Heisenberg 38 Jun 16 12 同年

Department of Physics,
Osaka Imperial University,
Osaka, Japan, July 15, 1938.

Dear Prof. W. Heisenberg,

It is a great honour for me that my previous work won your praise, which, I fear, was far higher than it deserved. It is also a pleasure that Dr. Euler of your school obtained a value for the mean life time of the heavy electron, which was in qualitative agreement with the result of our theory. It is a pity that there was an error of factor 2 in our calculation, so that the mean life time for the heavy electron at rest with the mass $m_u = 100\ m$ becomes 0.25×10^{-6} sec, which makes the agreement with Euler's value a little worse. The assumption made in our paper, however, leads to the theory of β-disintegration of Fermi type, as you pointed out, so that it is important to carry out also a calculation based on the theory equivalent to Konopinski-Uhlenbeck theory. Recently, we succeeded in constructing a general scheme including both types of interaction and we obtained an expression for the prob. per unit time of annihilation w of the heavy electron with the energy E as follows.

$$w = \frac{g'^2}{\hbar c}\cdot\frac{m_u c^2}{\hbar}\cdot\frac{m_u c^2}{E}\left\{\frac{2}{3}\left|\lambda_1 + i\frac{1-\mu}{2}\lambda_2\right|^2 + \frac{1}{3}\left|\mu_1 + i\frac{1-\mu}{2}\mu_2\right|^2\right\}$$

where μ is the ratio of masses of the neutrino and the electron and $\lambda_1, \lambda_2, \mu_1, \mu_2$ are numerical constants of the order of 1. In the special case $\lambda_1 = \mu_1 = 1$, $\lambda_2 = \mu_2 = 0$ corresponding to pure Fermi interaction, w reduces to (67) (with $g_1' = g_2' = g'$) in §8, III multiplied by 2, as it should be. On the other hand, in the case $\lambda_1 = \mu_1 = 0$, $\lambda_2 = \mu_2 = 1$ corresponding to pure K.-U. interaction, the mean life time $\tau = 1/w$ is four times as large as that in Fermi case, if we take the same values for g', m_u and $\mu = 0$. The numerical values for both cases with $g' = 4\times10^{-17}$, $m_U = 200$ m, (instead of 100 m) and $\mu = 0$ are summarized in the following table.

Kinetic Energy	$E - mc^2$	0	10^9	10^{10}	10^{11}	eV
Mean Life Time	Fermi	1.3×10^{-7}	1.3×10^{-6}	1.3×10^{-5}	1.3×10^{-4}	sec
	K.-U.	5×10^{-7}	5×10^{-6}	5×10^{-5}	5×10^{-4}	sec.

Thus, the theoretical result in the case of K.-U. agrees with the experiment as good as (or even better than) in the case of Fermi. The details of the calculation will be described in a subsequent paper.

In this connection, I should like to inform you that a cloud chamber photograph obtained by Mr. P. Ehrenfest (C. R. 206, 428, 1938) seems to me to indicate the annihilation of the heavy electron. According to him, a track of the heavy electron of positive charge with the mass about 200 m and $H\rho = 1.9\times10^5$ gauss. cm ends at the wall, and from there starts a positron with $H\rho = 1.6\times10^5$ gauss. cm, i.e. with the energy about 100 mc^2. Thus, it is possible that the heavy electron slowed down in the wall annihilates into a positron and a neutrino each with the energy about 100 mc^2, though also other interpretations can not be excluded completely.

Recently, I read with great interest your paper in Ann. d. Phys., which was related on the problem of the universal length in the theory of the nucleus. I would be very obliged, if you would kindly send me a copy of the paper (and others, if any, on related topics). In fact, it is noticeable that, in the theory of the vectorial field for the heavy electron, as developed by Kemmer, Frohlich and Heitler, by Bhabha and by us, we have to make [use of] an expansion not only in powers of $g^2/\hbar c$ but also in powers of $k/\varkappa$, where $1/\varkappa = \hbar / m_u c$ is the universal length and k the wave number of the heavy electron concerned. Thus, as you have emphasized, we can expect the explosion when the energy of the particles concerned is very large, although our theory in the present form can not be applied to such a high energy region.

I remain,

Yours very sincerely,

Hideki Yukawa.