dielectric-metal phase transition in vapors of alkali and base metals, hydrogen and excitons

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The unified thermodynamic model that allows to calculate the parameters of the critical point and binodal for insulator-metal (vapor-liquid) phase transition in the vapor of alkali and other metals, atomic hydrogen and excitons is suggested. The model is based on the assumption that the main reason for the transition is the appearance in a dense atomic gas (gas near the critical point) of a special kind of attraction between the atoms of the metal due to the occurrence of the conduction band and the appearance of the conduction electrons. For liquid and solid metal densities this attraction is well known – it is a cohesion (cohesive energy). For atomic hydrogen [1], alkali metal vapors [2] and the gas of excitons cohesion can be calculated analytically for all atom densities. For most other metals having many-electron valence shell, cohesion can be calculated only numerically using the Hartree-Fock method and the density functional. For such metals, we used the scaling dependences for energy coupling, generalizing the results of numerous numerical computations and describes a simple and universal expression for various types of binding energy (Universal Bind Energy Relation, UBER). Universal expression for the cohesive energy is defined through evaporation energy, normal density and isothermal elastic modulus of the metal at normal density.

Isotherms for all substances, considered as in [1, 2], when the temperature decreases show the appearance of the van der Waals loops, which clearly indicates the presence of the first order phase transition of vapor-liquid. Analysis of the isotherms can immediately evaluate the critical temperature, density and pressure. Calculations are performed for the alkali and alkaline earth metals, Boron group and transition metals, and noble metals. We applied our model to the calculation of the critical parameters of the vapor-liquid transition in a gas of excitons. Good agreement with experiment is obtained.

The calculated critical point parameters are in reasonable good agreement with the experimental data for the alkali metals and with estimates of the parameters of the critical point of the other metals made by other authors. The model allows to calculate analytically the vapor-liquid phase transition binodal for all considered substances and to obtain the density of the liquid and the gas phase near the critical point. The liquid phase is a metallic one because it contains conduction electrons. Transitions in liquid metal state precedes the formation of a new, unusual substance – Likal'ter gaseous metal. The analogy of this phase transition in metal vapors, atomic hydrogen and excitons is discussed.

Thus, in this paper we propose a new method for calculating the parameters of the critical points and binodal vapor-liquid transition (insulator-metal) in the vapor of alkali and other metals, atomic hydrogen and gas of excitons. All transitions are of the same nature, as described by an unified thermodynamic model, which is based on a single hypothesis about the dominant role of quantum collective interatomic bonding energy - cohesion for condensed matter, and in the gas near the critical point. The proposed model gives a definite answer to the question posed by Landau and Zeldovich [3] on the possible mismatch vapor-liquid transition and insulator-metal. We could say that, with respect to the metals, atomic hydrogen and gas of excitons in our model, they coincide with one correction: the conversion of the gas atoms in the metallic liquid goes through the intermediate and unusual substance – Likal'ter gaseous metal.

Referencies

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3. Landau L.D., Zeldovich Ya.B., JETP, 1944, **14**, p. 32.