Non-linear screening and thermodynamics of complex plasma.

Martynova I.A.[1,2], Iosilevskiy I.L.[1,2]

[1]Joint Institute for High Temperatures of the Russian Academy of Sciences, RUSSIA
[2]Moscow Institute of Physics and Technology (State University), RUSSIA

The present work is devoted to the analysis of the applicability range of a basic assumption in the phase diagram [1] of complex plasma in the κ–Γ plane (κ is the structural parameter, Γ is the coupling parameter), i.e., linearized (Debye) screening of macroions by microions which leads to the Yukawa form of effective interactions between macroions. Parameters of non-linear screening of macroions were obtained within the direct Poisson-Boltzmann approximation [2]. Two effects were revealed as a result of such calculations: (i) decomposition of all microions into two subclasses, bound and free ones, and (ii) significant reduction of an effective charge Z^* of the initial bare charge Z under non-linear screening by a small high-density envelope of the bound microions. The effective charge Z^* grows in the direct proportion to Z first and then, the change of the effective charge Z^* is negligibly thin. This renormalization of the initial Z and macroion concentration at the border of the cell leads to corresponding renormalization of initial parameters κ and Γ into κ^* and Γ^* ($\kappa^* < \kappa$ and $\Gamma^* < \Gamma$) [2]. The corresponding calculated shifts of excess internal energy are discussed and calculated. Moreover, we used three modifications of the excess internal energy calculated in [3] where the Debye-Hückel-hole approximation was used. We took the non-linear screening effect into account, first, in microion distribution inside the hole and, second, in reduction of the effective macroion charge in comparison with the bare one outside the hole. Third, we considered not point-like macroions, but finite-sized ones. The value of the resulting modified excess internal energy is bigger than the one which can be obtained from [3] where the non-linear screening effect was not taken into account. This work was supported by the Russian Science Foundation, grant No. 14-50-00124.

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