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Numerical study of the mixed spin-1 and spin-5/2 BEG model on the Bethe lattice

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Abstract. The mixed spin-1 and spin-$\frac{5}{2}$ ferromagnetic Ising model with bilinear (J) and biquadratic (K) nearest-neighbor exchange interactions and a single-ion potential or crystal-field interaction (D) is studied on the Bethe lattice by means of exact recursion equations. First, the phase diagram of the system at zero temperature is obtained in the $(D/Jq, K/Jq)$ plane, where q denotes the coordination number of the lattice. Second, the sublattice magnetizations as functions of the temperature, the crystal-field and the biquadratic interaction strengths are thoroughly investigated. For $q = 3$, the resulting phase diagrams show first and second order phase transitions as well as compensation points where the net magnetization of the whole lattice should vanish in the antiferromagnetic version of the model. One interesting feature of the model concerns the presence of tricritical points. Our calculations show that at non-zero temperature, none of the sublattice can order separately. However, under an external magnetic field, some interesting phase diagrams with partially ordered phases arise.

1 Introduction

These last years, there has been an increasing interest in the field of spin-crossover materials (metal complexes with suitable ligands) which show under various constraints, e.g. an external magnetic field, a transition between low and high spin states [1]. On the other hand, molecular-based magnetic materials with spontaneous magnetic moments are also of considerable interest due to their potential technological applications [2,3]. The synthesis of such materials where ferrimagnetic ordering plays a crucial role, is nowadays an active field of research in materials science. When several sublattices with inequivalent magnetic moments interact, it may happen that the resulting moment vanishes under certain conditions. The existence of such a compensation point is known to be very useful, in particular, in thermomagnetic writing, reading and erasing devices because of the high coercivity around that point [4]. Mixed Ising models defined on a bipartite lattice (of sublattices A and B), with the interacting spin variables s_A and σ_B, $s_A \neq \sigma_B$, are theoretical schemes where the compensation phenomenon in magnetic materials can be observed and studied. Most recent works in molecular magnetism have been devoted to sublattice mixed-spin models where $\sigma = s_A - \sigma_B \leq 1$ and various methods were utilized [5–16]. However, Ising systems with higher σ are not without interest and, as far as we know, very little attenttion has been payed to this case. This is why in the present work, we choose to study the case $\sigma = 3/2$ on the Bethe lattice. The Bethe lattice is the deep sites of the infinite Cayley tree and consists of equivalent sites with the same coordination number q. Historically, it gets its name from the fact that its partition function is exactly the same with the one in the Bethe-Peierls' approximation [17]. This graph has been often used in statistical mechanics because of its recursive and uniform structure and also because it often reflects the essential features of Ising systems when the conventional mean field approach failed [18–23].

In this paper, we consider the mixed-spin ferromagnetic Blume-Emery-Griffiths (BEG) model that we define on the Bethe lattice. The purpose of this paper is to investigate the effects of the normalized crystal-field and the quadripolar interactions $\Delta = D/J$ and $\alpha = K/J$ as well as the presence of an external field constraint on the physical properties of the model. We believe that such a study is important for both experimental and theoretical perspectives. Recently, Deviren et al. [24] studied the Blume-Capel version of the same model in an external magnetic field using an effective field theory with correlations and obtained some interesting phase diagrams. The BEG version of the same model has been recently considered and investigated in an oscillating magnetic field within the mean-field approach and exhibited also

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