Pressure of Partially Ionized Non-degenerate Hydrogen Plasmas

Z. Mazhit*

after S. Toraigyrov Pavlodar State University, 140003 Pavlodar, Kazakhstan
z.mazhit@psu.kz

Physical parameters of plasma – ionization degree, pressure, an average distance between particles, etc. – are connected with its thermodynamic functions (chemical potential, free energy, etc.) [1, 2]. Dense plasmas and moderate density plasmas thermodynamic, transport et al. properties depend on collective effects, especially pair interactions of charged particles [1, 2]. In classical plasmas an interaction between charged particles obeys Coulomb's law at large distances. The Coulomb potential diverges at small distances between charged particles. At small distances the interaction between particles should be considered by taking into account quantum effects. That is at classical consideration of plasma one should suggest short-range repulsive forces influence. By including short-range repulsive forces at small distances between charged particles plasma medium is considered as quasiclassical system of particles. This allows one to avoid the difficulty with the Coulomb potential's divergence.

Quantum effects of diffraction cause weakening of charged particles interactions and decrease of plasmas ionization degree [3]. In practice of importance is to define pressure of quasiclassical plasmas. So the purpose of the article is a definition of pressure of partially ionized non-degenerate hydrogen plasma at thermal equilibrium by its ionization degree. The method of investigation is applying modified equation of the ionization equilibrium for non-ideal plasmas, obtained on the basis of Saha equations and F. Baimbetov approximation [4].

Modified equation of the ionization equilibrium for non-ideal plasmas is given by [4]

$$\frac{1-\alpha}{\alpha^2} = n\lambda_{Br}{}^3\sigma(T)\exp\left(-\frac{e^2\kappa_0\sqrt{\alpha}}{k_BT}G(\kappa_0\lambda_{ie}\sqrt{\alpha})\right).$$

In F. Baimbetov approximation excess pressure is given by [4]

$$\beta\cdot P_{ex} = n(1+\alpha) - \frac{1}{24\pi}(\kappa_0\sqrt{\alpha})^3\,\Phi(z),$$

variable "z" and its function $\Phi(z)$ are defined as follows

$$z = \sqrt{\pi\alpha}\,\kappa_0\lambda_{ie}/4,$$

$$\Phi(z) = \frac{3}{5\sqrt{1+2z}} - 4\left(\frac{1+z-0.5z^2-\sqrt{1+2z}}{5z^3\sqrt{1+2z}}\right).$$

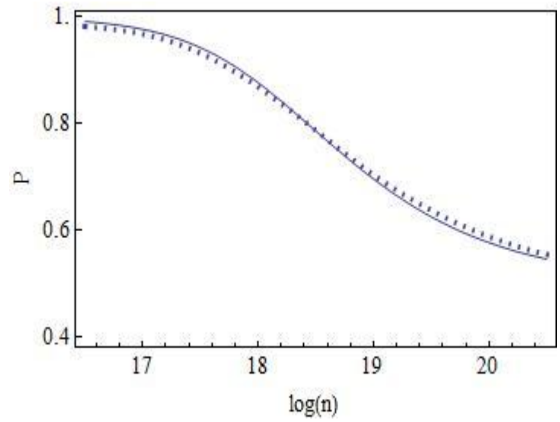

Figure 1. Relative pressure in F. Baimbetov approximation versus concentration, T=20000K: solid line – this work, dotted line– [2].

Pressure of quasiclassical hydrogen plasmas at different concentrations and T=20000K is shown on Figure 1. Also for comparison on Figure 1 the same dependence accomplished by other authors [4] is shown.

Non-degenerate hydrogen plasma model proposed is based on the Saha approach and includes non-ideality effects: quantum effects as well as the screening of charged particles. Ionization degree and pressure as functions of parameters of plasma are defined.

References

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