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EXCITATION OF POLARIZED ATOMS BY FAST ELECTRONS

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The general expression for excitation cross-section of polarized atoms by fast electrons is derived by using the methods of the theory of an atom adapted for polarization in the plane wave Born approximation. In describing the alignment of excited atoms, the special cases of the general expression are obtained for both the polarized and non-polarized atoms and for the magnetic dichroism of the total ionization cross-section of polarized atoms.

Keywords: excitation of atoms by electron impact, polarization, angular distribution

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1. Introduction

For the simulation of the radiation spectrum from plasma, the electron impact excitation cross-sections are necessary. The electron impact-excited radiation for high temperature plasma diagnostics was implemented in the Joint European Torus, a fusion research device of tokamak design [1, 2]. Here the spectrum in the vicinity of deuterium Balmer α line (656 nm) was used. This radiation was excited following the charge exchange reaction between a neutral beam of deuterium atoms and the deuterium nuclei in bulk plasma. However, the emission of radiation can also be excited by the collisions with fast electrons from the bulk plasma that have energy exceeding 100 keV [1, 2]. For such high energies the plane wave Born (PWB) approximation usually allows one to obtain the values of the cross-section with sufficient accuracy. In tokamak, the population of the magnetic sublevels of atoms and ions should be taken into account because of the presence of external magnetic and the Lorentz electric fields. Therefore, the cross-sections and other parameters describing the transitions between sublevels are of importance. The non-equilibrium population of magnetic sublevels or the ordering of angular momentum of the excited atoms, otherwise called the self-alignment, arises in the collision processes because of the oriented flow of neutral atoms injected also for diagnostics purposes. For a theoretical modelling of this process, the expressions for the cross-section that take into account the polarization of the states of an atom both in the initial and final states is needed.

In the present work, the general expression for the electron impact excitation of polarized atoms is derived with the help of the method used in the theory of an atom [3–5]. This method was successfully applied for the investigation of polarization phenomenon in the photoionization [4, 5], photoexcitation [6], ionization of atoms by electrons [7], radiative [8] and Auger [9] decay, as well as photo- and dielectronic recombination [10, 11]. In this method, the probability or cross-section of the interaction is expressed as the multiple expansion over the multipoles (irreducible tensors) of both the initial and final states of all the particles taking part in the process. The applied approach in this case is an alternative to the density matrix method [12] where the density matrix elements are expressed via multipoles or statistical tensors. The density matrix formalism was used for the study of some special cases of the polarization of the particles occurring in the excitation process [13].

The main task of the present work is the derivation of a general expression describing the excitation of polarized atoms by non-polarized electrons in PWB approximation by using the method based on the theory of an atom [3]. The next section is devoted to the obtaining of a general expression. Its special cases are presented in Section 3. The atomic system of units is used.

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2. General expression

In the case of the energy of projectile electron being much larger than the excitation energy of an atom, the PWB approximation can be used for the evaluation of the electron impact excitation cross-section of an atom. Usually the spin polarization states of the projectile and scattered electrons are not defined in the process

$$A(\alpha_0 J_0 M_0) + e^-(\mathbf{p}_1) \to A(\alpha_1 J_1 M_1) + e^-(\mathbf{p}_2)\,, \quad (1)$$

where α_i indicates the configuration and other quantum numbers, J_i is the total angular momentum, and M_i is its projection onto a chosen direction for the atom. Here i is equal to 0 and 1 for the initial and final states, respectively. In (1), $\mathbf{p}_1$ and $\mathbf{p}_2$ are the momenta of a free electron in the initial and final states, respectively.

The excitation cross-section equals the probability when the wave function of the projectile electron is normalized to the unity flow [14],

$$\phi_{\mathbf{k}_1}(\mathbf{r}_e) = \frac{1}{\sqrt{k_1}} \mathrm{e}^{\mathrm{i}\mathbf{k}_1\mathbf{r}_e}\,, \quad (2)$$

and that of the scattered electron is normalized to $\delta(\mathbf{k}_2 - \mathbf{k}_2')$,

$$\phi_{\mathbf{k}_2}(\mathbf{r}_e) = (2\pi)^{-3/2}\, \mathrm{e}^{\mathrm{i}\mathbf{k}_2\mathbf{r}_e}\,, \quad (3)$$

where $\mathbf{k}_i = \mathbf{p}_i/\hbar$ and $k_i = |\mathbf{k}_i|$. Then the expression for the cross-section can be written as follows [14]:

$$\frac{\mathrm{d}\sigma(\alpha_0 J_0 M_0 \mathbf{p}_1 \to \alpha_1 J_1 M_1 \mathbf{p}_2)}{\mathrm{d}\Omega_2} =$$

$$\frac{k_2}{(2\pi)^2 k_1} \langle \alpha_1 J_1 M_1 \mathbf{p}_2 | H | \alpha_0 J_0 M_0 \mathbf{p}_1 \rangle$$

$$\times \langle \alpha_1 J_1 M_1 \mathbf{p}_2 | H | \alpha_0 J_0 M_0 \mathbf{p}_1 \rangle^* \delta(E_0 - E_1)\,, \quad (4)$$

where the operator of the electrostatic interaction between the projectile and atomic electrons is

$$H = \sum_{j=1}^{N} \frac{1}{|\mathbf{r}_j - \mathbf{r}_e|} - \frac{Z}{\mathbf{r}_e}\,. \quad (5)$$

Here Z is the nuclear charge of an atom, N is the number of electrons, $\mathbf{r}_e$ and $\mathbf{r}_j$ are the coordinates of the projectile and atomic electrons, respectively, E_0 and E_1 are the energies of the system 'atom+electron' in the initial and final states, respectively.

Let us assume that the basis of the radial wave functions of an atom is orthogonal. Then the second term of the Hamiltonian (5) does not contribute. The insertion of (2), (3), and (5) into a matrix element from (4) leads to the expression

$$\langle \alpha_1 J_1 M_1 \mathrm{e}^{-\mathrm{i}\mathbf{k}_2\mathbf{r}_e} | H | \alpha_0 J_0 M_0 \mathrm{e}^{\mathrm{i}\mathbf{k}_1\mathbf{r}_e} \rangle =$$

$$\left\langle \alpha_1 J_1 M_1 \left| \sum_j \int d\mathbf{r}_e\, \mathrm{e}^{\mathrm{i}\mathbf{q}\mathbf{r}_e} \frac{1}{|\mathbf{r}_j - \mathbf{r}_e|} \right| \alpha_0 J_0 M_0 \right\rangle =$$

$$\frac{4\pi}{q^2} \left\langle \alpha_1 J_1 M_1 \left| \sum_j \mathrm{e}^{\mathrm{i}\mathbf{q}\mathbf{r}_j} \right| \alpha_0 J_0 M_0 \right\rangle, \quad (6)$$

where $\mathbf{q} = \mathbf{k}_1 - \mathbf{k}_2$ is the transferred momentum. The integral in (6) was integrated with the help of the formula

$$\int \mathrm{d}\mathbf{r}_e\, \mathrm{e}^{\mathrm{i}\mathbf{q}\mathbf{r}_e} \frac{1}{|\mathbf{r}_k - \mathbf{r}_e|} = \frac{4\pi}{q^2}\, \mathrm{e}^{\mathrm{i}\mathbf{q}\mathbf{r}_k}\,. \quad (7)$$

For the exponent in (6), the following expansion can be used:

$$\mathrm{e}^{\mathrm{i}\mathbf{q}\mathbf{r}} = 4\pi \sum_{t=0}^{\infty} \mathrm{i}^t j_t(qr) \sum_{p=-t}^{t} Y_{tp}^*(\hat{q})\, Y_{tp}(\hat{r}) =$$

$$\sum_{t=0}^{\infty} \sqrt{(2t+1)} \sum_{p=-t}^{t} Q_p^{(t)}(q\mathbf{r})\, D_{p0}^t(\hat{q})\,, \quad (8)$$

where $j_t(qr)$ is the spherical Bessel function [15], $Y_{tp}(\hat{q})$ is the spherical function [16], and the tensor operator $Q_p^{(t)}$ is defined as

$$Q_p^{(t)}(q\mathbf{r}) = \mathrm{i}^t\, j_t(qr)\, C_p^{(t)}(\hat{r})\, \sqrt{2t+1}\,. \quad (9)$$

Here $C_p^{(t)}$ is the operator of the spherical function [17].

The insertion of (8) into (6) and assumption that the projections of the angular momenta $\mathbf{J}_0$ and $\mathbf{J}_1$ and the rank $\mathbf{t}$ are all defined with respect to different axes lets us to write down the final expression for the matrix element (6):

$$\langle \alpha_1 J_1 M_1 | H(\mathbf{q}) | \alpha_0 J_0 M_0 \rangle = \frac{4\pi}{q^2} \sum_{t, \tilde{M}_0, \tilde{M}_1, p} \sqrt{2t+1}$$

$$\times \langle \alpha_1 J_1 \tilde{M}_1 | Q_p^{(t)}(q\mathbf{r}) | \alpha_0 J_0 \tilde{M}_0 \rangle$$

$$\times D_{\tilde{M}_0 M_0}^{J_0}(\hat{J}_0)\, D_{\tilde{M}_1 M_1}^{*J_1}(\hat{J}_1)\, D_{p0}^t(\hat{q})\,. \quad (10)$$

Here the transformation [16]

$$|j\tilde{m}\rangle = \sum_m D_{m\tilde{m}}^j(\alpha, \beta, \gamma)\, |jm\rangle \quad (11)$$

is used, and the hats on J_0, J_1, and t indicate the polar and azimutal angles in laboratory frame.

The expression for the cross-section (4) is obtained by inserting the matrix element (10) into (3):

$$\frac{\mathrm{d}\sigma(\alpha_0 J_0 M_0 \to \alpha_1 J_1 M_1 \mathbf{q})}{\mathrm{d}\Omega_q} =$$

$$\frac{4k_2}{k_1 q^4} \sum_{t,t',\tilde{M}_0,\tilde{M}_0',\tilde{M}_1,\tilde{M}_1',p,p'} \sqrt{(2t+1)(2t'+1)}$$

$$\times \langle \alpha_1 J_1 \tilde{M}_1 | Q_p^{(t)} | \alpha_0 J_0 \tilde{M}_0 \rangle \langle \alpha_1 J_1 \tilde{M}_1' | Q_{p'}^{(t')} | \alpha_0 J_0 \tilde{M}_0' \rangle^*$$

$$\times D^{J_0}_{\tilde{M}_0,M_0}(\hat{J}_0)\ D^{*J_1}_{\tilde{M}_1,M_1}(\hat{J}_1)\ D^{t}_{p,0}(\hat{q})\ D^{*J_0}_{\tilde{M}_0',M_0}(\hat{J}_0)$$

$$\times D^{J_1}_{\tilde{M}_1',M_1}(\hat{J}_1)\ D^{*t'}_{p',0}(\hat{q})\,. \qquad (12)$$

The angular part of the expression (12) coincides with that of the cross-section of the excitation of atoms by photons [6]. Therefore, the same angular momentum diagrams can be used for integration over the angular part of the expression (12). Then the expression for the electron impact excitation cross-section can be written as follows:

$$\frac{\mathrm{d}\sigma(\alpha_0 J_0 M_0 \to \alpha_1 J_1 M_1 \mathbf{q})}{\mathrm{d}\Omega_q} = \frac{4k_2}{k_1 q^4}$$

$$\times \sum_{K_0,K_1,K_t} \frac{1}{\sqrt{2K_1+1}}\, \mathcal{B}^{\mathrm{exB}}(K_0,K_t,K_1)$$

$$\times \sum_{N_0,N_1,N_t} \begin{bmatrix} K_0 & K_t & K_1 \\ N_0 & N_t & N_1 \end{bmatrix} T^{*K_0}_{N_0}(J_0,J_0,M_0|\hat{J}_0)$$

$$\times T^{K_1}_{N_1}(J_1,J_1,M_1|\hat{J}_1)\,\sqrt{4\pi}\,Y^*_{K_tN_t}(\hat{q})\,, \qquad (13)$$

$$\mathcal{B}^{\mathrm{exB}}(K_0,K_t,K_1) =$$

$$\times \sum_{t,t'} [(2J_0+1)(2J_1+1)(2t+1)(2t'+1)]^{1/2}$$

$$\times (-1)^{t'} \begin{bmatrix} t & t' & K_t \\ 0 & 0 & 0 \end{bmatrix} \begin{Bmatrix} J_0 & K_0 & J_0 \\ t & K_t & t' \\ J_1 & K_1 & J_1 \end{Bmatrix} \qquad (14)$$

$$\times\, (\alpha_1 J_1 || Q^{(t)}(q) || \alpha_0 J_0)\, (\alpha_1 J_1 || Q^{(t')}(q) || \alpha_0 J_0)^*\,.$$

Here the braces and square brackets stand for the $9j$ and Clebsch–Gordan coefficients, respectively, [17], and the relation

$$(\alpha_1 J_1 || Q^{(t)}(q) || \alpha_0 J_0) =$$

$$[2J_1+1]^{1/2}\,\langle \alpha_1 J_1 || Q^{(t)}(q) || \alpha_0 J_0 \rangle \qquad (15)$$

is used. In (13), the tensor T^K_N is defined as [8]

$$T^K_N(J,J',M|\hat{J}) = \left[\frac{4\pi}{2J+1}\right]^{1/2} (-1)^{J'-M}$$

$$\begin{bmatrix} J & J' & K \\ M & -M & 0 \end{bmatrix} Y_{KN}(\hat{J})\,. \qquad (16)$$

The relation between the reduced matrix elements calculated for the states described by the total orbital L and spin S angular momenta and by the total angular momentum J is as follows:

$$\langle \alpha_1 L_1 S_1 J_1 || Q^{(t)}(q) || \alpha_0 L_0 S_0 J_0 \rangle =$$

$$(-1)^{L_1+S_1+J_0+t}\,[(2J_0+1)(2J_1+1)]^{1/2} \qquad (17)$$

$$\times\, \langle \alpha_1 L_1 S_1 || Q^{(t)}(q) || \alpha_0 L_0 S_0 \rangle \begin{Bmatrix} L_1 & J_1 & S_0 \\ J_0 & L_0 & t \end{Bmatrix}\,.$$

If the excitation is the first step of a multi-step process, the following expression for a single term of the expansion over multipoles of the intermediate state should be used:

$$\frac{\mathrm{d}\sigma_{K_1N_1}(\alpha_0 J_0 M_0 \to \alpha_1 J_1 \mathbf{q})}{\mathrm{d}\Omega_q} =$$

$$\frac{4k_2}{k_1 q^4} \sum_{K_0,K_t} \mathcal{B}^{\mathrm{exB}}(K_0,K_t,K_1) \frac{1}{\sqrt{2K_1+1}}$$

$$\times \sum_{N_0,N_t} \begin{bmatrix} K_0 & K_t & K_1 \\ N_0 & N_t & N_1 \end{bmatrix} T^{*K_0}_{N_0}(J_0,J_0,M_0|\hat{J}_0)$$

$$\times \sqrt{4\pi}\,Y^*_{K_tN_t}(\hat{q})\,. \qquad (18)$$

The expression (13) is a general one and can be used for the derivation of simpler expressions describing the total excitation cross-section of non-polarized and polarized atoms by non-polarized electrons as well as the alignment of non-polarized and polarized atoms.

3. Special cases

3.1. Total cross-section for the excitation of non-polarized atoms

The total cross-section describing the excitation of non-polarized atoms by non-polarized electrons can be obtained from the general expression (13) by summation over the magnetic components of the particles in

the final state and averaging over them in the initial state as well as by integration over the angles of a scattered electron.

In PWB approximation, the differential cross-section depends on the scattered electron angles via the transferred momentum, therefore the integration over angles can be performed by integrating over the transferred momentum. The inspection of the expression (13) shows that only the tensors $T_N^K(J,J,M|\hat{J})$ depend on the projections. The application of the formula

$$\sum_M T_N^K(J,J,M|\hat{J}) = \delta(K,0)\delta(N,0) \qquad (19)$$

for all tensors T_N^K gives $K_0 = N_0 = K_1 = N_1 = K_q = N_q = 0$. The substitution of these values into (13) and integration over the transferred momentum leads to the following expression for the total cross-section:

$$\sigma_t(\alpha_0 J_0 \to \alpha_1 J_1) =$$

$$\frac{8\pi}{(2J_0+1)k_1^2}\int\limits_{q_{\min}}^{q_{\max}} \frac{\mathrm{d}q}{q^3}\, \mathcal{B}^{\mathrm{exB}}(0,0,0)\,, \qquad (20)$$

where $k_1^2 = 2\varepsilon_1$, ε_1 is the energy of the projectile electron, $q_{\min} = k_1 - k_2$, and $q_{\max} = k_1 + k_2$.

3.2. Total cross-section for the excitation of polarized atoms

The expression for the total cross-section for the excitation of polarized atoms by non-polarized electrons can be obtained by performing the summation of the general expression (13) over the projections M_1 of the total angular momentum J_1 and integration over the angles of the scattered electron. It is as follows:

$$\sigma(\alpha_0 J_0 M_0 \to \alpha_1 J_1) =$$

$$\frac{8\pi}{k_1^2}\sum_{K_0,N_0}\int\limits_{q_{\min}}^{q_{\max}}\frac{\mathrm{d}q}{q^3}\,\mathcal{B}^{\mathrm{exB}}(K_0,K_0,0)\,(-1)^{J_0-M_0+K_0}$$

$$\times\left[\frac{4\pi}{(2J_0+1)(2K_0+1)}\right]^{1/2}\begin{bmatrix} J_0 & J_0 & K_0 \\ M_0 & -M_0 & 0\end{bmatrix}$$

$$\times\, Y^*_{K_0N_0}(\hat{J}_0)\,\sqrt{4\pi}\,Y_{K_0-N_0}(\hat{q})\,. \qquad (21)$$

Here

$$\mathcal{B}^{\mathrm{exB}}(K_0,K_0,0) =$$

$$\sum_{t,t'}\left[\frac{(2J_0+1)(2t+1)(2t'+1)}{2K_0+1}\right]^{1/2}(-1)^{2J_0}$$

$$\times\begin{bmatrix} t & t' & K_0 \\ 0 & 0 & 0\end{bmatrix}\begin{Bmatrix} t & t' & K_0 \\ J_0 & J_0 & J_1\end{Bmatrix}(\alpha_1 J_1||Q^{(t)}||\alpha_0 J_0)$$

$$\times\,(\alpha_1 J_1||Q^{(t')}||\alpha_0 J_0)^*\,. \qquad (22)$$

The degree of magnetic dichroism in the total electron impact excitation cross-section of polarized atoms can be defined as follows:

$$\Delta = \frac{\sigma(\alpha_0 J_0 M_0 \to \alpha_1 J_1) - \sigma(\alpha_0 J_0 -M_0 \to \alpha_1 J_1)}{\sigma(\alpha_0 J_0 M_0 \to \alpha_1 J_1) + \sigma(\alpha_0 J_0 -M_0 \to \alpha_1 J_1)}\,. \qquad (23)$$

After inserting (21) into (23) and taking into account the fact that only the terms with $K_0 =$ odd and $K_0 =$ even contribute to the numerator and denominator, respectively, one arrives at the expression for the degree of the magnetic dichroism

$$\Delta = -\Bigg\{\sum_{K_0=\mathrm{odd}}\sqrt{2K_0+1}\,B^{\mathrm{exB}}(K_0)$$

$$\times\begin{bmatrix} J_0 & J_0 & K_0 \\ M_0 & -M_0 & 0\end{bmatrix}P_{K_0}(\hat{J}_0)\Bigg\}\Bigg\{\sum_{K_0=\mathrm{even}}\sqrt{2K_0+1}$$

$$\times B^{\mathrm{exB}}(K_0)\begin{bmatrix} J_0 & J_0 & K_0 \\ M_0 & -M_0 & 0\end{bmatrix}P_{K_0}(\hat{J}_0)\Bigg\}^{-1}\,. \qquad (24)$$

Here $P_K(\cos\theta)$ is the Legendre polynomial, the laboratory axis z is directed along the transferred momentum q, and

$$B^{\mathrm{exB}}(K_0) = \int\limits_{q_{\min}}^{q_{\max}}\frac{\mathrm{d}q}{q^3}\,\mathcal{B}^{\mathrm{exB}}(K_0,K_0,0)\,. \qquad (25)$$

The expression (24) becomes simpler when the direction of J_0 coincides with the z axis. Then $M_0 = J_0$, $P_{K_0}(0) = 1$, and

$$\Delta = -\Bigg\{\sum_{K_0=\mathrm{odd}}\sqrt{2K_0+1}\,B^{\mathrm{exB}}(K_0)(-1)^{K_0}$$

$$\times\begin{bmatrix} J_0 & J_0 & K_0 \\ J_0 & -J_0 & 0\end{bmatrix}\Bigg\}\Bigg\{\sum_{K_0=\mathrm{even}}\sqrt{2K_0+1}\,B^{\mathrm{exB}}(K_0)$$

$$\times\begin{bmatrix} J_0 & J_0 & K_0 \\ J_0 & -J_0 & 0\end{bmatrix}\Bigg\}^{-1}\,. \qquad (26)$$

In the case of $J_0 = 1/2$,

$$\Delta = -\frac{\sqrt{3}B^{\rm exB}(1)\begin{bmatrix}1/2 & 1/2 & 1\\ 1/2 & -1/2 & 0\end{bmatrix}}{B^{\rm exB}(0)\begin{bmatrix}1/2 & 1/2 & 0\\ 1/2 & -1/2 & 0\end{bmatrix}} = \frac{-\sqrt{3}B^{\rm exB}(1)}{B^{\rm exB}(0)}\,. \tag{27}$$

For $J_0 = 1$, it is as follows:

$$\Delta = \frac{3B^{\rm exB}(1)}{\sqrt{2}B^{\rm exB}(0) + \sqrt{5}B^{\rm exB}(2)}\,. \tag{28}$$

The expression of the magnetic dichroism can also be obtained for larger values of J_0.

3.3. The alignment of excited atoms

The axial symmetry with respect to the direction of the movement of a projectile electron is characteristic to the electron impact excitation of atoms. Therefore, the excited atoms cannot be oriented. They can be only aligned with respect to this direction [12]. When the scattered electrons are not polarized and both the projectile electrons and the target atoms are randomly oriented, the expression of the cross-section describing the alignment of the excited atoms can be obtained by averaging the expression (18) over the projections of J_0 and integrating over the angles of a scattered electron. It is as follows:

$$\sigma^A(\alpha_0 J_0 \to \alpha_1 J_1) =$$

$$\frac{1}{2J_0+1}\sum_{M_0}\int {\rm d}\Omega_e \frac{{\rm d}\sigma(\alpha_0 J_0 M_0 \vec{q} \to \alpha_1 J_1)}{{\rm d}\Omega_e} =$$

$$\frac{8\pi}{k_1^2(2J_0+1)}\sum_{K_1 N_1}\left[\frac{4\pi}{2K_1+1}\right]^{\frac{1}{2}}$$

$$\times \int\limits_{q_{\rm min}}^{q_{\rm max}} \frac{{\rm d}q}{q^3} B^{\rm exB}(0,K_1,K_1)\, Y^*_{K_1N_1}(\hat{q}) =$$

$$\sigma_t(\alpha_0 J_0 \to \alpha_1 J_1)\left[1 + \sum_{K_1>0} A_{K_1}\right], \tag{29}$$

where

$$A_{K_1} = \left[\int\limits_{q_{\rm min}}^{q_{\rm max}} \frac{{\rm d}q}{q^3} B^{\rm exB}(0,K_1,K_1)\, P_{K_1}(\cos\theta)\right]$$

$$\times \left[\int\limits_{q_{\rm min}}^{q_{\rm max}} \frac{{\rm d}q}{q^3} B^{\rm exB}(0,0,0)\right]^{-1} \tag{30}$$

is the alignment parameter and the angle θ is measured from the direction of a projectile electron. In (30),

$$\cos\theta = \frac{q^2 + k_1^2 - k_2^2}{2qk_1} = \frac{1}{[2\mu\varepsilon_1]^{1/2}}\left(\frac{q}{2} + \frac{\mu\Delta E}{q}\right) \tag{31}$$

is the angle between the directions of a projectile electron and momentum transfer [18], ε_1 and ε_2 are the energies of the projectile and scattered electrons, respectively, ΔE is the energy lost by the projectile electron.

4. Concluding remarks

In the PWB approximation, the general expression for the electron impact excitation of polarized atoms is obtained for the first time. The cross-section is represented in the form of the multiple expansion over the multipoles of the initial and final states of an atom as well as the state of transferred momentum. The general expression is used to derive simpler expressions for the total cross-section of electron impact excitation of non-polarized and polarized atoms, the alignment of excited atoms, and the magnetic dichroism in the excitation of polarized atoms by non-polarized electrons.

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POLIARIZUOTŲ ATOMŲ SUŽADINIMAS GREITAISIAIS ELEKTRONAIS

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Santrauka

Taikant atomo teorijos matematinį aparatą, Borno artinyje gautos poliarizuotų atomų sužadinimo greitais nepoliarizuotais elektronais diferencialinio skerspjūvio bendrosios išraiškos. Jos patogios aiškinant atskirus poliarizacijos atvejus, sutinkamus konkrečiuose eksperimentuose, bei gaunant juos aprašančių diferencialinių skerspjūvių išraiškas. Gautos poliarizuotų atomų sužadinimo nepoliarizuotais elektronais pilnutinio skerspjūvio magnetinio dichroizmo išraiška bei nepoliarizuotais elektronais sužadinto atomo rikiavimo išraiška kaip atskiri bendrosios išraiškos atvejai.