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Short Note

The Mass and the Mean Life Time of the Mesotron

By

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According to the present theory of the nuclear forces and the β-decay,[1] the mesotron with the charge $-e$ (or $+e$) can transform into a negative (or positive) electron and an antineutrino (or a neutrino) even in vacuum, the mean life time due to this process being proportional to the energy.[1] In the previous papers,[2] ~~the proper life time, i.e.~~ the mean life time ~~of the mesotron at rest,~~ the proper life time, i.e. of the mesotron ~~was calculated on the basis of the theory of the mesotron satisfying the Dirac-Proca equations and was found to be of the order of~~

$$\tau_0 = 1.3 \times 10^{-7}\,\text{sec},$$

~~for the mass of the mesotron m_0~~ if we assume the proper mass m_0 to ~~be equal to 200m.~~[2] of it at rest by assuming the interaction of it with the light particle equivalent, that in, ~~corresponding~~ to ~~the~~ Fermi's theory of β-decay and was found to ~~be of the order of~~ ~~have the form~~ be

$$T_0 = \frac{\hbar c}{g'^2}\cdot\frac{\hbar}{m_0 c^2}\Big/\left\{\frac{2}{3}\lambda_1 + \frac{1}{3}\mu_1^2\right\}, \quad (1)$$

which has a numerical value about ~~$T_0 = 1.3 \times 10^{-7}$ sec~~

$$T_0 \cong 1.3 \times 10^{-7}\,\text{sec} \quad (2)$$

for $\lambda_1 = \mu_1 = 1$, $g' = \ldots$ ~~the proper mass~~ $m_0 = 200\,m$, whereas ~~the life~~ it T_0 became far smaller ~~very much too short~~, if we assumed the interaction equivalent to Konopinski-Uhlenbeck's theory. On the other hand, that in the proper life time ~~value~~ determined ~~determined from the experiments~~ by ~~many~~ various authors[3] ~~to~~ from the experiments on the cosmic ray according to the suggestion of Euler and Heisenberg[4] (Ferretti) all pointed to a value of the order of

$$T_0 = 2 \times 10^{-6}\,\text{sec}, \quad (3)$$

~~Thus, the agreement of the theory and the experiment is not very satisfactory~~, so that which is in qualitive agreement with

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the theoretical value (1) corresponding to Fermi's ~~many~~ types of interaction, ~~whereas K.-U. interaction although there remains a discrepancy of a factor 10 between them in numerical~~ ~~The discrepancy of a factor 10~~ ~~Now between them~~ ~~If the whole fundamental assumption of the present theory is not is not on the wrong line~~, The discrepancy of a factor 10 between the numerical values (2) and (3) seems to be ~~originated~~ due to various uncertainties on the side of the ~~theory~~ theoretical ~~calc~~ estimation rather than to errors on the side of the experiment. In fact, the ~~theoretical~~ value ~~life time~~ depends sensitively on the proper mass m_0, ~~m_u because~~ ~~since~~ the constant g' in (1) ~~becomes smaller~~ as m_u becomes smaller. ~~since~~ g' in (1) changing rapidly ~~with m_u~~, so that it will be worthy while to determine the numerical value of τ_0, as the function of m_u, more carefully

~~Now we have to First~~ In the first place, we ~~have to~~ determine the constants ~~with~~ g_1, g_2 ~~which~~ characteristic to the interaction between the mesotron and the heavy particle. According to Kemmer[5)] and ~~others~~ [illegible], in S state, the interaction between two heavy particles is given ~~takes the form in the first~~ approximately by

$$V_{12} = \tau^{(1)}\tau^{(2)}\left\{\frac{1}{8} + \frac{5}{24}(\vec{\sigma}^{(1)}\vec{\sigma}^{(2)})\right\}\frac{g^2 e^{-\kappa r}}{r} \quad (4)$$

by assuming $g_1^2 = \frac{g^2}{4}$, $g_2^2 = \frac{5g^2}{4}$ (5) ~~The fact that~~ From the small binding energy 2.17×10⁶eV ~~for the binding energy~~ of the deutron it follows that the combination

$$\frac{g^2 M}{\kappa \hbar^2} = a \quad (6)$$

changes slowly with $\varkappa = \frac{m_u c}{\hbar}$, where M is the mass of the heavy particle. Indeed, according to the result of solution of deuteron problem by assuming the interaction of the form (4), 7) we obtain

$\frac{1}{\varkappa}$	1.18	1.54	1.93	2.39
m_u	[illegible]	[illegible]	~200m	~150m
a	2.30	2.50	2.70	2.78

from which we can determine the numerical values of

$$\frac{g_1^{\prime 2}}{\hbar c} = \frac{a}{4}\left(\frac{m_u}{M}\right) \qquad \frac{g_2^{2}}{\hbar c} = \frac{5a}{8}\left(\frac{m_u}{M}\right) \qquad (7)$$

for a given value of m_u.

In order to determine g', we have to consider the theoretical mean life time of the radioactive nucleus T, which is given by

$$\frac{1}{T} = \frac{mc^2}{\hbar}\{G_1^2|M_1|^2 + G_2^2|\vec{M}_2|^2\}\int_0^{\varepsilon_0}(\varepsilon_0-\varepsilon)^2\sqrt{\varepsilon^2-1}\,d\varepsilon \qquad (8)$$

with

$$\left.\begin{aligned} G_1 &= \frac{m^2c}{\sqrt{2\pi^3}\hbar^3}\frac{4\pi g_1 g' \lambda_1}{\varkappa^2} \\ G_2 &= \frac{m^2c}{\sqrt{2\pi^3}\hbar^3}\frac{4\pi g_2 g' \mu_1}{\varkappa^2} \\ M_1 &= \iint \tilde{v}_m u_n\, dv \\ \vec{M}_2 &= \iint \tilde{v}_m \vec{\sigma}\, u_n\, dv \end{aligned}\right\} \qquad (9)$$

where u_n, v_m are the wave functions of the neutron and the proton respectively and ε_0 is the upper limit of the energy spectra divided by mc^2. Now we want to [redacted] take

In the special case i) $\lambda_1 = 0$, $\mu_1 = 1$,

we obtain

$$\frac{g'^2}{\hbar c} = \frac{\pi}{5^2}\frac{G_2^2}{a}\left(\frac{M}{m}\right)\left(\frac{m_u}{m}\right)^2 \qquad (10)$$

6) Bethe and Bacher

7) Sachs and Goeppert-Mayer
Witson,

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According to the present theory of the nuclear forces and the β-decay, the mesotron with the elementary charge and the mass from 100 to 200 times as large as the electron mass, with the charge −e (or +e) can transform spontaneously into a negative (or positive) electron and an antineutrino (or a neutrino) even in vacuum. The mean life time due to this process was shown to be proportional to the energy[1] in the previous paper[2], being the proper life time, i.e. the mean life time of the mesotron at rest, was shown to be of the order of

$$\tau_0 = 1.5 \times 10^{-7}\ \text{sec}, \qquad (1)$$

if we assume the mass m_μ to be equal to $200\, m$[2]; whereas is about ten times smaller by a factor 10 than the value $\tau_0 \cong 2 \times 10^{-6}$ sec determined from the experiment for the cosmic ray[3] according to the suggestion of Euler and Heisenberg[4], so that the agreement by using (5) and (6), the numerical value of G_2 can be determined from the relation the corresponding expression in Fermi's theory, so that

$$G_2 = f \frac{g_F\, m^2 c}{\sqrt{(2\pi)^3}\hbar} \qquad (\ )$$

which can be obtained by comparing (8) with the corresponding expression in Fermi's theory, where g_F is the Fermi's constant g. Thus we have

$$G_2 = 1.1 \times 10^{-13}$$

by taking $g_F = 4 \times 10^{-50}\ \mathrm{cm}^3\,\mathrm{erg}$, so that (10) and inserting ( ) in ( ) for g', take the numerical value

$$\frac{g'^2}{\hbar c} = 5.7 \times 10^{-18} \left(\frac{m_u}{100\,m}\right)^3 \qquad (\ )$$

by taking $a = 2.47$.

In the case

ii) $\lambda_2 = 1, \quad \mu_1 = 0,$

we obtain in a similar way

$$\frac{g'^2}{\hbar c} = \frac{\pi}{2} \frac{G_1^2}{a} \frac{M}{m} \left(\frac{m_u}{m}\right)^3,$$

which takes the value

$$1.4 \times 10^{-17} \left(\frac{m_u}{100\,m}\right)^3. \qquad (\ )$$

Inserting ( ) in ( ), we obtain finally

$$\tau_0 = 6.7 \times 10^{-6} \left(\frac{m_u}{100\,m}\right)^4 \qquad (\ )$$

for the case i) and

$$\tau_0 = 1.3 \times 10^{-6} \left(\frac{m_u}{100\,m}\right)^4 \qquad (\ )$$

for the case ii). The proper life time for $m_u = 100m, 150m, 200m,$ expressions ( ) and ( ) show that the proper life time of the mesotron increases

を有する。磁氣能率は原子スペクトルの超微構造、原子線及び分子線の不均一磁場に於ける屈曲等から決定される。その大いさは一般に核磁子(nuclear magneton) $\frac{e\hbar}{2M_pc}$ の程度である。統計的性質は分子スペクトルの強度分布から決定され、一般にAが偶數の核はBose統計に從ひ、奇數の核はFermi統計に從ふ。

これ等の結~~論~~果は原子核が電子と陽子とから成るとする假説と矛盾する。これに反して、原子核は陽子と中性子とから構成されるとし、中性子は $\frac{1}{2}\cdot\frac{h}{2\pi}$ のスピンを有し、Fermiの統計に從ふと假定すると全て具合よく説明出來る。今後陽子と中性子とを總稱して重粒子と呼ぶことにする。

~~次の表に~~水素から酸素までの安定な原子核及び放射能原子核の基本的な諸性質を次に掲げて置く。

rapidly with decreasing mass m_0, the numerical values for several cases being summarized in the following table.

m_0	100 m	150 m	200 m
Case i) $\lambda_1 = 0$			
Case ii) $\mu_1 = 0$			

Thus, the agreement between theory and experiment is very satisfactory, if we assume a value of m_0 intermediate between (150 m, 200 m) as long as the constant μ_1 has, at least, the same order of magnitude as λ_1. In this connection it is interesting that the K-electron capture of ^7Be can be explained satisfactory only if μ_1 is not smaller than λ_1.

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場合の値として、

$$\tau_0 = 2 \times 10^{-6}\ \mathrm{sec} \qquad (89)$$

を得た。最近 Blackett, Rossi, Ehrenfest, Fréon[40] も上記と同趣旨の実験を行ひ、τ_0として(89)と殆んど同じ値を得て居る。これを理論値 $\tau_0 = 1.3 \times 10^{-7}\ \mathrm{sec}$ と比較すると一桁異なるが、理論的にも実験的にも曖昧な点が多いことを考へると、両者は矛盾して居ないといふべきである。Ehrenfest[41]が得た霧函写真は、実際上記の過程によつて、陽電気を帯びたU粒子が陽電子と中性微子に転化したものと解釈出来るが、この他には未だ直接的な證據はない。

(40) Blackett, Nature **142** (1938), 992; Rossi, ibid. **142** (1938), 993; Ehrenfest et Fréon, C.R. **207** (1938),
(41) Ehrenfest, C.R. **206** (1938), 428.