A thermodynamical model describing the liquid-vapor phase change with the appereance of metastable states

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In this work, we propose a mathematical model describing the liquid-vapor phase change and allowing the appearance of the metastable states contained in the van der Waals Equation of state. Metastable states correspond to a gaseous (or liquid) state which, after a slight perturbation, changes to a liquid (or gaseous) state quickly. Using the Gibbs formalism, we study the thermodynamic equilibrium of a mixture, which is supposed to be composed of I phases. According to the second principle of thermodynamics, the entropy of the mixture reaches its maximum (under certain constraints) to thermodynamic equilibrium. By convex analysis arguments, we will show that, for the van der Waals equation of state, the maximization problem is valid only for $I \leq 2$ (see [4, 1]). We will then study the problem of constrained maximization in the case $I = 2$ and we will characterize all possible equilibrium states : the state of coexistence, the pure phases whose metastable states and the unphysical states of the spinodal zone. To understand the metastable character, we will then construct dynamical systems [1, 3, 2] whose equilibria concide with the thermodynamical equilibrium. Finally, we illustrate numericaly the properties of these systems.

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