Geometrically frustrated Cairo pentagonal lattice stripe with Ising and Heisenberg exchange interactions

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Motivated by the recent discoveries of some compounds such as the $\text{Bi}_2\text{Fe}_4\text{O}_9$ which crystallizes in an orthorhombic crystal structure with the $\text{Fe}_3$ ions, and iron-based oxyfluoride $\text{Bi}_4\text{Fe}_5\text{O}_{13}\text{F}$ compounds following the pattern of Cairo pentagonal structure, among some other compounds. We propose a model for one stripe of the Cairo pentagonal Ising-Heisenberg lattice, one of the edges of a pentagon is different, and this edge will be associated with a Heisenberg exchange interaction, while the Ising exchange interactions will associate the other edges. We study the phase transition at zero temperature, illustrating five phases: a ferromagnetic phase (FM), a dimer antiferromagnetic (DAF), a plaquette antiferromagnetic (PAF), a typical antiferromagnetic (AFM) and a peculiar frustrated phase (FRU) where two types of frustrated states with the same energy coexist. To obtain the partition function of this model, we use the transfer matrix approach and following the eight vertex model notation. Using this result we discuss the specific heat, internal energy and entropy as a function of the temperature, and we can observe some unexpected behavior in the low-temperature limit, such as anomalous double peak in specific heat due to the existence of three phase (FRU, PAF(AFM) and FM) transitions occurring in a close region to each other. Consequently, the low-lying energy thermal excitation generates this double anomalous peak, and we also discuss the internal energy at the low temperature limit, where this double peak curve occurs. Some properties of our result were compared with two dimensional Cairo pentagonal lattices, as well as orthogonal dimer plaquette Ising-Heisenberg chain.

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