Stepwise magnetization curves and bipartite entanglement of an exactly solvable spin-1/2 Ising-Heisenberg branched chain

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The spin-1/2 Ising-Heisenberg branched chain composed of a regularly alternating Ising spin and a couple of the Heisenberg spins, the former of which is laterally branched by the additional Ising spin, is rigorously solved in a presence of the external magnetic field. The exact solution is based on the transfer-matrix approach following a partial trace over degrees of freedom of the Heisenberg dimers. Within the framework of this rigorous method we have examined in detail the ground-state phase diagram, magnetization process and concurrence serving as a measure of bipartite entanglement. We have found four different ground states depending on a mutual interplay between the magnetic field, the Ising and Heisenberg coupling constants. Two ground states have character of the modulated quantum antiferromagnetic phase with a translationally broken symmetry, one ground state has character of the quantum ferrimagnetic phase, and the last ground state is the classical ferromagnetic phase. The three quantum ground states are manifested in zero-temperature magnetization curves as intermediate plateaux at zero and one-half of the saturation magnetization. The pair correlation functions and the concurrence are used to quantify the bipartite entanglement between the nearest-neighbor Heisenberg spin pairs, which are quantum-mechanically entangled in three quantum ground states either with or without spontaneously broken symmetry. The ground-state phase diagram and zero-temperature magnetization curves of the spin-1/2 Ising-Heisenberg branched chain are compared with the analogous results of the fully quantum spin-1/2 Heisenberg branched chain obtained within the density-matrix renormalization group calculations.

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