Thermodynamic properties of non-isothermal plasma of ICF

M.T. Gabdullin[1], T.S. Ramazanov[2], T.N. Ismagambetova*[2], Zh.A. Moldabekov[2], Zh.Y. Otarbay[2], M.B. Mamatova[2]

[1]NNLOT, al-Farabi Kazakh National University, Almaty, 050040, Kazakhstan
[2]IETP, al-Farabi Kazakh National University, Almaty, 050040, Kazakhstan
*Corresponding author: miriael@mail.ru

In this work dense non-ideal, non-isothermal plasma of ICF (inertial confinement fusion) was considered. Correct calculation of plasma properties requires taking into account parameters of plasma. For this purpose interaction potentials of particles were used. The electron-ion temperature in [1] was used in the form $T_{\alpha\beta}=\sqrt{T_\alpha T_\beta}$.

Effective screened interaction potentials taking into account the quantum-mechanical effect of diffraction were used [2-3]:

$$\Phi_{\alpha\beta}(r)=\frac{Z_\alpha Z_\beta e^2}{r}\frac{1}{\gamma^2\sqrt{1-\left(2k_D/\lambda_{ee}\gamma^2\right)^2}}\times$$
$$\times\left(\left(\frac{1/\lambda_{ee}^2-B^2}{1-B^2\lambda_{\alpha\beta}^2}\right)\exp(-Br)-\left(\frac{1/\lambda_{ee}^2-A^2}{1-A^2\lambda_{\alpha\beta}^2}\right)\exp(-Ar)\right)-$$
$$-\frac{Z_\alpha Z_\beta e^2}{r}\frac{(1-\delta_{\alpha\beta})}{1+C_{\alpha\beta}}\exp(-r/\lambda_{\alpha\beta}), \quad (1)$$

where $k_D^2=k_e^2+k_i^2$ is the screening parameter taking into account the contribution of electrons and ions, $\gamma^2=k_i^2+1/\lambda_{ee}^2$,

$$A^2=\frac{\gamma^2}{2}\left(1+\sqrt{1-\left(\frac{2k_D}{\lambda_{ee}\gamma^2}\right)^2}\right), B^2=\frac{\gamma^2}{2}\left(1-\sqrt{1-\left(\frac{2k_D}{\lambda_{ee}\gamma^2}\right)^2}\right),$$
$$C_{\alpha\beta}=\frac{k_D^2\lambda_{\alpha\beta}^2-k_i^2\lambda_{ee}^2}{\lambda_{ee}^2/\lambda_{\alpha\beta}^2-1}.$$

Pair correlation functions were obtained in the exponential approximation:

$$g_{\alpha\beta}(r)=\exp(-\frac{\Phi_{\alpha\beta}(r)}{k_B T}), \quad (2)$$

Composition of plasma was studied using the system of Saha equations:

$$\frac{n_0}{n_e n_i}=\frac{g_0}{g_e g_i}\exp\left(\frac{I-\Delta I}{k_B T}\right), \quad (3)$$

where gk is statistical weight, ΔI is the lowering of the ionization potential.

Thermodynamic properties were calculated on the basis of effective potentials (1): internal energy $U=\sum_\alpha 3/2N_\alpha k_B T_\alpha+U_N$, where the correlation energy of interaction is:

$$U_N=2\pi V\int_0^\infty\sum_{\alpha,\beta}n_\alpha n_\beta\varphi_{\alpha\beta}(r)g_{\alpha\beta}(r)r^2dr, \quad (4)$$

and the equation of state:

$$P=P_{id}-\frac{2\pi}{3}\int_0^\infty\sum_{\alpha,\beta}n_\alpha n_\beta\frac{\partial\varphi_{\alpha\beta}(r)}{\partial r}g_{\alpha\beta}(r)r^3dr, \quad (5)$$

where $P_{id}=n_e k_B T_e+n_i k_B T_i$ is the pressure of ideal plasma, N is the number of particles in the system.

The obtained thermodynamic properties were used for solving the Hugoniot equation [4].

The Hugoniot equation describes the connection between density and pressure of the gas in front of and behind the shock front. Parameters of gas change very rapidly and in a very narrow field with the passage through the shock wave.

References

[1] R. Bredow, Th. Bornath, W.-D. Kraeft, R.Redmer 2013 *Contrib. Plasma Phys.,* **53**, 276.
[2] T. S. Ramazanov, Zh. A. Moldabekov, and M. T. Gabdullin 2015 *Physical Review E,* **92**, 023104.
[3] T. S. Ramazanov, K.N. Dzhumagulova, Zh.A. Moldabekov 2014 *Phys. Sc. And Techn.,* **1(1)**, 47-53.
[4] P.R. Levashov, V.S. Filinov, M. Bonitz, V.E. Fortov 2006 *J. Phys. A: Math. Gen.*, **39**, 44474452.