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Thermodynamic and magnetic properties of the finite spin complexes of the Ising type

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ABSTRACT

In the frame of the static fluctuation approximation (SFA) the analysis of the thermodynamic and magnetic properties of the finite spin clusters in the 1D Ising model is performed It has been shown that under the influence of the magnetic impurity that forms the fixed value of the magnetization on the ends of spin complex the total magnetic ordering of the whole chain becomes possible. The results obtained in the frame of this model can open a way to understanding of magnetic properties of a wide class of the finite cluster systems.

1. Introduction

The magnetic properties of nanoparticles and clusters have been interesting subjects for the last two decades due to their important technological applications and their novel characters that are quite different from those of bulk materials [1–3]. Surface effects for the clusters are of great importance since they dominate magnetic properties and become more important with reducing size of the particle. For clusters with a radius of several nanometers, the picture of a single-domain magnetic particle in which all spins point into the same direction and the coherent relaxation processes are produced is not valid as the surface effects become really crucial. A large surface effects have been found in a lot of nanoparticles [4–6]. For example, Mossbauer spectra and magnetization measurements for the cobalt, nickel ferrite, γ-Fe_2O_3 and other nanoparticles have shown that the magnetization and spin configuration are strongly influenced by the surface and size effects.

Recently, magnetic clusters in molecular beams, metals and semiconductors have become hot topics in the area of magnetism and magnetic materials [7]. The free clusters were obtained from molecular beams [8–10]. It is important for understanding the magnetism of a cluster to probe the properties of an individual one instead of an ensemble by ignoring the interaction between both clusters or between a cluster and the surrounding medium.

The basic aim of this theoretical paper is to suggest a very simple model that demonstrates a possibility of formation of magnetic complexes from magneto-active molecules in the confined geometry containing a magnetic impurity in a low concentration.

2. The model

Having in mind the demonstration of a possibility of formation the magnetically-ordered spin complexes in nanostructures we consider here only linear clusters. For description of the thermodynamic and magnetic properties of these spin complexes (linear clusters) we choose the spin Hamiltonian coinciding with the Ising model. The studying of the thermodynamic and magnetic properties of spin clusters in the frame of 1D-Ising model facilitates essentially the analytic calculations and makes more transparent understanding of appearance of new magnetic properties in spin clusters confined geometry. The general Hamiltonian of the Ising model is written in the form

$$H = -\sum_f h_f I_f^z - \frac{1}{2}\sum_{f,g} U_{f,g} I_f^z I_g^z = -\sum_f (h_f + \theta_f) I_f^z, \quad (1)$$

where $I_f^z - z$—component of nuclear spin of molecule localized in the fth knot of the spin complex considered, $U_{f,g}$—defines a potential of spin–spin interaction between molecules localized in the chosen knots f and g, h_f—determines the value of external magnetic field on the knot f,

$$\theta_f = \sum_g U_{f,g} I_g^z \quad (2)$$

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