Transport coefficients of Dense Helium Plasmas

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In this work transport properties of dense helium plasmas are considered. Transport properties are obtained on the basis of Coulomb logarithm using the effective potentials for ICF plasma. The Coulomb logarithm based on the effective interaction potential of particles is determined by the scattering angle of pair Coulomb collisions. Therefore, in this work we present the results of calculations of the viscosity, diffusion, thermal conductivity, and electrical conductivity of helium plasma at high temperatures.

The study of a dense plasma with helium ions and atoms is a great importance for the inertial confinement fusion (ICF) and astrophysics [1–2]. Experimental investigations of helium under extreme conditions include shock compression and laser heating [3].

Accurate values of the transport coefficients of high temperature dense plasmas are necessary input data for the reliable numerical simulation of thermal plasmas. Therefore, in this work we present the results of calculations of the viscosity, diffusion, thermal conductivity, and electrical conductivity of helium plasma at high temperatures.

Transport properties are studied on the basis of screened pair interaction potentials using the Coulomb logarithm [4-5]. In the case of a singly-ionized helium, the pair interaction potential between an atom and a proton during the elastic collision is considered as a sum of attractive and repulsive terms [6-7]. The effective potential is derived using the long wavelength expansion of the polarization function and quantum potential which takes into account the finite value of the interaction potential at close distance. Further, this pair potential was used for the calculation of the Coulomb logarithm. To show the correctness of the model, its results are compared with the results of QMD and OFMD simulations [8].

The Coulomb logarithm is determined by the center of mass scattering angle θ_c [4-5]:

$$\lambda_{\alpha\beta} = \frac{1}{b_\perp^2}\int_0^{b_{\max}} \sin^2\left(\frac{\theta_c}{2}\right) b\,db, \qquad (1)$$

$$\theta_c = \pi - 2b\int_{r^0}^{\infty} \frac{dr}{r^2}\left(1 - \frac{\Phi_{\alpha\beta}(r)}{E_c} - \frac{b^2}{r^2}\right)^{-1/2}, \qquad (2)$$

where $E_c = \frac{1}{2} m_{\alpha\beta}\upsilon^2$ is the energy of the center of mass, $m_{\alpha\beta} = m_\alpha m_\beta / (m_\alpha + m_\beta)$ is the reduced mass of the particles of kinds α and β (electron and ion); $b_\perp = Z_\alpha Z_\beta e^2 / (m_{\alpha\beta}\upsilon^2)$, $b_{\min} = \max\{b_\perp, \lambda_{\alpha\beta}\}$ describes the minimum impact parameter, where is $\lambda_{\alpha\beta} = \hbar / \sqrt{2\pi m_{\alpha\beta} k_B T}$ is the thermal de Broglie wavelength.

In Figs. 1 the results for thermal conductivity of the dense helium plasmas as a function of temperature are presented.

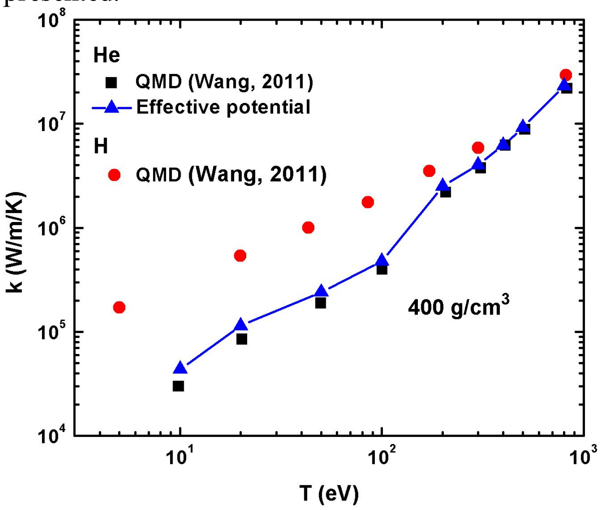

Fig. 1. Thermal conductivity for helium plasma as a function of temperature.

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