High-temperature and low-temperature chemical models of dense metal vapor plasma

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State of the metals changed from the solid to gaseous state at Joule heat, there is occurs metal-nonmetal transition. Many experiments and theoretical papers are devoted to investigation of features of this transition. Pressure, internal energy and conductivity are experimentally measured for rapid heated metal wires and foils [see for example 1, 2, 3 and the references there]. Theoretical papers might be separated conventionally on two groups. In the first group, the approaches developed in the theory of liquid metals are used with the subsequent extrapolation in the gas-plasma region [4]. The second group of papers are focused on a dense gas-plasma mixture and extrapolates calculations in near-critical region of liquid metals parameters [5]. Of course, that the first group of papers are well calculated a phase of melting of metals and badly described transition in gas-plasma state of the evaporated metal. The second group of papers have the basic difficulties to describe the high density state, especially at low temperatures ($T < 5000$ K).

In the present study, which can be referred to the second group, for advance in the region of low temperatures and high densities the chemical models of aluminum vapor plasma are developed. In addition to electrons, atoms and various ion species A^{l+} where $l = 1, 2, 3$ considered in paper [5], we added molecules and molecular ions of aluminum (high temperature variant) and also neutral and charged clusters with number of atoms up to 6, thus multi-charged ions not considered (low temperature variant). The models are used for calculation of caloric and thermal equations of state. To take into account a charge-charge interaction in multi-charged plasma, the approaches used in the literature were analyzed and as a result other expressions than in work [5] are used [6]. A charge-neutral interaction is considered in approach of Likalter [7] that was refined for an ion-atom interaction. The approach of scattering length for electron-atom interaction was used. The data available in the literature have been used for calculation of oscillation and rotation partition functions of clusters. This calculation allowed to analyzed the charge composition of cesium and aluminum plasma with use of low temperature variant of model. Dependence of a resistivity of plasma on internal energy was calculated using Frost's interpolation formula, the received caloric EOS and various approximations for transport cross-sections calculation. The satisfactory agreement with experimental data is received and the important role of molecules, molecular ions and clusters of aluminum in an initial phase of heating is shown.

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