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HEAT CAPACITY OF DILUTE CuMn IN STRONG MAGNETIC FIELDS

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The phase diagram of RKKY spin-glasses is discussed in the light of calorimetric data on three dilute CuMn samples in applied fields, 9kOe$\leq$H$\leq$75kOe.

As a contribution to the establishment of a T-H phase diagram for RKKY spin-glasses we have measured the heat capacity of 3 dilute $Cu_{1-x}Mn_x$ alloys in fields 9kOe$\leq$H$\leq$75kOe. The heat capacity of pure Cu and an additional hyperfine term have been subtracted to obtain the spin-glass contribution $\Delta C(T)$. Figure 1 shows data in the vicinity of the temperature of the maximum in ΔC, T_{max}, for one sample in three different fields. Theoretical curves are calcualted in the nearest neighbor pair approximation (NNPA) to the RKKY model.[2,3] A Schottky anomaly for the same H and S has a height of 0.81 k_B per spin and is narrower in the wings. The value $W_1/k=(650\pm30)K$ deduced for the RKKY-amplitude in this sample is perfectly consistent with the value from magnetization data.[4,5]

Fig. 2 is a diagram of the T-H plane in reduced variables, indicating the paths followed by various experiments. Values of T_{max} are indicated by the symbols. The dashed line represents the relation $k_BT_{max}/x=0.74g\mu_BH/x+1.68W_1$, the exact asymphotic expression for $H/x\to\infty$ and S=2 in the RKKY model. The numerical coefficients are determined by the first and second virial terms in the RKKY free energy.[2,3] The curved boundary line is the convergence radius for the virial expansion of the free energy in NNPA. (Virial terms beyond the second are only aproximate!) This line roughly delimits the phase-space in which a super-paramagnetic interpretation in terms of finite clusters is possible--the outer region. The line can also be interpreted as a bond percolation threshold[7,8] generalized to finite field. Considering the well-confirmed value of W_1, it seems impossible to locate the percolation threshold in zero field at a temperature as low as T_{sg}, the temperature of the susceptibility cusp.[9] More likely, the system is already in the state of a collective paramagnet around T_{max}, for those maxima falling within the percolation threshold. Experimentally, not only T_{max} breaks way from the super-paramagnetic line but the heat capacity maximum itself goes through a minimum value of 0.58 k_B per impurity between H/x=30 and 40 Oe/ppm i.e., near the crossing of the percolation threshold. For $H/x\to0$ it rises again, to ~0.78 k_B, almost as high as the Schottky value. So far, there is apparently no theory explaining this feature. The NNPA predicts broadening and flattening of the specific heat anomaly as H/x is lowered.

In considering the phase-space encompassed by the virial expansion radius one should keep in mind that the sharpness of the susceptibility cusp[3] is destroyed by reduced fields as low as 0.5 Oe/ppm. Thus, there is a very narrow region around the zero field axis governed by an energy different from xW_1 and very much smaller in magnitude. This may be associated with collective actions of very large groups of spins. The concept of frustration[10] may be invoked to explain qualitatively why T_{sg} is lower than the percolation threshold and why no marked features occur in the thermodynamic functions at this threshold.

Fig. 3 gives additional information on the initial T dependence of $\Delta C(T)$ for our highest produced field. An enhancement $\gamma(H)T$ over the Schottky curve is predicted by the NNPA,[2,3,12] but the experimental γ is even larger. The upward curvature seen in zero field[7] is also present here.

A more detailed paper on our in-field heat capacity data is in preparation in which we shall also discuss the question of entropy variations with applied field.

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FIGURE CAPTIONS

Fig. 1: Spin-glass heat capacity in units of k per impurity, (n = number of mols of alloy, R = gas constant). (XBL 814-9291)

Fig. 2: Temperature ranges covered in tht T-H plane at constant H, with values of T_{max} for three different samples. (XBL 814 9292)

Fig. 3: Initial T-dependence for the highest reduced field of Fig. 2. (XBL 814-9293)

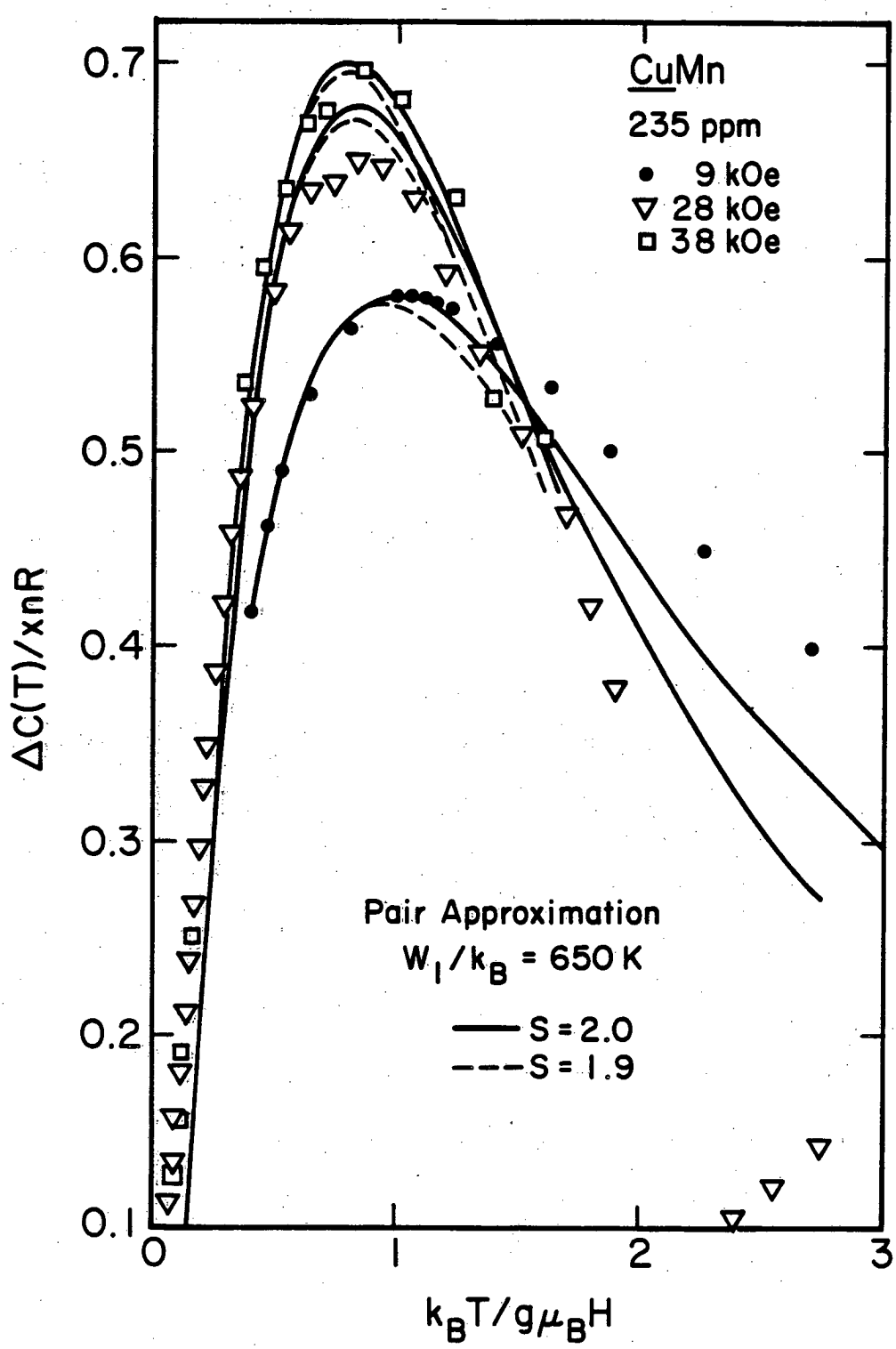

Figure 1

XBL 814-9291

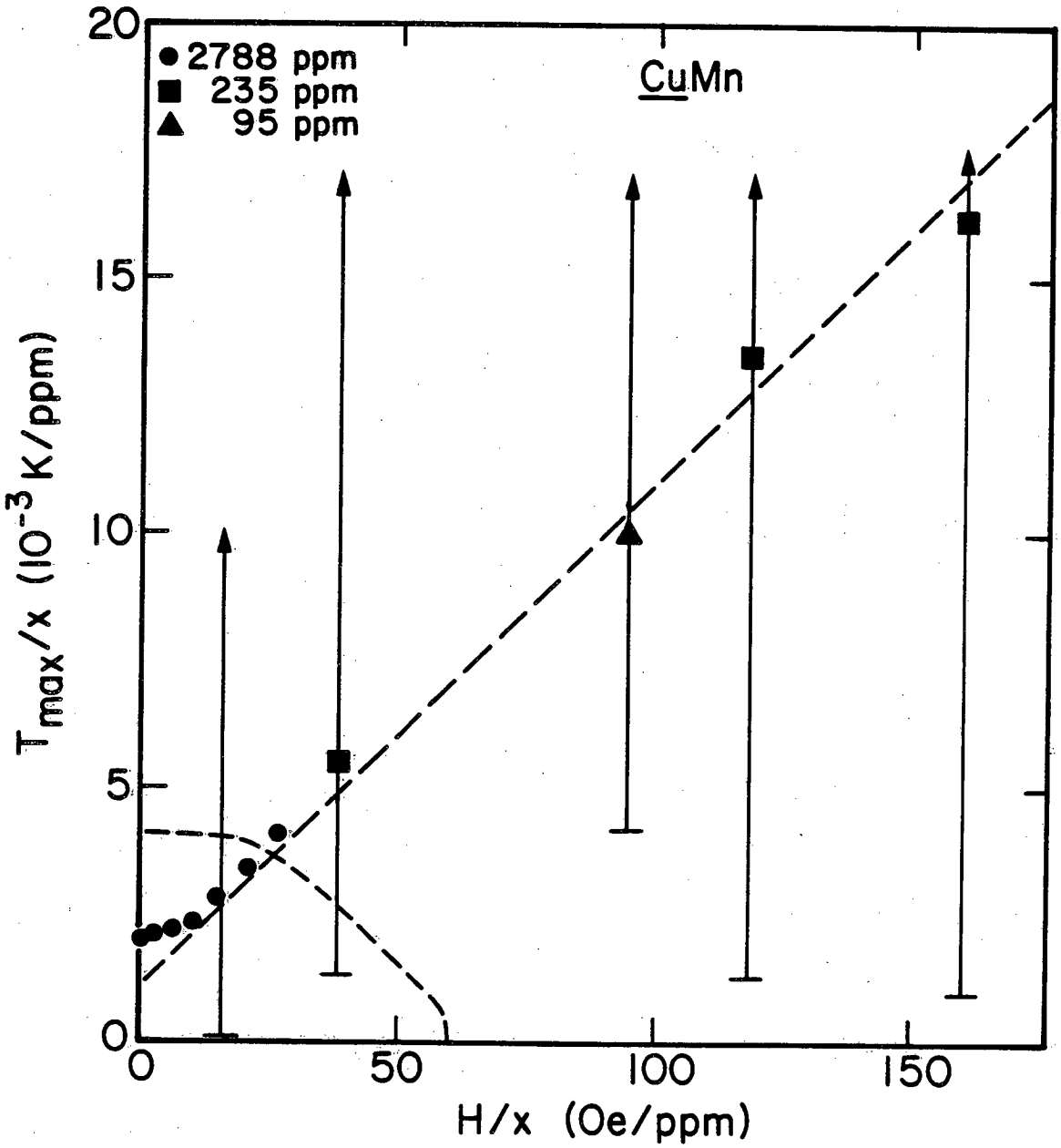

Figure 2

XBL 814-9292

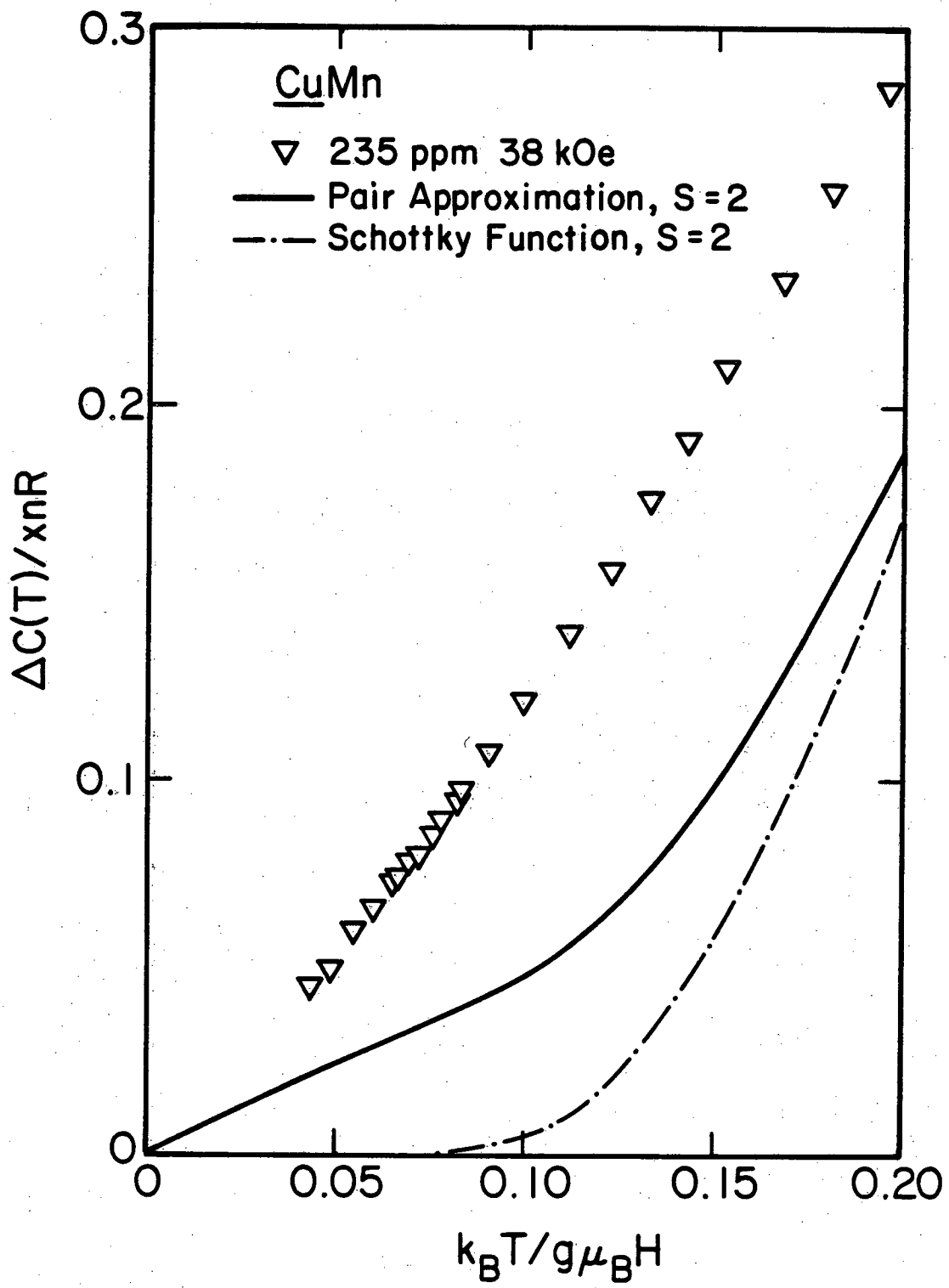

Figure 3

XBL 814-9293

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