Spin-1/2 quantum anisotropic Heisenberg ferromagnet with magnetoelastic interaction

Majid Moradi Kelardeh
Michal Jaščur

1 Institute of Physics, P.J.Šafárik University in Košice, Park Angelinum 9, 040 01Košice, Slovakia

majidofficial@gmail.com
michal.jascur@upjs.sk

In this contribution, we investigate the spin-1/2 quantum anisotropic Heisenberg ferromagnet with magnetoelastic coupling. To clarify the influence of lattice energy on the magnetic properties of the system, we assume that the total Helmholtz free energy consists of three contributions: (i) the static lattice energy, described by a volume-dependent Morse potential; (ii) the vibrational energy, treated within the Grüneisen quasi-harmonic modification of Einstein's phonon theory; and (iii) the magnetic contribution, represented by the quantum anisotropic Heisenberg model with distance- (or volume-) dependent nearest-neighbor exchange interactions, treated within the Oguchi approximation.
We derive analytical expressions for the total energy of the system using a theoretical framework previously applied to Ising systems with magnetoelastic interactions [1]. In addition to the Helmholtz free energy, we calculate the equations of state and other relevant thermodynamic quantities using standard methods of statistical mechanics.
Numerical results are obtained for a simple cubic lattice.
We discuss in detail the dependence of the critical boundaries on the freely adjustable model parameters and show that, besides second-order phase transitions, the anisotropic Heisenberg model with magnetoelastic coupling also exhibits first-order phase transitions. Our conclusions are supported by an analysis of the temperature dependences of the magnetization, the relative volume change, and the Helmholtz free energy of the system.

References

[1] T. Balcerzak, K, Szalowski and M. Jaščur, "Self-consistent model of a solid for the description of lattice and magnetic properties," Journal of Magnetism and Magnetic Materials, vol. 426, pp. 310–319, March 2017. doi: 10.1016/j.jmmm.2016.11.107.

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