Investigation of the electron capture process in semiclassical plasma

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Non-ideal dense plasma can contain the bound states even at high temperature. This is associated with decrease in the rate of the thermal ionization at pressure growing, up to very high densities corresponding to the Mott transition, after which the plasma becomes fully ionized due to the pressure ionization. Thus, in the high dense plasma a wide range of the elementary inelastic processes may occur, such as the ionization by the electron-impact or atomic-impact, the formation of the negative ions, the excitation of the bound states, etc.

One of the basic process that affects on the kinetics of ionization is the process of the electron capture by the atom (the formation of a negative ion). In work [1] the electron capture cross section was theoretically evaluated in the framework of the perturbation theory, in other words, unperturbed linear trajectory of the projectile was considered.

In this work the effective potential for electron – atom interaction considering effects of screening and diffraction and presented in work [2], was used. It has the following form:

$$\Phi_{ea}(r) = -\frac{\alpha e^2}{2r^4(1-4\lambda^2/r_D{}^2)}\left(e^{-Br}(1+Br)-e^{-Ar}(1+Ar)\right)^2 \quad (1)$$

here $A^2 = \frac{1}{2\lambda_{ea}^2}\left(1+\sqrt{1-4\lambda_{ea}^2/r_D^2}\right)$; $B^2 = \frac{1}{2\lambda_{ea}^2}\left(1-\sqrt{1-4\lambda_{ea}^2/r_D^2}\right)$, $\lambda_{ea} = \hbar\big/\sqrt{2\pi m_{ea}k_B T}$ is the de Broglie thermal wavelength; $m_{ea} = m_e m_a/(m_e+m_a) \approx m_e$ is the reduced mass of the atom and electron pair, α is the polarizability of the atom. For hydrogen atom it equals $4.5a_B^3$ ($a_B = \hbar^2/m_e e^2$ is the Bohr radius). Potential (1) is screened and also has finite values at the distances close to zero.

For comparison all calculations were done for the polarization potential of the electron-atom interaction, which does not take into account the screening and diffraction effects:

$$\Phi_{ea}(r) = -\frac{\alpha e^2}{2r^4} \quad (2)$$

The following dimensionless parameter were used: $\Gamma = e^2/(a\,k_B T)$ is the coupling parameter (the average distance between particles is $a = (3/4\pi n)^{1/3}$, $n = n_e + n_i$ is the numerical density of electrons and ions; T is the plasma temperature; k_B is the Boltzmann's constant) and $r_s = a/a_B$ is the density parameter).

Thus, the capture radius R_c was calculated. It can be determined by the following relation:

$$\Phi(R_c) \cong \frac{1}{2}m_e V_0^2 \quad (3)$$

The time of the capture was determined as the time, when electron moves within capture radius. The cross section of the electron capture was estimated on the basis of the capture time. The conclusion that taking into account of the screening and diffraction effects decreases the probability of the electron capture by atom was made.

References

[1] Dae-Han Ki and Young-Dae Jung. The Journal of Chemical Physics. **137** (2012) 094310.
[2] T.S. Ramazanov, K.N. Dzhumagulova, Y.A. Omarbakiyeva. J. Phys. A: Math. Gen. **39** (2006) 4369.