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The effects of transverse field on the magnetic properties in a diluted mixed spin-2 and spin-5/2 Ising system

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Abstract

The magnetic properties of a diluted mixed spin-2 and spin-$\frac{5}{2}$ ferrimagnetic Ising system are investigated on the basis of the effective-field theory with correlation. The influences of transverse fields and concentrations of magnetic atoms on the magnetic properties are examined numerically. © 2000 Elsevier Science B.V. All rights reserved.

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A number of experimental studies have accumulated recently in the area of molecular-based magnetic materials, and the magnetic properties, namely molecular magnetism, have become an important focus of scientific interest [1]. Theoretically, the systems can be rather well described by a mixed spin (Ising or Heisenberg) model. In recent work [2], we have proposed that the mixed spin-2 and spin-$\frac{5}{2}$ ferrimagnetic Ising system on honeycomb lattice can explain the characteristic temperature dependence of magnetization observed at low temperatures in the molecular-based magnetic material, $N(n\text{-}C_4H_9)_4Fe^{II}Fe^{III}(C_2O_4)_3$ [3].

The aim of this work is to report some characteristic effects of a transverse field and concentrations of magnetic atoms on the magnetic properties in the diluted mixed spin-2 and spin-$\frac{5}{2}$ ferrimagnetic Ising system on honeycomb lattice, using the effective-field theory with correlations (EFT) [2,4]. As far as we know, only a few studies have dealt with the effects of a transverse field on molecular magnetism [2,5].

The Hamiltonian of the system is given by

$$H = J\sum_{(ij)} S^z_{iA} S^z_{jB} \xi_{iA}\xi_{jB} - \Omega_A \sum_i S^x_{iA}\,\xi_{iA} - \Omega_B \sum_j S^x_{jB}\xi_{jB}, \quad (1)$$

where $J(>0)$ is the exchange interaction, S^α_{iA} ($\alpha = x$ or z) is the spin-$\frac{5}{2}$ operator and S^α_{jB} is the spin-2 operator. The first summation is over all nearest-neighbor pairs of atoms. ξ_{iA}(or ξ_{jB}) is a random variable which takes the value 1 with a probability p_A(or p_B) or 0 with a probability $1 - p_A$(or $1 - p_B$), depending on whether the site i (or j) is occupied by a magnetic atom or not. Ω_A and Ω_B are the transverse fields on the A and B sublattices.

We are here interested in studying the phase diagram and the thermal variation of the total longitudinal magnetization in the system, since there is an order with a finite total transverse magnetization at all temperatures. The total longitudinal magnetization M_z of the system is

$$M_z = \tfrac{1}{2}(p_A m^z_A + p_B m^z_B) \quad (2)$$

with

$$m^z_A = \frac{\langle\langle \xi_{iA} S^z_{iA}\rangle\rangle_r}{\langle \xi_{iA}\rangle_r} \quad \text{and} \quad m^z_B = \frac{\langle\langle \xi_{jB} S^z_{jB}\rangle\rangle_r}{\langle \xi_{jB}\rangle_r}, \quad (3)$$

where $\langle \cdots \rangle$ and $\langle \cdots \rangle_r$ denote the thermal and random averages. Within the EFT, the magnetizations and the transition temperature T_C can be easily obtained by the use of the formulation in Refs. [2,4]. The compensation temperature T_κ, if it exists in the system, can be determined from the relation $M_z = 0$.

Fig. 1(A) shows a typical phase diagram of the system with $\Omega_A = \Omega_B = \Omega = 0.0$ in the $(k_BT/J, p_A)$ plane, when the concentration p_B is changed from $p_B = 1.0$ to 0.3. The T_C curves exhibit the characteristic behavior expected for

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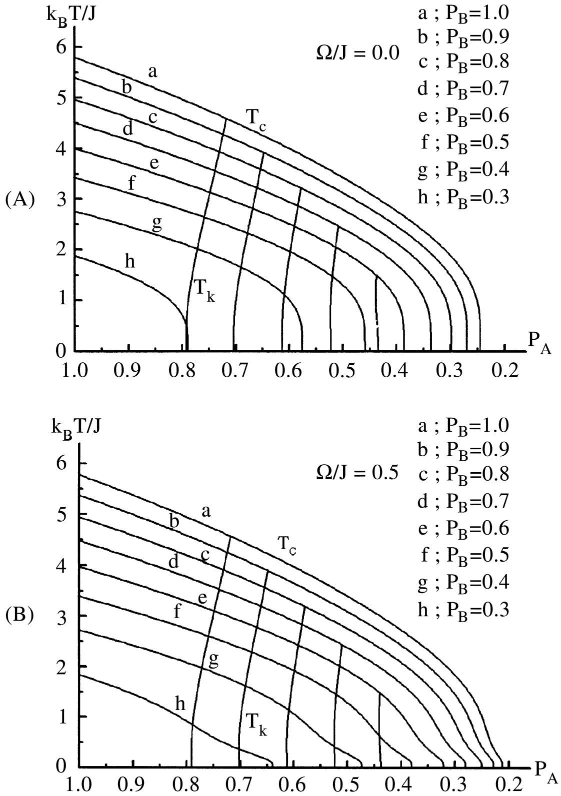

Fig. 1. Phase diagram in the $(k_B T/J, p_A)$ plane with transverse field $\Omega/J = 0.0$ (A) and $\Omega/J = 0.5$. (B)

diluted magnetic systems. But T_κ could not be obtained when p_B is lower than $p_B = 0.6$. Fig. 1(B) shows how the phase diagram is modified, when a finite transverse field ($\Omega/J = 0.5$) is applied.

Fig. 2 shows the temperature dependencies of M_z in the system with $p_A = 0.6$ and $p_B = 0.8$, when the transverse field is changed from $\Omega/J = 0.0$ to 3.0. The compensation point can be observed for relatively small transverse fields.

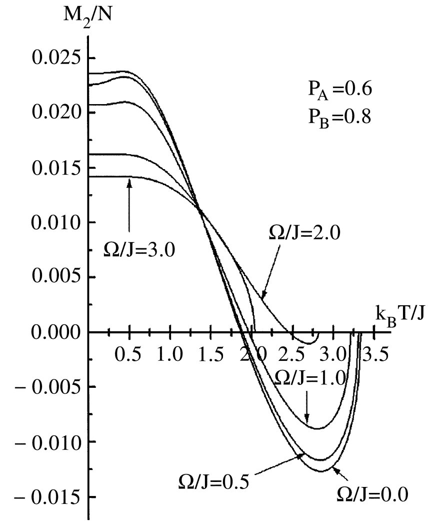

Fig. 2. The temperature dependencies of M_z in the system with $p_A = 0.6$ and $p_B = 0.8$.

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