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SINGULARITIES OF THE SPECIFIC HEAT OF FERRITES IN A MAGNETIC FIELD IN THE VICINITY OF THE CURIE POINT

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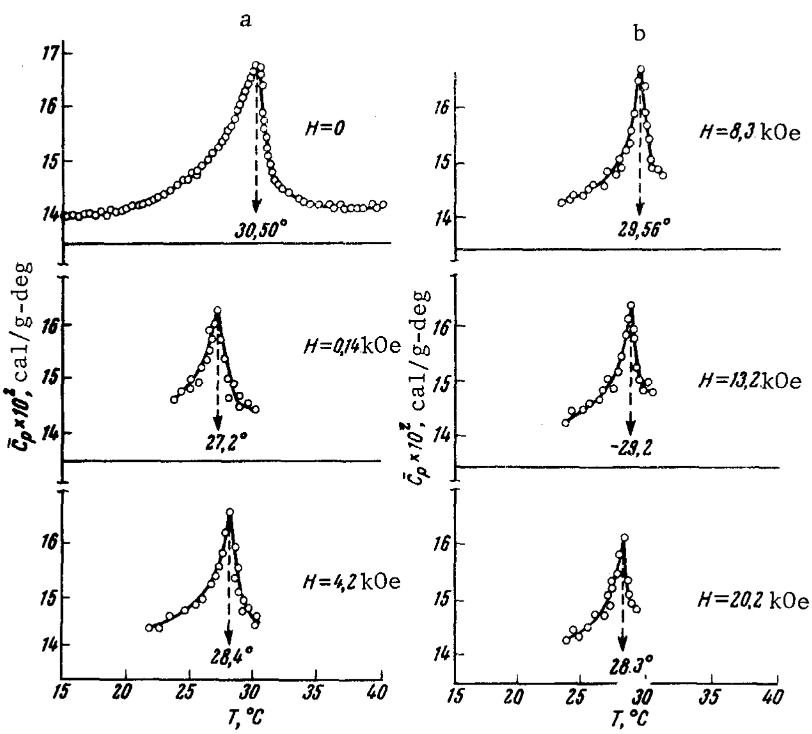
Experimental data are presented on the specific heat of the ferrite $Cu_{0.4}Cd_{0.6}Fe_2O_4$ in the vicinity of the phase transition, as a function of the external magnetic field intensity. The H-T phase diagram of the ferrite near the Curie point is obtained from these measurements. A discussion of the results is presented.

The main purpose of studying critical phenomena, namely to establish the exact form of the singularities of the physical parameters, including the specific heat (C), has not yet been attained. The only reliably known fact is that the character of the singularity of the specific heat in the critical region does not agree with the Weiss-Van der Waals-Bragg theory. There are even fewer studies of the behavior of the specific heat if the external conditions are altered. We present here the results of an investigation of the specific heat of $Cu_{0.4}Cd_{0.6}Fe_2O_4$ in the vicinity of the Curie point T_c. From the magnetic point of view, this ferrite is ferrimagnetic with three magnetic sublattices. The complicated magnetic sublattice structure may affect the behavior of C, particularly if it is investigated in a magnetic field H. The character of the anomalies of the specific heat at T_c of ferrites in an external field has not been investigated so far. The measured values of C of $Cu_{0.4}Cd_{0.6}Fe_2O_4$ in fields H = 0, 0.14, 4.2, 8.3, 13.2, and 20.2 kOe are shown in Figs. a and b.



The specific heat was measured with an adiabatic calorimeter [1].

The averaged results of numerous measurements of the specific heat in the region of T_c are shown in Fig. a (H = 0 curve). The experimental values of the jump of the specific heat ΔC_{exp} in a zero field are larger at T_c than ΔC_{theor} calculated on the basis of molecular-field theories, as is evidenced by the presence of a fluctuation contribution to the specific heat, a contribution not accounted for in these theories. For ferrites, the jump ΔC_{theor} calculated on the basis of molecular-field theories is even smaller [2]. In this case it is natural to calculate the critical exponents α for C. Owing to a certain smearing of C, the determination of α has no particular meaning, especially in the region $T \leq T_c$, where a domain contribution is expected and is difficult to calculate. In the case $T \gtrsim T_c$, however, where more or less reproducible values of C are obtained, the determination of α is not devoid of meaning. An appropriate data reduction shows that $C \sim |(T - T_c)/T_c|^{-0.31}$ in the paramagnetic region, i.e., α = 0.31. The Curie point was determined by us by the thermodynamic coefficient method to be 30.5°C.

Let us discuss the results of the measurements in a field H. The characteristic singularities in the behavior of the specific heat in a field are the following: 1) the anomalies of the specific heat at T_c are not eliminated by the field; 2) the value of the peak of C and the smearing of the transformations increases with increasing H, and, finally, the maximum of C shifts in weak fields to the left and then, up to H = 8.3 kOe, to the right, and then again to the left. This behavior does not fit any particular theory. We attempt, nevertheless, a qualitative interpretation of the obtained interesting experimental facts. The narrowing and lowering of the specific-heat peak in the vicinity of T_c are probably due to suppression of the spin fluctuations both far from the transition point and at the transition itself. The preservation of the specific-heat anomalies in the field demonstrates that the ordering parameter alone does not explain the ferrimagnetic-paramagnetic transition fully, as in the Landau theory. More suitable in this case are the ideas of [3], in which a magnetic phase transition in a field H is considered. From the point of view of that reference, a ferromagnet, owing to the magnetic-dipole forces, is in a magnetically-inhomogeneous state at $T < T_c$ and H = 0, and is in a homogeneous state above T_c. On going through T_c (in a field H) a phase transition takes place in the system, from a state with one type of magnetic ordering to a state with another type. It follows therefore that the second-order phase transition in a ferromagnet is preserved in a finite field H. It follows also from [3] that the maximum of C shifts in weak fields to the left, and then to the right, as is observed also in $Cu_{0.4}Cd_{0.6}Fe_2O$. A similar situation was observed in [4] for the components of the complex susceptibility of $Y_3Fe_5O_{12}$. In the opinion of [4], the magnetic moments of the inhomogeneous regions [5] are antiparallel at T_c, leading to a seemingly antiferromagnetic behavior of the system in weak fields, until this structure is destroyed. These maxima then shift to the right with increasing H, as is typical of ferromagnets. It might seem that further increase of the field should eliminate these anomalies. Our measurements of the specific heat in fields H from 13.2 to 20 kOe show, however, that the anomalies of the specific heat remain and their maxima shift towards lower temperatures (Fig. b). Such a behavior is typical of antiferromagnets. It can therefore be assumed that it is precisely in strong fields that the specific heat of the ferrite $Cu_{0.4}Cd_{0.5}Fe_2O_4$ exhibits a behavior characteristic of the phase diagram established in [6] for the antiferromagnetic structure, as is indeed realized in ferrimagnets from the point of view of the microscopic theory.

Thus, investigations of the specific heat in a magnetic field reveal new singularities of ferrites and lead to a rather distinct magnetic H-T phase diagram of these ferrites near the Curie point.

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