Collisional properties of particles in the dense neon plasma

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Introduction. In the evolution and dynamics of planets and stars, when they are in a condensed state, the properties of inert gases under conditions of extreme temperature and density are of the utmost importance. It is crucial to know the exact data on transport coefficients, equations of state, as well as the macroscopic and microscopic physical properties of their constituent materials in the regime of warm dense matter (WDM). To study the equations of state and transport properties of highly compressed materials, high-pressure methods have been developed and applied, one of which is pulsed energy [1-2]. It should be noted that for the science of high-density energy and inertial confinement [3], a setup based on pulsed energy provides a versatile experimental platform. Various experiments have been conducted to measure the electrical conductivity of warm dense neon (Ne) plasma [4-5] and xenon plasma [6-7]. However, due to the complexity of diagnostic equipment in extreme conditions, there are some discrepancies in these measurements of electrical conductivity. Linear Response Theory (LRT) [7] and Linear Mixing Rules (LMR) [8] provide important reference information for experimental design and optimization of WDM production and diagnostic methods to investigate the electrical conductivity of materials under high pressure. However, for LRT and LMR, theoretical predictions of WDM electrical conductivity require knowledge of plasma components, free electron density, and relevant scattering cross-sections; however, it is difficult to calculate the free electron density, as there is still no strict criterion for separating electrons into free and bound states [9].

Theory and methods. In this work, an effective optical potential was constructed, taking into account the quantum nonlocality of the field [10] and exchange-correlation effects [10], as well as the screening effect [11-17] (since it is well known that in dense degenerate plasma, the quantum nonlocality of the field and electron exchange-correlation effects (quantum degeneracy effect) can affect particle interactions):

$$V_{opt}^{SD}(r) = V_{HF}^{SD}(r) + V_{P}^{SD}(r) + V_{EX}^{SD}(r).$$

The phase function method [6, 18-19] for dense non-ideal plasma is used to study the collisional properties of plasma based on the asymptotic value of the phase function at large distances. It is based on solving the Calogero equation, which describes the behaviour of the correlation function in dense plasma.

Differential scattering cross sections, used to calculate angular scattering, are determined using phase shifts. Thus, the differential scattering cross section was calculated by the following formula [20]:

$$DCS(k,\theta) = \left|\frac{1}{k}\sum_{l=0}^{\infty}(2l+1)P_l(\cos\theta)\, e^{i\delta_l(k)}\, \sin\delta_l\,(k)\right|^2.$$

Results. In Figure 1, the effective optical potential dependence on the interparticle distance is shown, considering and without considering electronic non-ideality (γ_{EC}) at a fixed density parameter ($r_s = 3$), for different values of the degeneracy parameter (θ), considering the quantum nonlocality parameter of the field ($\lambda \neq 0$) (represented by red curves) and without considering ($\lambda = 0$) (black lines).

Figure 1. The effective optical potential of electron interaction with neon atoms, without considering (a) and considering (b) electronic non-ideality (γ_{EC}) at a fixed density parameter ($r_s = 3$), for different values of the degeneracy parameter (θ)

It is seen in Figure 1 the effect of the quantum nonlocality of the field significantly influences the potentials that are part of the optical potential at small distances. It is also noticeable that the exchange potential (V_{EX}^{SD}) is an order of magnitude weaker than the Hartree-Fock potential (V_{HF}^{SD}) and the polarization potential (V_P^{SD}). The overall result is that the optical potential (V_{opt}^{SD}) decreases (in absolute value) with an increase in the plasma degeneracy parameter (θ). In Figure 2 the scattering phase shifts of electrons on a neon atom based on the effective optical potential at a fixed density parameter ($r_s = 2$) and a degeneracy parameter ($\theta = 0.6$) are presented for two cases , when $\lambda = 0, \gamma_{EC} = 0$ and $\lambda \neq 0, \gamma_{EC} \neq 0$