Monte Carlo Simulation of Adiabatic Cooling and Nuclear Magnetism

A two-dimensional classical spin model of nuclear antiferromagnetism is studied by Monte Carlo computer simulation techniques as well as by mean-field calculations. The model includes nearest-neighbor dipolar and exchange interactions and a single-ion term. The phase boundary of the antiferromagnetic phase in the external-field–temperature plane exhibits sections of both first- and second-order transitions separated by a tricritical point. Particular attention is paid to the isentropes of the phase diagram, which correspond to the thermodynamic paths of constant entropy followed in experimental studies of nuclear magnetism using adiabatic demagnetization methods. It is found that, although fluctuations reduce the transition temperatures by 40%, the isentropes are reduced by less than 10% relative to those calculated by mean-field theory. The dynamics of the ordering process following constant-temperature or constant-magnetic-field quenches into the antiferromagnetic phase is found at late times to obey the classical Allen-Cahn growth law. The qualitative features of isentropic quenches and the nonequilibrium ordering phenomena during controlled heating treatments at constant rate are discussed in relation to recent experimental observations from neutron scattering experiments on nuclear antiferromagnetism in Cu.
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