BETA DECAY OF A SPIN-3/2 PARTICLE

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It is of some interest, in connection with the possible existence of hyperons with spin greater than $1/2$, to consider the decay of a spin-$3/2$ particle. Let us consider the β decay of such a particle according to the decay scheme $Y \rightarrow p + e + \tilde{\nu}$, in analogy with the neutron-decay scheme, in the first approximation of perturbation theory. We shall assume that the decay products are described by the Dirac equation and that the decaying particle is described by an equation of Rarita-Schwinger type.[1]

We write the interaction leading to decay in the form

$$H_{\text{int}} = (\bar{\psi}_p B^\mu)(C_V \bar{\psi}_e \gamma_\mu \psi_\nu + C'_V \bar{\psi}_e \gamma_\mu \gamma_5 \psi_\nu) + (\bar{\psi}_p \gamma_5 B^\mu)(C_A \bar{\psi}_e \gamma_\mu \gamma_5 \psi_\nu + C'_A \bar{\psi}_e \gamma_\mu \psi_\nu) + (\bar{\psi}_p \gamma_\mu B^\sigma)(C_T \bar{\psi}_e \gamma_\mu \gamma_\sigma \psi_\nu + C'_T \bar{\psi}_e \gamma_\mu \gamma_\sigma \gamma_5 \psi_\nu) + \text{compl. conj.} \tag{1}$$

Here B^μ, the wave function of the spin-$3/2$ particle, is a four-vector each of whose components is a bispinor. This function (when there is no interaction) satisfies the equation[1]

$$(i\gamma p + m) B^\mu = 0, \quad \gamma_\mu B^\mu = 0. \tag{2}$$

We sum over the states of the decay products in the usual way, and average over initial states of the spin-$3/2$ particle using the relations

$$\sum_{i=1}^{4} {}^{(i)}B_\rho^\mu (\pm \mathbf{p})\, {}^{(i)}B_\sigma^{\nu *} (\pm \mathbf{p}) = (\Lambda^{\mu\nu} \Lambda^\pm)_{\rho\sigma}. \tag{3}$$

The upper and lower signs correspond to summing over positive and negative energy states, respectively, $\Lambda^\pm$ is the usual projection operator of Dirac theory, and the operator $\Lambda^{\mu\nu}$ is given by

$$\Lambda^{\mu\nu} = \delta_{\mu\nu} + \frac{2}{3m^2} p_\mu p_\nu - \frac{1}{3} \gamma_\mu \gamma_\nu - \frac{1}{3m^2} (\gamma_\mu p_\nu - \gamma_\nu p_\mu)(\gamma p). \tag{4}$$

The resulting averaged and summed square of the matrix element for decay at rest is

$$|M_0|^2 = L_1 + \frac{1}{3} L_2 \frac{\mathbf{p}_e \mathbf{p}_\nu}{E_e E_\nu} + L_3 \left(\frac{\mathbf{p}_e}{E_e} + \frac{\mathbf{p}_\nu}{E_\nu} \right) \frac{\mathbf{p}_p}{E_p} + L_4 \left(\frac{\mathbf{p}_e}{E_e} - \frac{\mathbf{p}_\nu}{E_\nu} \right) \frac{\mathbf{p}_p}{E_p} + L_5 \frac{m_p}{E_p} \left(1 - \frac{1}{3} \frac{\mathbf{p}_e \mathbf{p}_\nu}{E_e E_\nu} \right) + L_6 \frac{m_e m_p}{E_e E_p} + L_7 \frac{m_e}{E_e} \left(1 - \frac{1}{3} \frac{\mathbf{p}_p \mathbf{p}_\nu}{E_p E_\nu} \right), \tag{5}$$

where the L coefficients depend only on the coupling constants and are given by

$$L_{1,2} = \frac{1}{2} [\pm (|C_V|^2 + |C'_V|^2 + |C_A|^2 + |C'_A|^2) + 2(|C_T|^2 + |C'_T|^2)],$$
$$L_3 = -\frac{1}{3} (|C_T|^2 + |C'_T|^2), \quad L_4 = -\frac{1}{6} (C_V C_A^* + C_V^* C_A + C'_V C'^*_A + C'^*_V C'_A), \tag{5'}$$
$$L_5 = \frac{1}{2} (|C_V|^2 + |C'_V|^2 - |C_A|^2 - |C'_A|^2), \quad L_{6,7} = \frac{1}{2} [(C_V \pm C_A) C_T^* + (C_V^* \pm C_A^*) C_T + (C'_V \pm C'_A) C'^*_T + (C'^*_V \pm C'^*_A) C'_T].$$

These calculations are performed on the assumption that the neutrino rest mass vanishes. Equation (5) is written in a form analogous to that obtained for the β decay of a spin-$1/2$ particle (see, for instance, Michel[2]). From this equation we easily obtain the known[3] expressions for "pure" V, A, or T coupling.

Equation (5) for the spin-$3/2$ particle is not the same as the corresponding equation in the β decay of a Dirac particle. The difference is, among other things, that the β-ν correlation coefficient cannot have an absolute value greater than $1/3$. This, in turn, leads to a difference in the shape of the decay-electron energy spectrum, which we give below:

$$w(E_e) = \frac{m_Y^2 (W - E_e)^2 \sqrt{E_e^2 - m_e^2}}{6 (2\pi)^3 z_1^3} [L_1 E_e \{z_2 [3m_Y (W - E_e) + E_e^2 - m_e^2] + 3m_p^4\} - \frac{L_2}{3} z_2 (m_Y - E_e)(E_e^2 - m_e^2) - L_3 \{z_2 [m_Y E_e (W - E_e) + (m_Y - 2E_e)(E_e^2 - m_e^2)] + 4m_Y^2 E_e (W - E_e)^2\} + L_4 \{z_2 m_Y [E_e (W - E_e) - E_e^2 + m_e^2] + 4m_Y^2 E_e (W - E_e)^2\} + L_5 2 z_1 m_p (3m_Y E_e - 2E_e^2 - m_e^2) + L_6 6 z_1 m_p m_e (m_Y - E_e) + L_7 \frac{m_e}{3} \{z_2 [12 m_Y (W - E_e) + 2 (E_e^2 - m_e^2) - 3m_p^2] + 18 m_p^4\}]. \tag{6}$$

Here

$$z_1 = m_Y(W - E_e) + {}^1/_2 m_p^2, \quad z_2 = 2(z_1 + m_p^2), \quad W = (m_Y^2 - m_p^2 + m_e^2)/2m_Y.$$

The present considerations can be used for μ-meson decay[4] of spin-$^3/_2$ particles according to the scheme $Y \rightarrow p + \mu + \tilde{\nu}$, as well as for the electron decay scheme considered above.

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ELECTRONIC PARAMAGNETIC RESONANCE IN ALLOYS OF ALKALI METALS

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REFERENCES 1 to 3 report on the influence of impurities on resonance absorption in metals due to conductive electrons.

We have investigated the 290-Mcs resonance absorption in alloys of sodium at T = 90°K and 300°K, as a function of the concentration of components. The following metals served as components: Li, K, Hg, Pb and Woods' alloy.

The measurement procedure was described previously.[4] The original sodium was 99.5% pure and contained approximately 0.4% of potassium. The alloys were produced under a layer of paraffin or in an argon atmosphere. To prevent skin effect from distorting the shape of the absorption lines,[5] the alloy was dispersed in paraffin; the average size of metal particles was approximately 4 μ. The width ΔH in the original sodium measured between the half-intensity points of the resonance-absorption curve, has a maximum of 16 Oe at room temperature and equals 9 Oe at 90°K.

Our data on the width coincide with the results of Gutovsky and Frank.[6] The measurements of paramagnetic resonance in alloys indicate that the metals used as alloy components can be divided into two groups. The first group includes

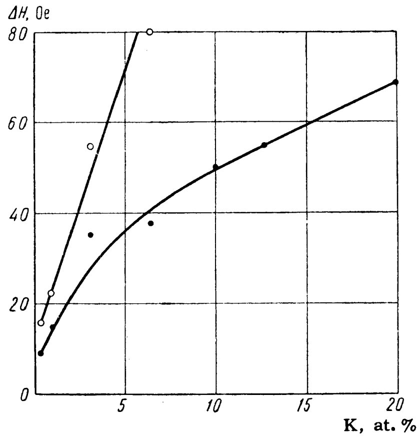

FIG. 1. Alloys Na–K. ● – T = 90°K, ○ – T = 300°K.

Li and K, which have little effect on ΔH, and consequently on T_1 and T_2.

In Na-K alloys ΔH has a greater temperature dependence than in the original sodium (Fig. 1).

The second group contains the heavy metals Hg, Pb and Wood's alloy, which increase ΔH almost 10^4 times more than the metals of the first group. (Fig. 2). In the alloys of these metals ΔH is independent of the temperature.

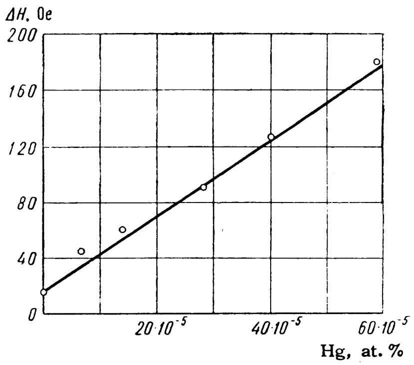

FIG. 2. Alloy Na–Hg. T = 300°K.