equation of state accounting for ion cores volume

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***Introduction.*** Gas plasma equation of state can be described by ionization equilibrium model (Saha model). High accuracy of the model is provided by using of experimentally measured ionization potentials. Though at super-high densities plasma encounters transition to liquid state. Here 2 questions arise: 1) how large is the contribution of interaction between charged particles and 2) how to account for non-zero size of ion cores.

***Charged particles interaction*** has been a matter of discussion for many years. Plasmatic phase transitions were supposed to take place but experiments didn't discover them. As a matter of fact, we should take into account that in plasma there exists microscopic fluctuating electric field produced by chaotic thermal movement of charged particles Electric field has positive energy which compensates negative energy of particles interaction. Consequently, plasma remains ideal even at super-high densities.

***Ion core volumes.*** The volume of -manifold ion core can be expressed via potential of -manifold ionization. So we can introduce ion cores volumes into free energy functional . in order to do so, in classical functional one should replace atomic particle volume  with  where  is total volume of all ion cores ( is concentration of -manifold ions). Free electrons are supposed to not classical but partially degenerate.

***Calculations*** via the proposed model were carried out for multi-electron atom. The domain of applicability of the Saha model drastically extended. The model provides physically reasonable results even at super-high densities and low temperatures where plasma encounters transition to liquid state. Earlier, in this region Tomas-Fermi model with quantum and exchange corrections (TFC) was implied. Now thermodynamic functions according to Saha model have become quite close to the ones of the TFC model.

Ionization degree  and pressure  isoterms at  are examples of such coincidence.. While ion core volume  is larger than  – the neutral atom volume, the model provides , . For , non-zero  and  appear which monotonically increase as  decreases. Consequently, Saha model with non-zero size ions describes the phenomenon of cold compression ionization. Also, the  and  dependencies turn out to be close to corresponding curves of TFC model.

***“Gluing”***of Saha and TFC models was proposed in [2] in order to construct wide-range equation of state. The proposed enhancement of Saha model sufficiently increases the accuracy of this wide-range equation of state. Apart of that, the constructed equation of state is rigorously thermodynamically consistent, i.e. all thermodynamic functions satisfy all thermodynamic relations.

Consistency is a strong advantage of the proposed equation of state compared to well-known SESAME library (Los-Alamos): in the latter, thermodynamic relations are strongly violated at the stitching boundaries of different models.

References

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