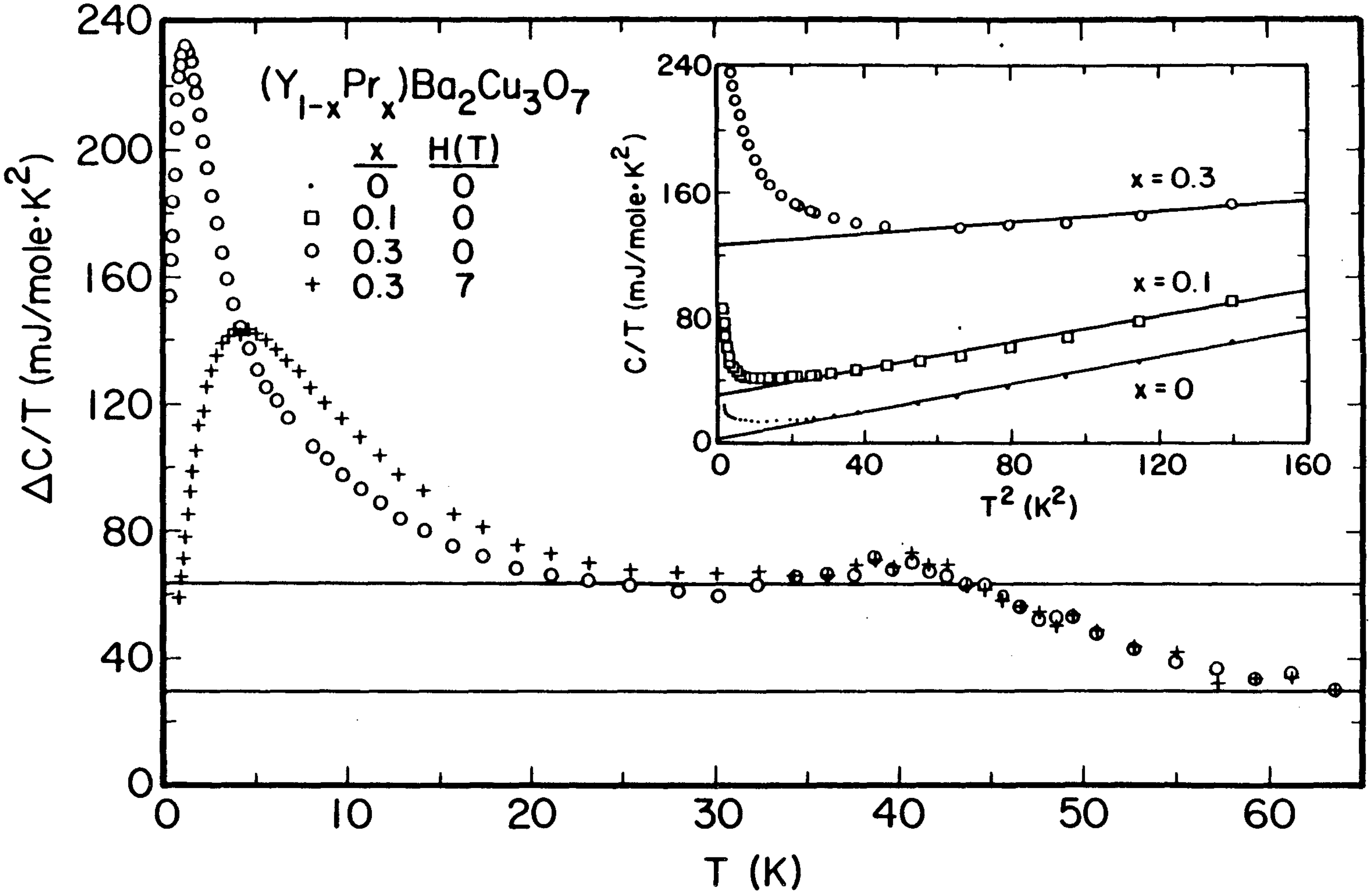

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FIGURE 4

Magnetic ordering and electronic contributions to C.

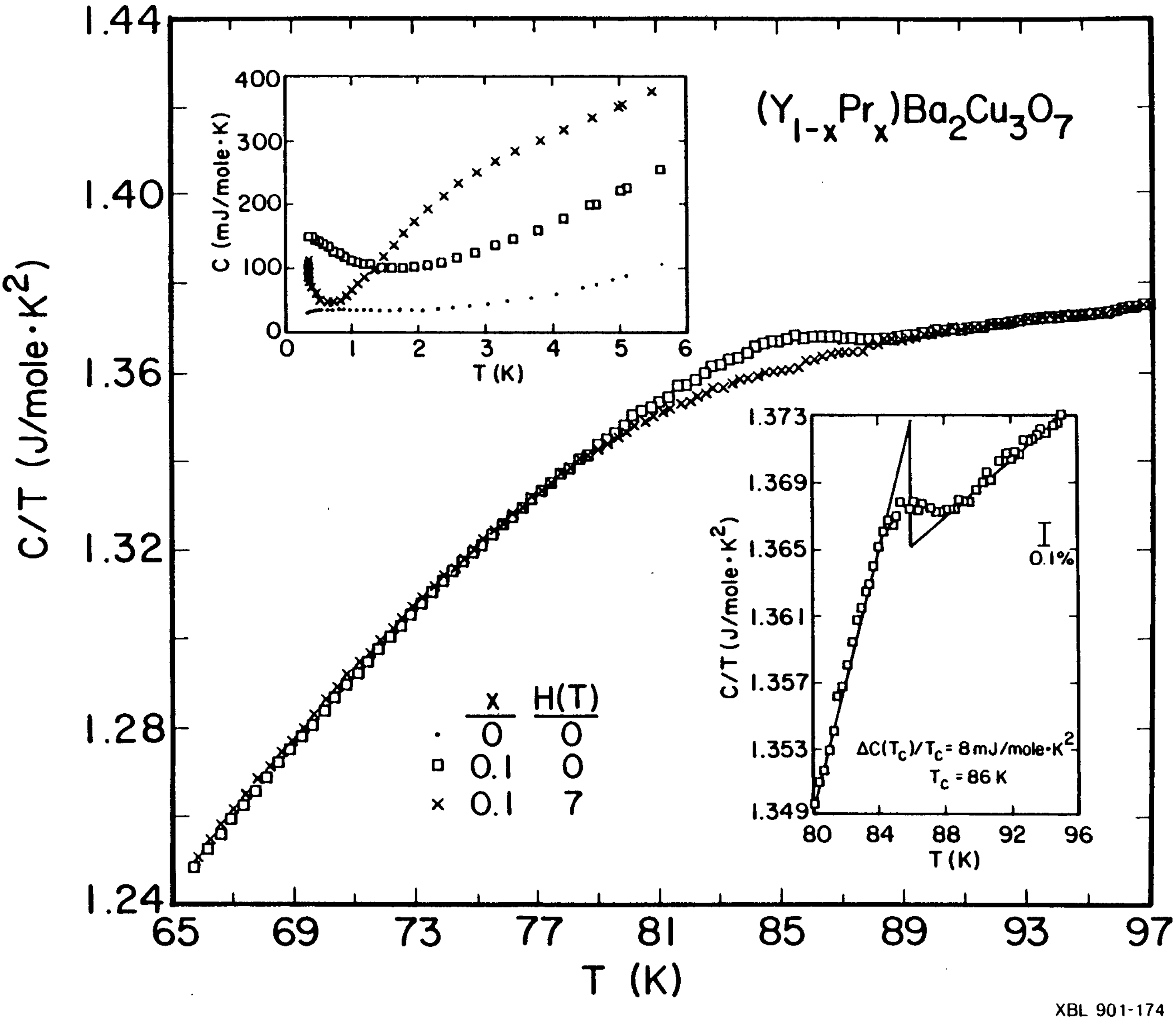

FIGURE 5

C/T vs T for x=0.1

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