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Concentration dependence of the random-field-crossover scaling in $Fe_xZn_{1-x}F_2$

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The proportionality between the field-induced shifts $\Delta T_c(H)$ and $\Delta T_{\mathrm{eq}}(H)$ of the transition and equilibrium temperatures $T_c(H)$ and $T_{\mathrm{eq}}(H)$ and the root-mean-square random field h_{RF} was studied over a wide range of concentration ($0.31 \le x \le 0.84$) in the ideal random-field Ising model (RFIM) system $Fe_xZn_{1-x}F_2$. $T_c(H)$ and $T_{\mathrm{eq}}(H)$ were determined experimentally from the optical birefringence Δn, for which $d(\Delta n)/dT$ exhibits a peak at $T_c(H)$ proportional to the magnetic specific heat. $T_{\mathrm{eq}}(H)$ was determined from the point above which zero-field-cooled and field-cooled measurements gave identical results. For all x studied, $T_c(H)$ and $T_{\mathrm{eq}}(H)$ were found to shift from the $H=0$ transition at T_N as $[\Delta T_c(H), \Delta T_{\mathrm{eq}}(H)] = [c, c_{\mathrm{eq}}] T_N h_{\mathrm{RF}}^{2/\phi}$ as predicted, with $\phi = 1.42 \pm 0.03$, the universal random exchange to RFIM crossover exponent, after a mean-field correction bH^2. The nonuniversal quantities c and c_{eq} were found to be of order unity as expected, but slightly x dependent. An empirical x dependence for c and c_{eq} is suggested. This analysis is applied to existing data on $Mn_xZn_{1-x}F_2$, and leads to very similar behavior for c, with essentially equal numerical values.

INTRODUCTION

Amongst the earliest results[1] on the random-field Ising model (RFIM) problem were the predicted field-scaling properties near the phase transition and the proportionality between the applied field and the random field for one realization of the RFIM: a diluted antiferromagnet placed in a uniform field H. Later work[2] presented a detailed form for the rms random field h_{RF} and its dependence on the concentration x of magnetic ions and other material properties. While other critical exponent measurements have been made,[3,4] the random exchange to RFIM crossover exponent ϕ has been obtained with considerable precision[4,5] and shown to be universal[5] in the sense of being identical for different random Ising systems [$Fe_xZn_{1-x}F_2$,[4,6] $Mn_xZn_{1-x}F_2$,[5] and $Fe_xMg_{1-x}Cl_2$ (Ref. 7)], as well as for different values of x within a given dilute system.[5] All of these measurements made use of the scaling form[1] which relates the RF induced shift in the transition temperature $\Delta T_c(H)$ to h_{RF} (and implicitly H). However, no systematic *numerical* evaluation of the relation between $\Delta T_c(H)$ and h_{RF} (which is predicted[1] within a constant c of order unity) has been made. It is this topic which is the major focus of the present paper. A preliminary report of some of this work will appear in the Proceedings of the Conference on Magnetism and Magnetic Materials. In addition, we have evaluated the relation between the shift in $T_{\mathrm{eq}}(H)$ and h_{RF} versus x, where T_{eq} is the temperature above which all field and temperature cycling procedures yield identical results. Results of a previous study[5] on $Mn_xZn_{1-x}F_2$, which determined ϕ for several values of x, are also analyzed to determine $c(x)$. The values obtained are very similar to those of the present work.

CROSSOVER TO RFIM BEHAVIOR

Fishman and Aharony[1] showed that a randomly diluted antiferromagnet (AF), when placed in a *uniform* field H, was a physical realization of a random-field Ising model system. It was predicted that new critical behavior would be observed within a crossover region

$$|t| \le t_{\mathrm{cr}} \propto h_{\mathrm{RF}}^{2/\phi} , \qquad (1)$$

where $|t| \equiv |T - T_N + bH^2| / T_N$ is the reduced temperature measured relative to the mean-field phase boundary $T_N - bH^2$, h_{RF} is the reduced rms random field, and ϕ is the crossover exponent.

If a sharp phase transition exists (i.e., if $d > d_l$, the lower critical dimension), the new transition temperature $T_c(H)$ is expected to shift from the mean-field phase boundary by an amount

$$\Delta T_c(H) = T_N - bH^2 - T_c(H) = c T_N h_{\mathrm{RF}}^{2/\phi} \equiv C H^{2/\phi} , \qquad (2)$$

where c is a constant of order unity. The mean-square reduced random field for the site-diluted case has been shown to be,[2] in the limit $h_{\mathrm{RF}}^2 \ll 1$,

$$h_{\mathrm{RF}}^2 = \frac{x(1-x)[T_N^{\mathrm{MF}}(1)/T]^2 (g\mu_B SH/k_B T)^2}{[1+\Theta^{\mathrm{MF}}(x)/T]^2} , \qquad (3)$$

where $T_N^{\mathrm{MF}}(1)$ is the mean-field transition temperature of the pure system, and $\Theta^{\mathrm{MF}}(x)$ is the mean-field Curie-Weiss parameter. At $H=0$ one expects $T_N^{\mathrm{MF}}(x) \simeq x T_N^{\mathrm{MF}}(1)$ and $\Theta^{\mathrm{MF}}(x) = x\Theta^{\mathrm{MF}}(1)$. However, deviations from this relation are expected since $T_N(x) \to 0$ as $x \to x_p$, where $x_p = 0.24$ is the percolation concentration[8] for body-centered magnets. To simplify Eq. (3), we define

$$y(x) \equiv T_N(x)/T_N(1) ,$$

so that $y(x) \sim x$ except when $x \to x_p$. Also, $\Theta^{\mathrm{MF}} \simeq T_N^{\mathrm{MF}}$ for an AF with dominant intersublattice exchange. Equation (3) then becomes

$$h_{\mathrm{RF}}^2 = x(1-x)y^{-4}[g\mu_B SH/2k_B T_N(1)]^2 . \tag{4}$$

The magnetic specific heat C_m of a RFIM system is expected to scale as[1]

$$C_m(t,h_{\mathrm{RF}}) = h_{\mathrm{RF}}^{-2\alpha/\phi} f(t h_{\mathrm{RF}}^{-2/\phi}) , \tag{5}$$

where α is the $H=0$ random-exchange Ising model (REIM) specific-heat exponent and f is a universal scaling function. Assuming a sharp phase transition exists at $T_c(H)$, this becomes, within the crossover region,

$$C_m(t,h_{\mathrm{RF}}) = h_{\mathrm{RF}}^{2(\bar{\alpha}-\alpha)/\phi} |t-t_c|^{-\bar{\alpha}} , \tag{6}$$

where $t_c \equiv [(T_c(H) - T_N + bH^2]/T_N = -c h_{\mathrm{RF}}^{2/\phi}$, and $\bar{\alpha}$ is the RFIM specific-heat exponent.

The actual value of the RFIM crossover exponent ϕ is of particular interest because it depends upon the system from which the crossover takes place. Although the diluted antiferromagnet obviously corresponds to the random-exchange Ising model system, it was originally believed REIM exponents would not be observable in the experimentally accessible critical region.[1,9] Consequently, the crossover to RFIM behavior would be described by $\phi = \gamma_p$, the *pure* Ising (not REIM) susceptibility exponent. However, more recent renormalization-group calculations have shown that the random-exchange fixed point occurs at fairly weak disorder.[10] Experiment suggests[11] the crossover from pure Ising to REIM behavior would be essentially complete for $x \leq 0.9$; thus, REIM critical exponents should be, and are, observable *and* the crossover is from REIM to RFIM behavior in this range. However, for a random-exchange AF system, $\phi \neq \gamma$ (REIM), where γ (REIM) is the REIM staggered susceptibility exponent. For the $d=3$ RFIM diluted antiferromagnet problem, Aharony has shown[12] that $\phi > \gamma$ and is bounded by $1.05 \leq \phi/\gamma \leq 1.1$. Thus, the following inequalities are predicted for the $d=3$ REIM diluted AF: $\phi > \gamma$ (REIM) $> \gamma_p$ with γ (REIM) (Ref. 13) $=1.31$ and $\gamma_p = 1.24$ is the pure Ising exponent.[14]

EXPERIMENTAL PROCEDURE

The optical linear birefringence Δn has been measured in samples of AF $\mathrm{FeF_2}$ diluted with the isomorphic but nonmagnetic $\mathrm{ZnF_2}$. It has been shown that the temperature derivative of the linear birefringence $d(\Delta n)/dT$ is proportional to the magnetic specific heat C_m for both the pure[15-17] and diluted[18,19] fluorides. Δn was measured using the Sénarmont technique at the HeNe laser wavelength $\lambda = 632.8$ nm using a photoelastic modulator for increased sensitivity. The optical arrangement and technique are described in detail elsewhere.[17] For the experiments presented here, two different experimental apparatus were used; for low fields, an iron electromagnet for $H \leq 2$ T, and for high fields, a superconducting solenoid provided $H \leq 8$ T. Since the bore of the latter had no radial access, a sample holder with mirrors and tilting mechanisms was designed and constructed to allow propagation of the laser beam perpendicular to H. In order to study the phase transition at higher values of $h_{\mathrm{RF}} > 0.05$, we applied moderate external fields ($H \leq 2T$) on relatively low Fe concentration samples ($x < 0.60$), and higher fields ($H > 2T$) for those with $x \geq 0.60$.

The concentration gradients of all of the samples were characterized by room-temperature Δn measurements.[20] The scans of three of the samples studied here ($x = 0.35$, 0.46, and 0.84) are those appearing in Ref. 20. Typical gradients along the growth direction are 0.5–1 % per cm and smoothly varying. To minimize the effect of the axial gradients on the phase transitions, measurements were taken with a narrow laser beam defined by a pinhole of ≈ 0.2-mm diameter and aligned *perpendicular* to the growth direction, thereby reducing the axial variation to typically 10^{-3} in x.

Sample concentrations were determined from a measurement of T_N for $x \gtrsim 0.5$, assuming $T_N(x) = xT_N(1)$. Experimental determinations[21] of $T_N(x)$ versus x have yielded the relation

$$T_N(x)/T_N(1) = 0.99 \pm 0.04$$

for $x > 0.4$ in the $\mathrm{Fe}_x\mathrm{Zn}_{1-x}\mathrm{F}_2$ system. The assumed proportionality is thus well within experimental errors. Some theoretical justification for this relation is also found[22] using real-space renormalization-group methods in the diluted anisotropic exchange model. The initial slope, near $x = 1$, was shown to be close to unity for large anisotropy. For $0.31 \leq x \leq 0.35$, x was determined by density measurements to an estimated accuracy of ± 0.02, assuming a linear variation in lattice constants according to Vegard's law.

The sample temperature was measured and stabilized to a relative accuracy of ± 0.1 mK with an ac resistance bridge and carbon-glass thermometer with very low field dependence; the latter was measured and corrected for. Since large thermometry shifts (≈ 100 mK) occur upon warming the thermometer to room temperature, a series of measurements of a particular sample at various fields were made on the same day, if possible. Provided the thermometer was kept below $T = 100$ K, day-to-day shifts were of the order of 10 mK. For data collected over more than 1 day, a thermometry correction of these shifts was obtained by repeating the $H=0$ measurements.

EXPERIMENTAL RESULTS

We studied $d(\Delta n)/dT$ for a variety of crystals of $\mathrm{Fe}_x\mathrm{Zn}_{1-x}\mathrm{F}_2$, with $0.35 \leq x \leq 0.84$. In addition, data from a Faraday rotation measurement in a more dilute crystal ($x = 0.31$) (Ref. 23) and from a capacitance measurement[24] at $x = 0.73$ were also utilized in the analyses. Typical data are shown in Figs. 1 and 2 for $x = 0.46$ and 0.60, which exhibit cusplike behavior in $H=0$ for $d(\Delta n)/dT$. The important fact that concentration gradients result in a specific-heat peak whose maximum occurs *below* the average transition temperature at $\bar{T}_N$ has been taken into

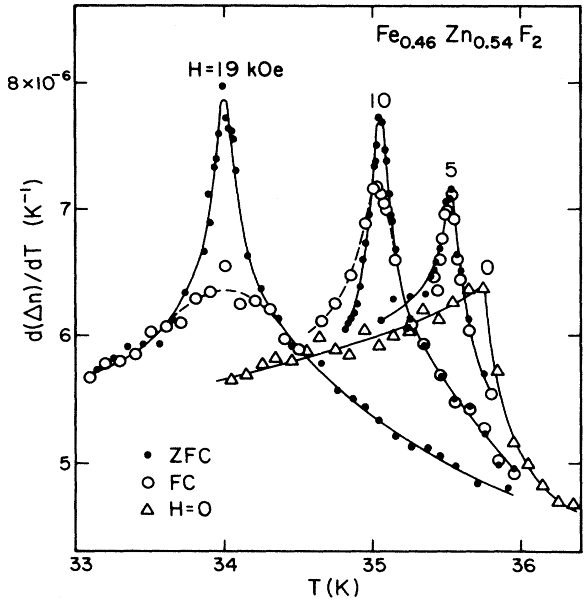

FIG. 1. Temperature derivative of the linear birefringence $d(\Delta n)/dT$ vs T for fields $H=0$ up to 19 kOe (where $h_{RF}=0.084$) in $Fe_{0.46}Zn_{0.54}F_2$. The solid circles indicate zero-field-cooled (ZFC) data, while the open circles indicate field-cooled (FC) data. The dramatic shift of the transition with field and other effects of the random field are discussed in the text. The lines are guides to the eye.

account in determining $\overline{T}_N$ for each x, following the method given in Ref. 25.

The field dependence of $d(\Delta n)/dT$ versus T is shown in Figs. 1 and 2 for data taken following a zero-field-cooling (ZFC) procedure. The ZFC peaks are seen to shift downward in T with increasing field and to become more symmetric. The former effect is a consequence of the REIM-RFIM crossover, while the latter is the onset of RFIM specific-heat critical behavior, which has been observed to exhibit a symmetric, logarithmic divergence[4] in $|t-t_c|$. The broadening of the peaks with field is a consequence of field-dependent crossover scaling,[1] while the increased rounding is a manifestation of extreme critical slowing down inherent in the RFIM dynamics.[26] All of these effects have been previously investigated in great detail in the $Mn_xZn_{1-x}F_2$ system.[5] Furthermore, it has been found that the extreme critical slowing down observed in the ac susceptibility[27] and neutron-scattering[28] experiments on $Fe_{0.46}Zn_{0.54}F_2$ is so great that even "dc" measurements are drastically affected.

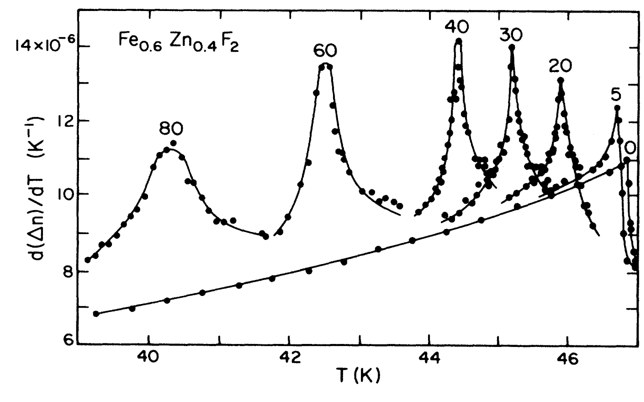

FIG. 2. Temperature derivative of the ZFC linear birefringence $d(\Delta n)/dT$ vs T for fields $H=0$ up to 80 kOe (where $h_{RF}=0.21$) in $Fe_{0.6}Zn_{0.4}F_2$. The dramatic effects of the random fields are discussed in the text. The lines are guides to the eye.

To understand the peak heights, both static and dynamic scaling must be considered. For $|t-t_c|<t^*$, a characteristic dynamic rounding temperature, the static critical divergence is cut off and finite peak heights are observed. In the region where the crossover is from REIM to RFIM, t^* contains the static scaling of Eq. (1), with only logarithmic field and frequency corrections, given by theories of activated dynamics.[26] This results in peak heights which scale predominantly with the static scaling of Eq. (6). The peak height is measured above the $H=0$ data as a background, and scales as $H^{0.13}$, since $\alpha=-0.09$ and $\overline{\alpha}\approx 0$. Thus, it is expected to increase very quickly for small H and then only very slowly for larger H. The effect of concentration-gradient rounding is to decrease the rapidity of the initial peak height increase at low H. This effect has been clearly demonstrated in Ref. 5.

The data in Figs. 1 and 2 exhibit all of the above effects and seem to be generally in agreement with what has been previously seen in the $Mn_xZn_{1-x}F_2$ system.[5] However, one new effect is observed in the $x=0.60$ data. The peak heights do increase up to $H=6.0$ T, but at 8.0 T there is a significant *decrease*. We note that here h_{RF} is large ($h_{RF}\approx 0.21$) and the relative shift of $T_c(H)$ is large [$\Delta T_c(H)/T_N\approx 0.14$]. With such a value of h_{RF}, it is perhaps not surprising that departures from the predicted small-field crossover behavior become apparent. Also t^* is determined by equating the RFIM characteristic frequency for the dynamics to the corresponding REIM quantity at the crossover boundary Eq. (1). in the model of Ref. 26. However, at such a large shift, the crossover is from RFIM directly to mean-field behavior. That is, the entire critical region ($|t|\leq 0.1$) is RFIM, and one would expect the low-field dynamical crossover scaling may also break down.

ANALYSIS

Unlike the asymmetric REIM case, the maxima of the symmetric peaks in the RFIM case *do* lie at $\overline{T}_c$, even in the presence of concentration gradients.[5] Thus, no correction is required and $T_c(H)$ is taken simply as the center of the $d(\Delta n)/dT$ peak. A mean-field correction bH^2 to the shift in $T_c(H)$ was made[2] with $b(x)=b(1)/x$, as indicated in Eq. (2). Least-squares fits were made to Eq. (2), letting T_N and $C(x)$ vary as free parameters. Although the quality of some of the data is not sufficient to yield accurate determinations of ϕ, fits to all the data give values of ϕ which are independent of x, within experimental error, as was found to be the case in the $Mn_xZn_{1-x}F_2$.[5] These agree within experimental error with the most accurate of the previously determined ones: $\phi=1.40\pm0.05$ at $x=0.6$ (Ref. 4) and $x=0.73$,[24] and $\phi=1.44\pm0.04$ at $x=0.47$ (Ref. 6) and $x=0.31$.[23] The value of ϕ was therefore *fixed* at 1.42, which is the average of these values. Thus, even at the extreme concentrations $x=0.31$ and 0.84, no crossover to other fixed points such as percolation of pure Ising was apparent. This is seen in Fig. 3, where we have plotted the mean-field corrected $\Delta T_c(H)$ versus H [see Eq. (2)] in a log-log plot for all the samples. The lines through the points represent the best fits to Eq. (2) with ϕ fixed to be 1.42.

The values of $C(x)$ determined by the fitting procedure are displayed in Table I. These values were then converted to the dimensionless units c by the use of Eq. (4) and are shown in Table I and in Fig. 4 as a function of x; it is seen they are, indeed, of order unity. That $c(x)$ varies somewhat with x is not surprising, since $c(x)$ is not a universal quantity. However, as $x \rightarrow 1$, $c(x)$ appears to approach a constant value, $c(1)\approx 0.7$ independent of x.

We have found an empirical expression which approximately describes the x dependence of $c(x)$; namely,

$$c(x)=c'(x)T_N(1)/T_N(x) \ . \qquad (7)$$

That $c'(x)$ is much less x dependent than $c(x)$ is illustrated in Fig. 5. This definition of $c'(x)$ is equivalent to replacing $T_N(x)$ in Eq. (2) by $T_N(1)$ as follows:

$$\Delta T_c=c'(x)T_N(1)h_{\mathrm{RF}}^{2/\phi} \ . \qquad (8)$$

Although we know of no theoretical justification for this form, it is useful to have a simple expression which accurately describes the data over the whole range of x.

The errors in $c(x)$ obtained by fitting the data to Eq. (2) are considerably smaller than those shown in Figs. 4 and 5; of the order of 5% for much of the data [see $C(x)$ in Table I]. It is not possible to draw a smooth curve through these error bars, so it is evident that there must be another source of error. Only likely error is in the absolute concentration x. Our experience suggests that some of the values of x could be in error by as much as ±0.02. Assuming an uncertainty in x of $\delta x=\pm0.02$ for each x, we have used Eqs. (2) and (4) to calculate the effect on $c(x)$. When these errors are convoluted with those obtained by the fitting, the result is as shown in Table I and Figs. 4 and 5. In most cases, indeed, the error in x is the dominant one.

TABLE I. Values of $C(x)$ obtained by fitting data for $\mathrm{Fe}_x\mathrm{Zn}_{1-x}\mathrm{F}_2$ and $\mathrm{Mn}_x\mathrm{Zn}_{1-x}\mathrm{F}_2$ (Ref. 5) to Eq. (2), with fixed $\phi=1.42$, and values of $c(x)$ derived with the use of Eq. (4) to give h_{RF}. Also shown are values of $c'(x)$ derived using Eq. (7).

x	T_N (K)	$C(x)$ ($\mathrm{RT}^{-2/\phi}$)	$c(x)$	$c'(x)$
		$\mathrm{Fe}_x\mathrm{Zn}_{1-x}\mathrm{F}_2$		
0.84	65.492	$8.5(4)\times10^{-4}$	0.67(8)	0.56(8)
0.73	57.224	$1.53(4)\times10^{-3}$	0.73(6)	0.53(6)
0.60	47.045	$4.2(2)\times10^{-3}$	1.21(11)	0.73(8)
0.55	43.192	$5.2(3)\times10^{-3}$	1.26(12)	0.70(9)
0.46	35.795	$9.5(3)\times10^{-3}$	1.63(13)	0.75(9)
0.35	28.045	$1.5(2)\times10^{-2}$	1.7(3)	0.62(12)
0.33	25.596	$2.0(1)\times10^{-2}$	2.0(2)	0.67(11)
0.31	19.494	$6.00(5)\times10^{-2}$	3.8(4)	0.95(15)
		$\mathrm{Mn}_x\mathrm{Zn}_{1-x}\mathrm{F}_2$		
0.83	52.355	$1.4(2)\times10^{-3}$	0.7(1)	0.56(8)
0.55	27.381	$1.22(4)\times10^{-2}$	1.30(4)	0.53(2)
0.40	12.55	$6.1(8)\times10^{-2}$	1.6(2)	0.30(4)

In contrast to the relatively sharp peaks seen in the ZFC data, the field-cooled (FC) peaks become drastically rounded for values of $h_{\mathrm{RF}}>0.05$ as seen in Fig. 1. Similar effects are found for $x=0.60$ at high H. These hys-

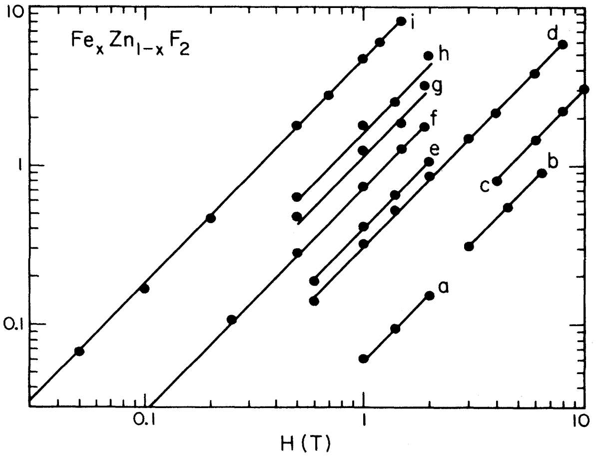

FIG. 3. Log-log plot of the random-field shift $\Delta T_c(H)$ vs field H after mean-field correction. See Eq. (2). Excellent fits, indicated by the solid lines, were obtained for all the data, with ϕ fixed to the value 1.42 of the universal REIM-RFIM crossover exponent. Curves a–i refer to values x of 0.836, 0.84, 0.73, 0.60, 0.55, 0.46, 0.35, 0.33, and 0.31, respectively. a and b are different points on the sample.

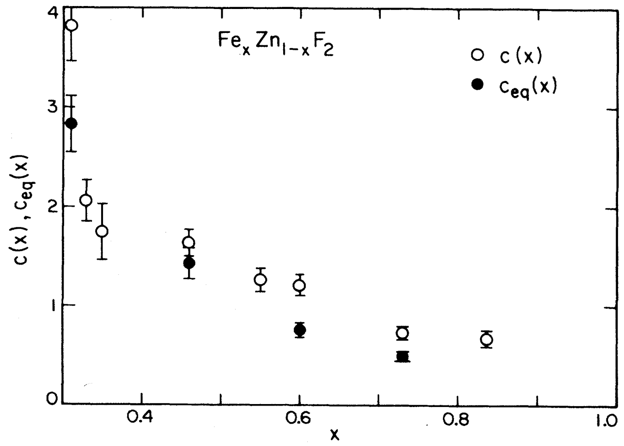

FIG. 4. Proportionality constants $c(x)$ and $c_{\mathrm{eq}}(x)$ relating the shifts $\Delta T_c(H)$ and $\Delta T_{\mathrm{eq}}(H)$ in the transition and equilibrium temperatures to the rms random field h_{RF}. $[\Delta T_c(H),\Delta T_{\mathrm{eq}}(H)]=[c(x),c_{\mathrm{eq}}(x)]T_N h_{\mathrm{RF}}^{2/\phi}$. These nonuniversal parameters are of order unity, as expected.

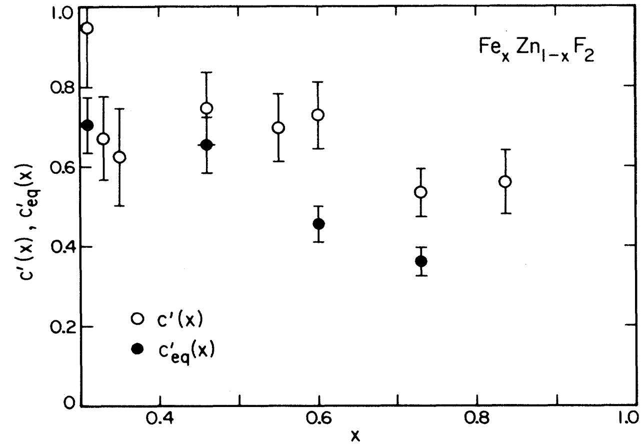

FIG. 5. Empirical expressions $c'(x)=c(x)T_N(x)/T_N(1)$ and $c'_{eq}(x)=c_{eq}(x)T_N(x)/T_N(1)$, which approximately describe the x dependence of $c(x)$ and $c_{eq}(x)$.

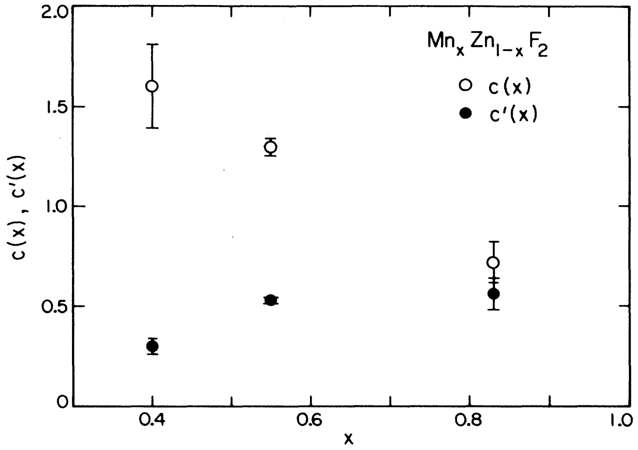

FIG. 6. Proportionality constant $c(x)$ relating $\Delta T_c(H)$ to h_{RF} in $Mn_xZn_{1-x}F_2$ together with $c'(x)=c(x)T_N(x)/T_N(1)$, which approximately describes the x dependence of $c(x)$. The data are taken from Ref. 5.

teretic effects only appear at relatively large values of h_{RF} and were not observed in previous Δn experiments on $Fe_{0.6}Zn_{0.4}F_2$ up to $h_{RF}=0.05$. The FC effect has been interpreted as a freezing-in of a domain structure of average size R. The divergence of the correlation length ξ is then limited to a value of the order of R and, consequently, the divergence of the specific heat is limited. The equilibrium temperature $T_{eq}(H)$, as defined in the Introduction, is determined experimentally as the point above which the FC and ZFC data in $d(\Delta n)/dT$ first differ. This can be seen in Fig. 1. Notice that $T_{eq}(H) > T_c(H)$ and is also well above the region of dynamic rounding of the phase transition.

It has been previously observed[24] that $T_{eq}(H)$ scales with field with RFIM crossover scaling, as does $T_c(H)$, according to

$$\Delta T_{eq}(H)=T_N-bH^2-T_{eq}(H)=C_{eq}H^{2/\phi} . \qquad (9)$$

In analogy with Eqs. (2) and (8), we define the constants c_{eq} and c'_{eq} as

$$\Delta T_{eq}(H)=c_{eq}T_N(x)h_{RF}^{2/\phi}=c'_{eq}T_N(1)h_{RF}^{2/\phi} . \qquad (10)$$

Using Eq. (4) to give the relation between h_{RF} and H, we have fitted data for $x=0.31$, 0.46, and 0.60, and 0.73 to Eq. (10). For these fits, T_N was fixed to be the value determined from the $T_c(H)$ fits, ϕ was fixed at $\phi=1.42$, and only $c_{eq}(x)$ was allowed to vary. Nevertheless, very reasonable fits were obtained for the data at all x.

The results are very similar to those found for the shift of $T_c(H)$. $c_{eq}(x)$ is found to be of order unity; it approaches an x-independent value for higher x, but exhibits a distinct x dependence for lower x. This can be seen in Fig. 4. $c'_{eq}(x)$ is considerably less x dependent than $c_{eq}(x)$ is, as can be seen in Fig. 5, although it too retains some x dependence. Comparing $c'_{eq}(x)$ with $c'(x)$, we find that $c'_{eq}(x)$ is, on the average, about 27% smaller than the corresponding value of $c'(x)$ and that no obvious x-dependent trend in this relationship is evident. This fact has been observed in previous capacitance measurements[24] on samples of $x=0.73$ (again presented here) and 0.46.

In an earlier study of the isostructural diluted antiferromagnet $Mn_xZn_{1-x}F_2$, Ramos *et al.*[5] determined ϕ for three concentrations: $x=0.40$, 0.55, and 0.83. Although pure MnF_2 is less Ising-like than FeF_2, its asymptotic critical behavior is also that of a $c=3$ Ising system. It was found that, for all three diluted samples studied, ϕ is identical with the value determined in the more ideally Ising $Fe_xZn_{1-x}F_2$. Ramos *et al.* also determined values of $C(x)$ for each fit to the data, which we have converted into the corresponding values of $c(x)$ and $c'(x)$ in Eqs. (2) and (8), using parameters appropriate to $Mn_xZn_{1-x}F_2$. The results appear in Table I and Fig. 6. As in the $Fe_xZn_{1-x}F_2$ case, $c(x)$ is of order unity, with a similar x dependence. Interestingly, as $x \rightarrow 1$, the magnitude of $c(1)\approx 0.7$ which is essentially the same value found in $Fe_xZn_{1-x}F_2$. The value of $c'(x)$ is found, as in the $Fe_xZn_{1-x}F_2$ case, to be much less x dependent than $c(x)$ is. As $x \rightarrow 1$, a value $c'(x)\approx 0.6$ is approached, which is very close to $c'(x)$ in $Fe_xZn_{1-x}F_2$.

CONCLUSIONS

We have used the RFIM crossover formalism[1] of Eq. (2) together with the explicit relation[2] of Eq. (3) between the rms random field h_{RF} and the uniform field H applied to a diluted Ising antiferromagnet. This has allowed us to evaluate the nonuniversal constants $c(x)$ and $c_{eq}(x)$ relating $\Delta T_c(H)$ and $\Delta T_{\mathrm{eq}}(H)$ to h_{RF} in both the ideal Ising system $\mathrm{Fe}_x\mathrm{Zn}_{1-x}\mathrm{F}_2$, and the slightly less ideal system $\mathrm{Mn}_x\mathrm{Zn}_{1-x}\mathrm{F}_2$. We find that $c(x)$ and $c_{\mathrm{eq}}(x)$ are indeed of order unity, as expected. We therefore conclude that Eqs. (2) and (3) must accurately represent the experimental situation over a surprisingly wide range of x.

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