Observation of a Gabay–Toulouse line in the ordered alloy $Fe_{0.6}Mn_{0.4}Pt_3$

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The application of an external magnetic field to a frustrated ferromagnet belonging to the group of structurally ordered $(Fe_xMn_{1-x})Pt_3$ alloys causes the temperature of the transition from the ferromagnetic state to the asperomagnetic state to vary along a Gabay–Toulouse line.

In a significant number of magnetic systems with a competing exchange interaction between spins, a transition from an ordered state to a spin-glass state occurs as the temperature is lowered (alternatively, the transition may occur to a mixed phase with a short order radius). Despite extensive experimental and theoretical research on such systems, the nature of this reentrant transition is not yet completely clear, particularly in the case of Heisenberg magnetic materials. According to the present theoretical understanding, a transition of this sort should actually consist of a sequence of two transitions.[1] The first would occur below the temperature T_C (or T_N) and would lead to the appearance of a nonergodic phase with a noncollinear ordering of magnetic moments (an asperomagnetic phase), in which a long-range magnetic order nevertheless persists. The position of this transition on the (H,T) state diagram would be determined by the Gabay–Toulouse (GT) line.[2] As the temperature is lowered further, the noncollinear phase with a long-range order should transform into a spin-glass state as the result of a second transition.

The presence of a nonergodic, noncollinear ordered state preceding the onset of the entrant spin glass has been experimentally confirmed primarily by neutron scattering and by the μSR method in $Fe_{80-x}Ni_xCr_{20}$ alloys.[3,4] It has been shown that both near T_C (or T_N) and near the temperature of the spin-glass ordering, T_g, one observes a significant spin dynamics associated with a transition from one magnetic phase to another. Near the GT line, however, no significant change in the dynamics of spins has been observed. In this situation, a study of the dynamics of local fields in the ordered state with a long-range magnetic order (including the dynamics not of a spin-wave type) is very important for clarifying the nature of the reentrant transition. An indication that the ferromagnetic phase is not uniform comes from the onset of a slight irreversibility of the magnetic susceptibility, as observed in an ordered $Fe_xMn_{1-x}Pt_3$ alloy.[5]

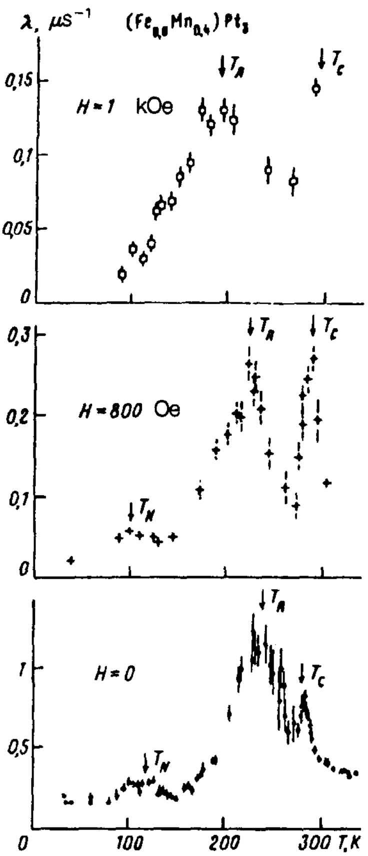

FIG. 1. Temperature dependence of the muon relaxation rate measured in longitudinal external magnetic fields $H=0$, 0.8, and 1.0 kOe. The arrows show the positions of T_C, T_N, and T_A.

In a study[6] of the dynamics of local fields in the ferromagnetic phase in $Fe_xMn_{1-x}Pt_3$ alloys, a significant spin dynamics was observed. It was reflected in the formation of a broad peak on the temperature dependence of the rate of depolarization of positive muons, $\lambda(T)$, with a peak at a temperature T_A lying between T_C and T_N. As the iron concentration is varied, the peak position T_A shifts, as was observed in Ref. 6.

To pursue the study of the physics of the phase transitions in Heisenberg magnetic materials, we studied the magnetic properties of the alloys $(Fe_{0.6}Mn_{0.4})Pt_3$ in a magnetic field in the muon beam of the St. Petersburg Institute of Nuclear Physics, using the μSR method. We examined only the depolarization caused by dynamic local magnetic fields. To analyze the experimental time-dependent μSR spectra, we accordingly used the following simple approximation of the muon depolarization function:

$$G(t)=\exp(-\lambda t).$$

Figure 1 shows the temperature dependence of the muon relaxation rate in magnetic fields of 0, 0.8 kOe, and 1.0 kOe. We see that the temperature T_C does not change in these fields, while the peak of the central broad maximum (T_A) shifts toward lower temperatures as the magnetic field is raised. Comparison of these results with the results

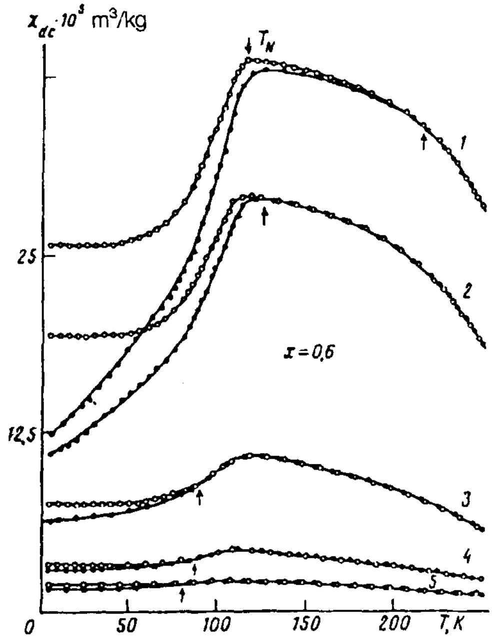

FIG. 2. Temperature dependence of the dc susceptibility of the ordered alloy $Fe_{0.6}Mn_{0.4}Pt_3$ from measurements taken as a sample was heated after cooling to 4.2 K in the absence of a magnetic field (filled circles) or in the measurement field (open circles). 1—$H=0.04\times 10^6$ A/m; 2—0.08; 3—0.28; 4—0.72; 5—1.60.

of the magnetic measurements shows that T_A essentially coincides with the temperature at which the magnetic susceptibility becomes slightly irreversible (see Fig. 2, where T_A is marked by the arrows). It can be seen from the H,T diagram constructed from our data (Fig. 3) that the experimental points correspond better to a Gabay–Toulouse dependence than to a Almeida–Thouless dependence. It is natural to suggest that the significant spin dynamics observed near T_A stems from a transition of this system from a collinear ferromagnetic phase into a nonergodic, noncollinear state with a long-range order. A possible reason for the significant width of the transition is a pronounced dispersion of the exchange energy over the sample, because of a statistical distribution of iron and manganese atoms. Further research on the distribution of the static magnetic fields might provide more definite information on the state of the spin system in $(Fe_xMn_{1-x})Pt_3$ alloys.

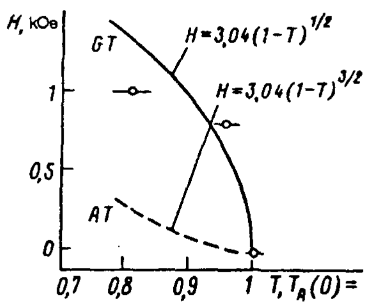

FIG. 3. The temperature T_A versus the longitudinal external magnetic field for a sample with $x=0.60$. Solid curve—Gabay–Toulouse (GT) line; dashed curve—Almeida–Thouless (AT) line.

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