Ionization and recombination coefficients of the dense nonideal hydrogen plasma: effects of screening and quantum diffraction

E O Shalenov[1,2]*, M M Seisembaeva[1], M N Jumagulov[1] and K N Dzhumagulova[1,2]

[1]Institute of Experimental and Theoretical Physics, al-Farabi Kazakh National University, Almaty, 050040, Kazakhstan
[2]Department of Physics, Nazarbayev University, Nur-Sultan, 010000, Kazakhstan

Synopsis Problems connected with the investigation of the excitation cross section of electron levels of atoms and atom ionization by electron impact were solved by finding phase shifts based on the solution of the Calogero equation. The results of the investigation of these elementary processes (their cross sections) were used to calculate the kinetic coefficients of ionization and recombination. Based on the effective interaction potential of particles of a nonideal semiclassical plasma, elementary processes are studied: electron capture, ion excitation and ionization.

To solve the actual problem of realizing thermonuclear controlled fusion (TCF) with inertial confinement, as well as to study the processes taking place in astrophysical objects (white dwarfs, the Sun, the bowels of giant planets, etc.), reliable data on the physical characteristics of a nonideal semiclassical plasma arising on Earth and in the Cosmos in many processes associated with the heating and compression of matter are needed. A nonideal dense plasma is observed, for example, when the target substance is compressed by a high-power laser radiation in nuclear fusion, in nuclear explosions, at supersonic motion of bodies in dense layers of planetary atmospheres, at impact of high-intensity energy fluxes on the surface of various materials.

The Saha equation allows us to determine the number of particles of different types per unit volume for the case when the plasma is in a state of thermodynamic equilibrium. In the general case, the composition of the plasma is determined on the basis of the so-called ionization kinetics equations. These equations describe the rate of change in the number of particles (growth or decrease) in a certain state (free, bound, etc.), due to various reactions.

In the work, we used the original potential for interaction between an electron and an atom that we developed earlier in [1–5]. This effective potential takes into account the quantum mechanical effect of diffraction at small distances, because of which it has a finite value at distances close to zero.

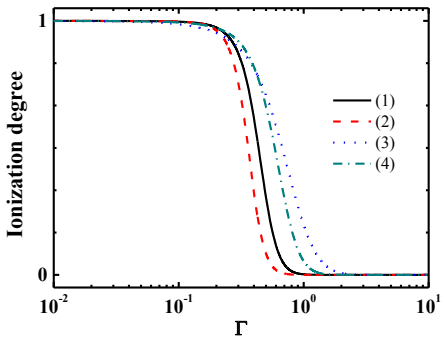

Figure 1. Dependence of the degree of ionization of a hydrogen plasma on the coupling parameter for various values of the density parameter. Solution of the kinetic equation of ionization 1) $r_s = 10$; 2) $r_s = 5$; solution of the Saha equation 3) $r_s = 10$; 4) $r_s = 5$.

The calculated dependences of the ionization degree on the coupling parameter for different values of the density parameter are shown in figure 1.

References

[1] Shalenov E O *et al* 2018 *Phys. Plasmas.* **25** 082706
[2] Shalenov E O *et al* 2019 *Contrib. Plasma Physics.* **59** e201900024
[3] Shalenov E O *et al* 2019 *J. Phys.: Conf. Ser.* **1400** 077035
[4] Shalenov E O *et al* 2019 *J. Phys.: Conf. Ser.* **1385** 012031
[5] Jumagulov M N *et al* 2020 *High Energy Density Physics.* **36** 100832

* E-mail: shalenov.erik@physics.kz