Phase shifts and cross sections of electron-atom scattering in the dense semiclassical plasma

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Collisional characteristics of the electron-atom scattering in the dense semiclassical plasma were calculated within the dynamic model of interaction. This model takes into account the quantum mechanical diffraction effect and dynamic screening which depends on the velocity of the colliding particles. On the basis of the Calogero equation the phase functions and the phase shifts were calculated. Phase shifts and cross sections obtained on the basis of the dynamic potential are larger than those obtained on the basis of the static model and converge with them at small values of the kinetic energy of colliding particles.

1. Dynamic interaction potential of electron and atom in the dense semiclassical plasma

Development of the interaction models of the semiclassical plasma particles and research on their basis of the collisional, transport properties represent a great fundamental and practical interest (see, for example, Refs. [1-6]). It is important for development of the technologies of the many practical applications connected with non-ideal plasma, for example, thermonuclear fusion with the laser compression and others.

In works [2,3] for electron – atom interaction the effective potential considering both effects of screening and diffraction was presented:

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

where

$$A^2 = \frac{1}{2\lambda_{ea}^2}\left(1+\sqrt{1-4\lambda_{ea}^2/r_D^2}\right),$$

$$B^2 = \frac{1}{2\lambda_{ea}^2}\left(1-\sqrt{1-4\lambda_{ea}^2/r_D^2}\right).$$

$\lambda_{ea} = \hbar\big/\sqrt{2\pi\mu_{ea}k_BT} \approx \lambda_e$ is the de Broglie thermal wavelength; $\mu_{ea} = m_e m_a/(m_e+m_a)$ is the reduced mass of electron and atom.

Potential (1) is screened and also has finite values at the distances close to zero. It is necessary to note that traditionally the screening of the electric field in plasma is represented by the static Debye – Huckel screening. This approach is valid, if the velocities of the colliding particles are near to the thermal velocity. Screening, depending on the velocity of the colliding particles, was called as the dynamic screening and now is often used in research of the non-ideal plasma properties. In works [4-6] the way of accounting of the dynamic screening was described. It is reduced to the replacement of the static Debye length by some effective one that is connected with the dynamic screening:

$$r_0 = r_D\left(1+\frac{v^2}{v_{Th}^2}\right)^{1/2} \quad (2)$$

Here v is the relative velocity of the colliding particles, v_{Th} is the thermal velocity. Then the pseudo-potential (1) for electron-atom interaction, which takes into account the dynamic screening, in a dimensionless form is:

$$\Phi_{ea}^{dyn}(r) = -\frac{e^2\alpha}{2r^4(1-4\lambda_{ea}^2/r_o^2)}\left(e^{-Br}(1+Br)-e^{-Ar}(1+Ar)\right)^2 \quad (3)$$

$$A^2 = \frac{1}{2\lambda_{ea}^2}\left(1+\sqrt{1-4\lambda_{ea}^2/r_o^2}\right),$$

$$B^2 = \frac{1}{2\lambda_{ea}^2}\left(1-\sqrt{1-4\lambda_{ea}^2/r_o^2}\right).$$

$$\delta = v/v_{Th}$$

In this work the following dimensionless parameters were used: $\Gamma = Z_\alpha Z_\beta e^2/(a\,k_BT)$ 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 the electrons and ions; T is the plasma temperature; k_B is the Boltzmann constant); $r_s = a/a_B$ is the density parameter ($a_B = \hbar^2/m_e e^2$ is the Bohr radius).

2. Phase shifts and scattering cross sections

The basic equation of the phase functions method is called as the Calogero equation and has the form:

$$\frac{d\delta_l(k,r)}{dr} = -\frac{1}{k}U(r)\times \left[\cos\delta_l(k,r)\cdot J_l(kr) - \sin\delta_l(k,r)\cdot n_l(kr)\right]^2, \quad (4)$$

$$\delta_l(k,0) = 0 \ .$$

Here k is the magnitude of the wave vector of the incident particle, $U(r) = \frac{2m}{\hbar^2}\Phi(r)$, $j_l(kr)$ and $n_l(kr)$ are the Ricatti - Bessel functions.

The phase shifts can be found as the asymptotic values of the phase functions:

$$\delta_l(k) = \lim_{r\to\infty}\delta_l(k,r) \,. \quad (5)$$

Total cross section can be evaluated by the phase shifts:

$$Q^{\Pi}(k) = \frac{4\pi}{k^2}\sum_l (2l+1)\sin^2\delta_l(k) \quad . \quad (6)$$

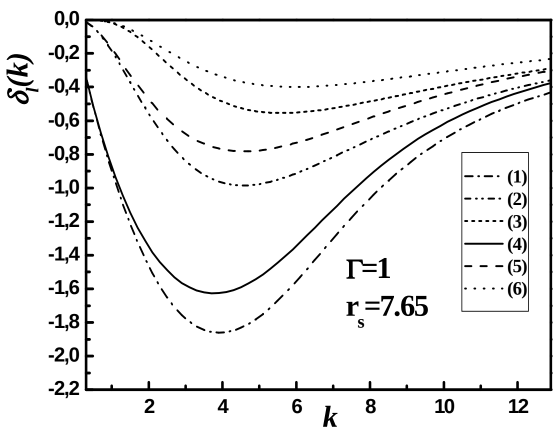

Figure 1 – Electron phase shifts at $\Gamma = 1$, $r_s = 7.65$ on the basis of the potential (3): 1) l=0; 2) l=1; 3)l=2; on the basis of the potential (1): 4) l=0; 5) l=1; 6) l=2

Phase shifts are presented on Figure 1. Figure 2 shows the partial and total cross sections for electron scattering by an atom. Magnitudes of the phase shifts and cross sections for electron-atom scattering are larger in case of the model with dynamic screening as for electron-electron scattering [6].

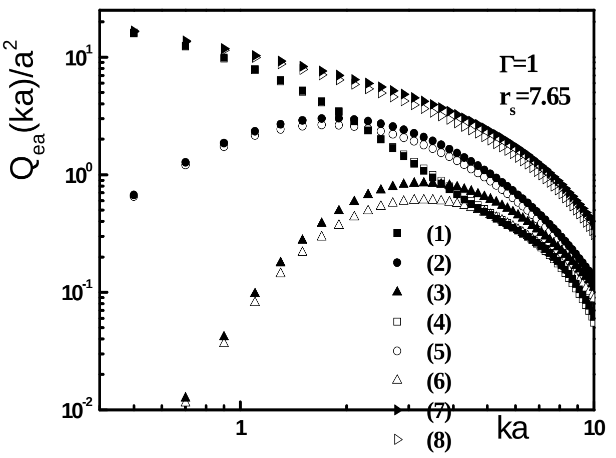

Figure 2 – Partial and total cross sections of electron scattering by atom on the basis of the potential (3): 1) $\ell = 0$; 2) $\ell = 1$; 3) $\ell = 2$; 7) total cross section, on the basis of the potential (1): 4) $\ell = 0$; 5) $\ell = 1$; 6) $\ell = 2$; 8) total cross section

3. References

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