Quantum critical point, reentrant phase transitions and weak-universal critical behaviour of the spin-1/2 Ising-Heisenberg model with the pair XXZ Heisenberg interaction and the quartic Ising interaction

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The spin-1/2 Ising-Heisenberg model is defined on a two-dimensional lattice of edge-sharing octahedrons, each of them having four Ising spins in a basal plane and two Heisenberg spins in apical positions of the elementary octahedron. The ensemble of all Ising spins then forms a square lattice, which has a couple of the Heisenberg spins above and below a center of each elementary square face formed by four Ising spins. Assuming the pair XXZ Heisenberg interaction between two apical spins and the quartic Ising interaction between two apical spins and two basal spins from opposite corners of a square face of the same octahedron, the model under investigation becomes exactly solvable by applying the generalized star-square transformation that establishes a precise mapping relationship with the corresponding eight-vertex model on a square lattice generally satisfying Baxter's zero-field (symmetric) condition [1].

It is shown that the spin-1/2 Ising-Heisenberg model with the ferromagnetic pair interaction exhibits a remarkable phase diagram with two marked wings of critical lines, which merge together at a very special quantum critical point. As could be expected from the exact mapping to the zero-field eight-vertex model, the critical exponents vary continuously along the critical lines when changing parameters of the Hamiltonian. The changes of critical exponents are in accordance with Suzuki's weak universality hypothesis [2] in spite of a peculiar singular behaviour to emerge at a quantum critical point of the infinite order, which occurs at the isotropic limit of the XXZ Heisenberg pair interaction. The origin of observed reentrant phase transitions is explained from the disorder solution, as well as, the different ground-state degeneracies of two phases coexisting at the quantum critical point.

1. R.J. Baxter, PRL 26 (1971) 832; Ann. Phys. 70 (1972) 193.
2. M. Suzuki, Progr. Theor. Phys. 51 (1974) 1992.