Ising-Heisenberg diamond-decorated square lattice in a magnetic field: exact results for phase transitions and critical points

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The thermal phase transitions of a spin-1/2 Ising-Heisenberg model on the diamond-decorated square lattice in a magnetic field are investigated by making use of a decoration-iteration mapping transformation and classical Monte Carlo simulations. A generalized decoration-iteration transformation exactly maps this classical-quantum lattice-statistical model onto an effective classical spin-1/2 Ising model on the square lattice with temperature-dependent effective nearest-neighbor interaction and magnetic field. The effective magnetic field vanishes along a ground-state phase boundary of the original classicalquantum model, separating a classical ferrimagnetic phase and a quantum monomer-dimer phase. At finite temperatures this phase boundary gives rise to an exactly solvable surface of discontinuous (firstorder) phase transitions, which terminates in a line of Ising critical points. The existence of discontinuous reentrant phase transitions emergent within a narrow parameter regime is reported and explained in terms of the low-energy excitations from both phases. These exact results, obtained from the mapping to the zero-field effective Ising model, are independently corroborated by classical Monte Carlo simulations of the effective classical spin-1/2 Ising model on the square lattice with temperature-dependent effective nearest-neighbor interaction and magnetic field.

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