LETTERS TO THE EDITOR

CONVERSION OF L II AND L III ELECTRONS WITH EMISSION OF E1-QUANTUM IN E0 NUCLEAR TRANSITIONS

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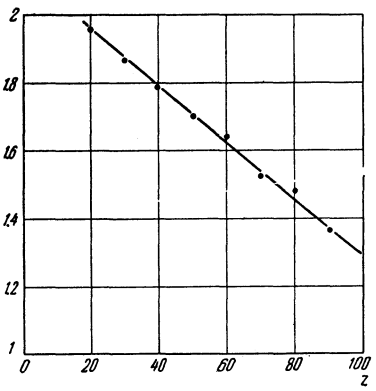
SHELL electron conversion in nuclear E0 transition is determined by the interaction in the region $r \leq R_0$ inside the nucleus. The probability of E0 conversion of the L II and L III electrons is therefore substantially less than that of the L I electron (see Ref. 1).

$$W_{E0}(L\,\mathrm{II}) = {}^3/_2\,(Ze^2/2)^2\,p_f^2\,(\varepsilon_f + 1)^{-2}W_{E0}(L\,\mathrm{I});$$
$$W_{E0}(L\,\mathrm{III}) \sim (p_f R_0)^2\,(Ze^2R_0/2)^2 W_{E0}(L\,\mathrm{I}) \approx 10^{-8} \div 10^{-9} W_{E0}(L\,\mathrm{I}).$$

Here p_f, ϵ_f are the electron energy and momentum in the final state; relativistic units $\hbar = m = c = 1$ and $e^2 = 1/137$ are used throughout.

It would be interesting to consider conversion of L II and L III electrons whereby the electron, emitting a dipole quantum (E1), changes to a state with momentum $j = 1/2$, $\ell = 0$ and then converts in the E0-nuclear transition. We give below the results of the calculations. We consider the emission of quanta with energies $k \leq Ze^2/2$; the calculations are carried out with the Coulomb functions of the electrons in the field of the nucleus in second-order perturbation theory. Screening is neglected. The finite dimensions of the nucleus are taken into account only in the calculation of the matrix element of the E0 transition.



After inserting the matrix elements of the E0 and E1 transitions, the integrals over the intermediate states for L II and L III electrons reduce to integrals of the type

$$J = \int_0^\infty dx \frac{\Phi_\delta(x)\, x^m}{(1+x^2)^n\,(1+x^2+2\xi/\alpha)}, \quad x = \frac{p}{\alpha}, \quad m < n,$$

where

$$\alpha = Ze^2/2, \ \Phi_\delta(x) = x^{2\gamma-1}(1+x^2)^{3\delta/2}\exp(-4\varepsilon \tan^{-1} x/x), \quad \gamma = \sqrt{1-4\delta}, \quad \delta = \alpha^2, \quad \xi = k/\alpha.$$

To calculate this integral, Φ_δ is approximated in the interval $0.2 \leq x \leq 15$ by means of a power function $e^{-4+\lambda}x^\nu$. The dependence of ν on Z is given in the diagram. The value of λ is restricted to $0.9 \leq \lambda \leq 1.1$. Thus the permissible error does not exceed 20%. The calculated value of J is

$$J = \frac{\exp(-4+\lambda)}{2} I_n^{\nu m}\left(-\frac{2\xi}{\alpha}\right) = \frac{\exp(-4+\lambda)}{2\Gamma(n+1)}\Gamma\left(n + \frac{1-m-\nu}{2}\right)\Gamma\left(\frac{1+\nu+m}{2}\right){}_2F_1\left(1,\ n+\frac{1-m-\nu}{2};\quad n+1;\quad -\frac{2\xi}{\alpha}\right),$$

from which we obtain for the unknown probabilities

$$dW_{\gamma E0}(L\,\mathrm{II}) = 1.2\cdot 2^{4\gamma-2}\,[\Gamma(2\gamma+1)]^{-2}\,e^2 W_{E0}(L\,\mathrm{I})\left\{\left[I_2^{\nu 0} + \frac{\gamma+1}{6}\xi^2\left(\frac{2\gamma+3}{3}\mathfrak{M} + 2I_3^{\nu 0} - (2\gamma+3)\,\mathfrak{N}\right)\right]^2\right.$$
$$\left. + 2\left[\frac{(2\gamma+3)(2\gamma+2)}{45}\right]^2 \xi^4\mathfrak{M}^2\right\}\delta(\Delta - \varepsilon_1 - k - \varepsilon_f + 1)\,\xi d\xi\, d\varepsilon_f, \quad \mathfrak{M} \approx I_5^{\nu 0} - I_5^{\nu 4} - 4I_5^{\nu 2}, \quad \mathfrak{N} \approx 0.6 I_7^{\nu 5} + 2.5 I_7^{\nu 6} - 5 I_7^{\nu 2} - 3 I_7^{\nu 0};$$

$$dW_{\gamma E0}(L\,\mathrm{III}) = 2.2\frac{2^{4\gamma-2}[\Gamma(\gamma_1+\gamma+1)]^2}{\Gamma(2\gamma_1+1)[\Gamma(2\gamma+2)]^3} W_{E0}(L\,\mathrm{I})\left\{\left[I_2^{\nu 0} + \frac{(\gamma+3)(\gamma+4)}{6}\xi^2\mathfrak{M}\right]^2\right.$$

$$\left. + \frac{9}{32}\left[\frac{(2\gamma+1)(\gamma+3)(\gamma+4)}{15}\right]^2 \xi^4\left(\mathfrak{N} + \frac{5}{3}\mathfrak{M}\right)^2\right\}\delta(\Delta - \varepsilon_1 - k - \varepsilon_f + 1)\,\xi d\xi\, d\varepsilon_f, \quad \gamma_1 = 2\sqrt{1-\alpha^2}, \quad \gamma = \sqrt{1-4\alpha^2},$$

where Δ is the nuclear transition energy and ϵ_1 is the binding energy of the L electron, equal to $(Ze^2)^2/8$.

If $\Delta \gg \alpha^2$ it is easy to estimate the lower limit of the total transition probability:

$$W_{\gamma E0}(L\,\mathrm{II}) \gtrsim W_{E0}(L\,\mathrm{I},\ \Delta)\frac{1}{137}\,1.2\,\frac{2^{4\gamma-2}}{[\Gamma(2\gamma+1)]^2}\frac{\alpha^2}{16}C, \quad W_{\gamma E0}(L\,\mathrm{III}) \gtrsim W_{E0}(L\,\mathrm{I},\ \Delta)\frac{1}{137}\,2.2\,\frac{2^{4\gamma-2}[\Gamma(\gamma_1+\gamma+1)]^2}{\Gamma(2\gamma_1+1)[\Gamma(2\gamma+2)]^3}\frac{\alpha^2}{16}C,$$

where the constant C is $\gtrsim 2$.

For the ratio of the two probabilities we obtain

$$W_{E0}(L\,\mathrm{II}) / W_{\gamma E0}(L\,\mathrm{II}) \leqslant (1.37\cdot 10^3/C)\, 2^{3-4\gamma}[\Gamma(2\gamma+1)]^2 p_f^2(\varepsilon_f+1)^{-2}.$$

if $\Delta \sim \alpha^2$ the ratio of the probabilities can be on the order of unity, owing to the smallness of p_f.

The ratio $W_{E0}(L\,\mathrm{III})/W_{\gamma E0}(L\,\mathrm{III})$ does not exceed 10^{-4} to 10^{-5} for all values of Δ.

Also possible for the LIII electron is a $\gamma - E0$ conversion with a transition first into the state $j = 1/2$, $\ell = 1$ and emission of a M1 and E2 quantum. In this case, however, the probability $dW_{\gamma E0}$ is proportional to $W_{E0}(L\,\mathrm{II})$ and is considerably less than the probability $dW_{\gamma E0}$ of a process with emission of an E1 quantum.

[1]D. P. Grechukhin, J. Exptl. Theoret. Phys. (U.S.S.R.) 32, 103 (1957), Soviet Phys. JETP 5, 846 (1957).

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SIGN OF THE SPACE CHARGE ON THE AXIS OF A POSITIVE COLUMN IN A LONGITUDINAL MAGNETIC FIELD

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THE magnitude of the space charge in a positive column, together with the magnitude of the transverse electric field, depends for a given current not only on the temperatures and masses of the particles and on the pressure, but also on the superimposed external longitudinal magnetic fields.[1] To calculate the deviation from the quasi-neutrality on the discharge axis one can use a scheme analogous to that proposed by Ecker.[2] However, since direct measurements of the excess space charge is difficult, it is advantageous to change over to transverse gradients.

The ratio of the transverse gradients near the axis in a magnetic field and without the field is given by

$$E_r^H / E_r = Z^H(L_e^H - L_p^H)(D_e b_p + D_p b_e) / Z(D_e - D_p)(D_e^H b_p^H + L_p^H b_e^H), \tag{1}$$

where D_e, D_p, b_e, and b_p are the coefficients of diffusion and mobility of the electrons and ions without a magnetic field (while the index H denotes the presence of a magnetic field), and Z is the ionization coefficient.

Under conditions usually existing in the positive column of a gas discharge, the transverse field decreases in the presence of a longitudinal magnetic field. The character of the decrease depends on the