STUDY OF THE STRUCTURE OF ATOMICS BY THE METHOD OF ELECTRON SCATTERING IN THE DISORTED-WAVE APPROXIMATION: ATOMIC ENERGY

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Abstract

The differential cross section of elastic scattering of electrons on atoms, obtained in the distorted-wave approximation, is calculated accordingly on the proposed mathematical method. The electron density distribution in the atom is chosen as a function calculated in the Dirac-Hartree-Fock-Slater approximation, which is a superposition of the spherically symmetric Yukawa potential. The differential cross sections for electron scattering by $_{49}In$, $_{31}Ga$, $_{34}Se$ and $_{70}Yb$ atoms were calculated at incident energy of 80 eV. In addition, the differential cross sections were calculated for the electron density in the $_{49}In$ and $_{20}Ca$ atoms expressed as a three-parameter Fermi function at incident electron energy of 100 eV. The obtained theoretical calculations of the cross sections were compared with the experimental data. Besides, the proposed mathematical method simplifies the calculation of integral expressions and makes it possible to obtain a convenient and simple expression for the atomic form factor. Data on the scattering cross sections of electrons on atoms are of considerable interest both in the field of fundamental science for in-depth study of interaction processes and in practical applications, and are necessary in many areas of research, such as modeling low-temperature plasma, astrophysics phenomena, laser physics, and atmospheric effects. etc. In addition to natural phenomena, the processes of collision of electrons with matter play an essential role in plasma technologies, such as, for example, microelectronics and biomedicine. Atomic physics, plasma physics and optics - fields directly related to electron-atom make a significant contribution to the fundamental understanding of the world. Despite the long study of the effects of electron scattering on atoms, and the results obtained in the physics of atomic collisions, this area still requires theoretical and experimental research, there is a significant lack of data on collision cross sections for their subsequent use in modeling and calculations. In particular, there are no systematized data on the cross sections for elastic scattering of high energy electrons by atomic.

Keywords. e (e, A) scattering; differential section; distribution density; spatial structure of the target atom.

Results

To calculate the differential cross section for elastic scattering of electrons by atoms, theoretical calculations should begin with the calculation of the plane-wave Born form factor (37). In this case, we need to choose the distribution function of the electron density in atoms. To this end, for the distribution function, we choose the well-known expression [7], in which, using the property of the electrostatic potential of an individual atom, calculated in the Dirac-Hartree-Fock-Slater approximation, the superposition of the spherical symmetric Yukawa potential:

$$\rho_0(x) = \frac{1}{4\pi}\sum_{\mu=1}^{3} A_\mu \alpha_\mu^2 \frac{e^{-\alpha_\mu x}}{x} \qquad (1)$$

For the Born form factor we obtain the following expression:

$$F_{\mathrm{B}}(q) = \frac{2i}{4\pi}\sum_{\mu=1}^{3} \frac{A_\mu \alpha_\mu^2}{q^2 + \alpha_\mu^2}\{qR - [qRcos(qR) + (\alpha_\mu R)\sin(qR)]e^{\alpha_\mu R}\} \qquad (2)$$

Results

The final expression for the atom form factor (1) takes the form:

$$F(q) = -2\pi(qR)\sum_{n=0}^{2}\beta_n\left[F_{\rm B}^{(n)}(q) - iF_{\rm B}^{(n)}(q)\right]. \qquad (3)$$

Here $F_{\rm B}^{(n)}(q) = \frac{\partial^n F_{\rm B}(q)}{\partial q^n}$.

To compare theoretical calculations with experimental data, we write the differential cross section for electron scattering on atoms in the following form:

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{Mott}\left|F_{\rm Re}(q)\right|^2 + \left|F_{\rm Im}(q)\right|^2$$

The results of theoretical calculations compared with experimental data for In, Ga, Se, and Yb atoms at energies of 80 eV are shown in Fig.1.

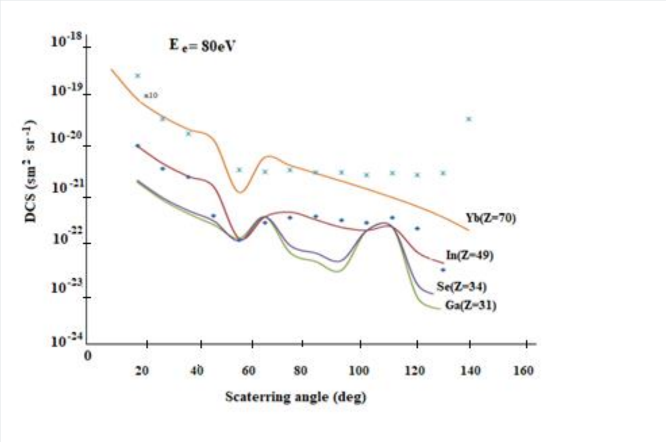

Figure 1. The differential cross sections (DCS) for electron scattering by $_{49}$In, $_{31}$Ga, $_{34}$Se, and $_{70}$Yb atoms.

Results

In addition, we calculated the differential cross section for scattering of electrons with an incident energy of 100 eV on $_{49}$In (*a*) and $_{20}$Ca (*b*) atoms . In this case, the three-parameter Fermi function was chosen for the distribution of the electron density in atoms:

$$\rho_e(x) = \rho_0(\omega_0 + \omega\frac{x^2}{R^2})(1+\exp(\frac{x-R}{d}))^{-1} \quad (4)$$

and for born form factor the following expression:

$$F_B(q) = -4\frac{\pi d}{R}\cdot e^{-\pi dq}\left\{[\omega_0 + \omega(1-3\pi(\frac{d}{R})^2)]\sin(qR-\frac{\pi d}{R}) + \left[\frac{\pi d}{R}(\omega_0 + \omega(3-(\frac{\pi d}{R})^2))\right]\cos(qR-\frac{\pi d}{R})\right\} \quad (5)$$

The results of theoretical calculations compared with experimental data for scattering of electrons with an incident energy of 100 eV on $_{49}$In (*a*) and $_{20}$Ca (*b*) atoms are shown in Fig.2.

As can be seen from the figures, in the case of calculating the differential cross section using the Fermi function, the results of theoretical calculations are more consistent with experiment.

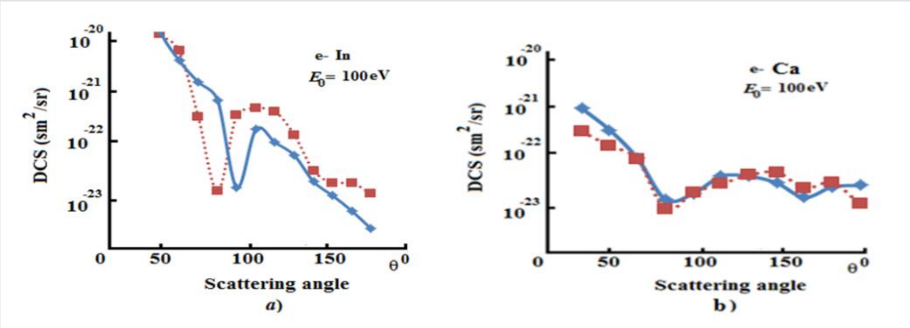

Figure 2. Differential cross section (DCS) of elastic scattering of electrons from $_{49}$In (*a*) and $_{20}$Ca (*b*) atomics.