is the other linearly independent solution of the hypergeometric equation; $a = \beta\Omega_\ell/4$.

The normalization constants $C_\ell$ may be obtained by comparing the assymptotic form of $n_\ell(x)$ for large x with the results of a calculation in the Fermi Age approximation. Thus, neglecting absorption for the sake of simplicity, one has for the case of a unit intensity source of neutrons at the point $\mathbf{r} = \mathbf{r}_0$ in the age approximation, the following

$$\psi_{\text{Age}}(\mathbf{r}, x) = \frac{\lambda M}{2}\sqrt{\frac{m}{2kT}}\frac{x^2}{x^4}\sum_l R_l(\mathbf{r})\left(\frac{x}{x_0}\right)^{\beta\Omega_l/2}, \tag{6}$$

where $x_0$ is the source neutrons speed. Hence

$$\psi(\mathbf{r}, x) = \frac{\lambda M}{2}\sqrt{\frac{m}{2kT}}\sum_l R_l(\mathbf{r}_0)R_l(\mathbf{r})x_0^{-\beta\Omega_l/2}\Gamma\left(\frac{\beta\Omega_l}{4}\right)\Phi\left(\frac{\beta\Omega_l}{4}, 2, x^2\right) \tag{7}$$

In the case of a source located in an infinite homogeneous medium the sum over $\ell$ must be replaced by the corresponding integral.

A detailed discussion of applications of the above results to various special cases will be published later.

In conclusion I express deep gratitude to F. L. Shapiro for valuable discussions in the process of this work.

[1] E. R. Cohen, Geneva Conference Paper 611, 1955.
[2] Hurwitz Jr., Nelkin, and Habetler, Nuclear Sci. and Eng. 1, 280 (1956).
[3] E. R. Cohen, Nuclear Sci. and Eng. 2, 227 (1957).

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## *INFLUENCE OF FINITE NUCLEAR SIZE ON EFFECTS CONNECTED WITH PARITY NONCONSERVATION IN BETA DECAY*

B. V. GESHKENBEIN

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FOR $\beta$-decay, particularly for forbidden transitions, the action of the nuclear field is of importance. As in Ref. 1, we take for the electron wave function

$$\psi_e = \begin{pmatrix}\varphi_e\\ \chi_e\end{pmatrix}, \quad \begin{aligned}\varphi_e &= [\alpha_0 + ipr\alpha_1 + i(\sigma\mathbf{r})(\sigma\mathbf{n})\beta_c]u_\xi,\\ \chi_e &= [\beta_0 + ipr\beta_1 + i(\sigma\mathbf{r})(\sigma\mathbf{n})\alpha_c](\sigma\mathbf{n})u_\xi,\end{aligned} \tag{1}$$

where

$$\mathbf{n} = \frac{\mathbf{p}}{p}, \quad \alpha_0 = \sqrt{\frac{\pi}{2p\varepsilon}}\, ie^{-i\delta_{-1}}g_{-1}, \quad \beta_0 = \sqrt{\frac{\pi}{2p\varepsilon}}\, f_1 e^{-i\delta_1}, \quad \alpha_1 = \sqrt{\frac{\pi}{2p\varepsilon}}\frac{3}{pr}e^{-i\delta_{-2}}g_{-2}, \quad \beta_1 = \sqrt{\frac{\pi}{2p\varepsilon}}\frac{3}{ipr}e^{-i\delta_2}f_2,$$

$$\beta_c = \sqrt{\frac{\pi}{2p\varepsilon}}\frac{1}{r}(e^{-i\delta_1}g_1 - e^{-i\delta_{-2}}g_{-2}), \quad \alpha_c = \sqrt{\frac{\pi}{2p\varepsilon}}\frac{1}{ir}(e^{-i\delta_{-1}}f_{-1} - e^{-i\delta_2}f_2)$$

($m_e = c = \hbar = 1$), $g_\kappa$, $f_\kappa$ are the inside-the-nucleus solutions of the radial Dirac equation joined with the outside solutions at $r = r_0$; $\delta_\kappa$ is the phase.[2] We write the $\beta$-interaction Hamiltonian as follows

$$H = \sum\left\{g_i(\bar\psi_2 O_i\psi_1)\left(\bar\psi_e O_i\frac{1-\gamma_5}{2}\psi_\nu\right) + g_i'(\bar\psi_2 O_i\psi_1)\left(\bar\psi_e O_i\frac{1+\gamma_5}{2}\psi_\nu\right)\right\} \tag{2}$$

(summation over i = S, T, V, A, P). If the two-component neutrino theory[3-5] holds, then emission of an antineutrino together with an electron corresponds to $g_i' = 0$, whereas emission of a neutrino corresponds to $g_i = 0$.

The results for allowed and first forbidden $\beta$-transitions are expressed in terms of the known tabulated functions $L_0$, $M_0$, $N_0$, $P_0$, $Q_0$, $R_0$, $L_1$, $P_1$.[6-8]

Taking finite nuclear size into acoount has in practice no effect on allowed and unique $\Delta j = 2$ (yes) transitions since these depend on $L_0$, $P_0$ and $L_0$, $P_0$, $L_1$, $P_1$ respectively, for which finite nuclear size is unimportant.[9] For the Coulomb transitions $M_0$ and $Q_0$ are relevant; these are significantly affected by finiteness of nuclear size, but since they are both multiplied by the same factor they will give no effect in practice. Thus nuclear size will affect only $0 \rightarrow 0$ (yes) transitions provided the pseudoscalar covariant is present in $\beta$-decay.

If one assumes that the axial covariant is absent, then the longitudinal polarization of electrons and the electron-neutrino angular correlation are given by

$$\langle \sigma n \rangle = (A_{av} - A_v)/(C_{av} + C_v), \quad W_{ev}(\theta) = 1 + \langle \sigma n \rangle \cos\theta, \tag{3}$$

where

$$A_{av} = -|g_T \int \sigma r|^2 \Big\{ \frac{1}{9} q^2 \sqrt{L_0^2 - P_0^2} + \sqrt{M_0^2 - Q_0^2} - \frac{1}{3} q \big(\sqrt{(L_0 + P_0)(M_0 + Q_0)} + \sqrt{(L_0 - P_0)(M_0 - Q_0)}$$
$$- \big(\sqrt{(L_0 + P_0)(M_0 + Q_0)} + \sqrt{(L_0 - P_0)(M_0 - Q_0)}\big) - \frac{2}{3} q \sqrt{(L_0^2 - P_0^2)} \operatorname{Re} \lambda_P + \big(\sqrt{(L_0 + P_0)(M_0 + Q_0)}$$
$$- \sqrt{(L_0 - P_0)(M_0 - Q_0)}\big) \cot(\delta_{-1} - \delta_1) \operatorname{Im} \lambda_P + \sqrt{L_0^2 - P_0^2} |\lambda_P|^2 \Big\} \sin(\delta_{-1} - \delta_1); \tag{4}$$
$$C_{av} = \Big\{ \frac{1}{9} L_0 q^2 + M_0 + \frac{2}{3} q N_0 + 2\Big(N_0 + \frac{1}{3} L_0 q\Big) \operatorname{Re} \lambda_P + L_0 |\lambda_P|^2 \Big\} |g_T \int \sigma r|^2 \qquad \lambda_P = -i g_P \int \gamma_5 \Big/ g_T \int \sigma r.$$

$A_\nu$ and $C_\nu$ follow from (4) upon replacement of $g_P$ by $g'_P$ and $g_T$ by $g'_T$.

For $Ze^2 \ll 1$, finite nuclear size effects are unimportant and all quantities can be written explicitly.[6] Since expressions for $Q_0$ and $P_0$ as well as for $\sin(\delta_{-1} - \delta_1)$ are not available, we give them here:

$$P_0 = 1/\varepsilon, \quad Q_0 = pv/9 - Z^2 e^4 / 4\varepsilon r_0^2, \quad \sin(\delta_{-1} - \delta_1) = (1 + Z^2 e^4 p^{-2})^{-1/2}. \tag{5}$$

If the pseudoscalar covariant is absent, the two-component neutrino theory holds, and $\lambda_P$ is real, then the polarization differs insignificantly (~ 3%) from v/c. In the presence of the pseudoscalar covariant the polarization can differ significantly from v/c only in a relatively narrow range of values of $\lambda_P$. For example, for $Pr^{144}$ the polarization differs from v/c for $\lambda_P \sim 10 \pm 1$ and may even change sign. If the two-component neutrino theory does not hold then the polarization obviously can take on any value.

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[1] Berestetskii, Ioffe, Rudik, and Ter-Martirosian, Nuclear Physics (in press).

[2] L. A. Sliv and B. A. Volchok, Таблицы кулоновских фаз и амплитуд с учетом конечных размеров ядра (Tables of Coulomb Phases and Amplitudes, Taking into Account The Finite Nuclear Size), Acad. Sci. Press, 1956.

[3] L. D. Landau, J. Exptl. Theoret. Phys. (U.S.S.R.) 32, 405 (1957), Soviet Phys. JETP 5, 336 (1957).

[4] T. D. Lee and C. N. Yang, Phys. Rev. 105, 1671 (1957).

[5] A. Salam, Nuovo cimento 5, 299 (1957).

[6] E. J. Konopinski and G. E. Uhlenbeck, Phys. Rev. 60, 308 (1941).

[7] L. N. Zyrianova, Izv. Akad. Nauk SSSR, Ser. Fiz. 20, 1399 (1956).

[8] B. S. Dzhelepov and L. N. Zyrianova, Влияние электрического поля атома на бета-распад (Influence of The Atomic Field on Beta-Decay), Acad. Sci. Press, 1956.

[9] M. E. Rose and D. K. Holmes, Phys. Rev. 83, 190 (1951).

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