Critical Properties of Ferroelectric and Ferromagnet Models

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Solving the problem of description of the behaviour of thermodynamic parameters near the critical points one considers either the simplest models, for which the partition function can be evaluated exactly, or an approximate solution of the problem. At the first approach the exactly solvable 2-dimensional models [1] are of great importance. The second approach is connected mainly with examination of the asymptotic behaviour of thermodynamic parameters near the critical points, as well as with the development of the scaling law hypothesis, the universality hypothesis and the renormalization group approximation and has appreciably succeeded. Indeed, the large class of real systems and models satisfies the scaling law and the universality hypotheses. The existence of real systems and exactly solvable 2-dimensional models, for which these hypotheses are violated, is also remarkable. The 6-vertex ferroelectric Lieb model and the 8-vertex Baxter model [1] are such examples. These models give a reasonable fit to real ferroelectrics (antiferroelectrics) and ferromagnets (antiferromagnets), because there are a lot of crystals with strong horizontal and weak vertical bonds in the nature, for which 2-dimensional models are suitable.

The properties of 2-dimensional exactly solvable Lieb and Baxter models in the critical region are considered on the base of thermodynamical method developed for investigation of critical state of one-component system. From the point of view of the thermodynamic stability the behaviour of the whole set of thermodynamic characteristics of stability for these models is analyzed. The reasons for the violation of the scaling law hypothesis and the universality hypothesis for the models are clarified. For ferroelectric Lieb model it is ascertained that in subcritical and supercritical areas two types of critical behavior, different in fluctuation growth of energy and electric polarization are realized. This results in symmetry breaking of subcritical and supercritical indices, in essentially different behaviour of the same thermodynamic parameters on each side of a critical point. Baxter model is characterized by the same two types of critical behaviour, one of which is also presented in three cases, depending on a slope of phase equilibrium curve at the critical point. The type of the behaviour is varying dependently on the interaction parameter of the model. It is interesting to emphasize that in each model while one hypothesis is violated, another nevertheless holds. In addition, the special case of the 8-vertex Baxter model, where the universality hypothesis is violated, is the Lieb model, in which the universality hypothesis is satisfied, but the scaling law hypothesis is violated, and the Ising model, where both hypotheses are fulfilled.

1. R.J. Baxter Exactly Solvable Models in Statistical Mechanics. – London: Academic Press, (1982). – 488 p.