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A self-consistent model of ionization potential depression of ions in hot and dense plasmas with local field correction

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We propose a consistent approach to determine the screening potential in dense plasmas with inhomogenous free electron micro-space distribution. Based on a local density and temperature-dependent ion-sphere model, the Saha equation approach is extended to the regime of strongly coupled plasmas by taking the free-electron-ion interaction, free-free-electron-interaction, inhomogenous free-electron micro-space distribution, and free-electron quantum partial degeneracy into account, in the free energy calculation. The ionization balance is determined by solving an extended Saha equation. All the quantities, including he bound orbitals with ionization potential depression, free-electron distribution, and bound and free-electron partition function contributions, are calculated self-consistently in the theoretical formalism. It has been shown that the ionization equilibrium is evidently modified by considering the above non-ideal characteristics of the free electrons [1]. To explicitly taking the exchange-correlation effect of free electrons into account, we incorporate the effective static approximation of local field correction (LFC) within our IPD framework through the connection of dynamical structure factor. The effective static approximation poses an accurate description for the asymptotic large wave number behavior with the recently developed machine learning representation of static LFC induced from the path-integral Monte Carlo data. Our calculation shows that the introduction of static LFC through dynamical structure factor brings a nontrivial influence on IPD at warm/hot dense matter conditions. The correlation effect within static LFC could provide up to 20% correction to free-electron contribution of IPD in the strong coupling and degeneracy regime. Furthermore, a new screening factor is obtained from the inhomogenous density distribution of free electrons calculated within the self-consistent model, with which excellent agreements are observed with other methods and experiments at warm/hot dense matter conditions[2].

References
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[2] Xiaolei Zan, Chengliang Lin, Yong Hou, and Jianmin Yuan, Local field correction to ionization potential depression of ions in warm or hot dense matter. Phys. Rev. E 104, 025203 (2021).

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