Letter to the Editor

A Consistent Theory of the Nuclear Force and the β-Disintegration

In spite of many attempts to develop the so-called "β-hypothesis of the nuclear force",[1)] there still remains in the current theory the well known inconsistency between the small probability of the β-decay and the large interaction of the neutron and the proton. Hence, it will not be useless to give on this occasion a brief account of one possible way of solving this difficulty which was proposed by the present writer about two years ago.[2)]

First, we introduce the field which is responsible for the short range force between the neutron and the proton and assume it to be something different from the so-called "electron-neutrino field" in contradistinction to the current theory. The simplest conceivable one is perhaps such that can be derived from two scalar potentials U and U, which are conjugate complex to eac each other and satisfy, in the presence of a heavy particle, the th equations

$$\left\{\Delta - \frac{1}{c^2}\frac{\partial^2}{\partial t^2} - \lambda^2\right\} U = -4\pi g \tilde{v} u \quad \text{or } 0 \qquad (1)$$

$$\left\{\Delta - \frac{1}{c^2}\frac{\partial^2}{\partial t^2} - \lambda^2\right\} \tilde{U} = 0 \quad \text{or } -4\pi g \tilde{u} v \qquad (2)$$

according as the latter is initially in the neutron state u or in the proton state v, where g is a constant with the same dimension as the electric charge and λ is another with the dimension of reciprocal length. These equation indicates the possibility of the transition of the heavy particle from the neutron to the proton state and vice versa owing to its interaction with the U-field. We can easily deduce from them the exchange force with the potential

$$g^2 \frac{e^{-\lambda r}}{r}$$

between the neutron and the proton. This force was found to be of Heisenberg type, but the Majorana force can also be obtained, if we assume additional potentials with the character of the space vector.

Next, we consider that this field interacts, on the other hand, with the light particle and lead the latter from the electron to the neutrino state and vice versa. Thus, we add to the right hand sides of (1) and (2) terms referring to the light particle with another constant g' instead of g, so that we can compute the probability of β-decay as due to the indirect interaction between the light and the heavy particles by means of the U-field. The result becomes essentially the same as that of Fermi, if we put $\frac{4\pi g g'}{\lambda^2}$ equal to his g. Hence, three constants λ, g and g' can be adjusted so as to give correct magnitudes both for mass defects and the probability of β-decay. If we take, for example $\lambda = 5 \times 10^{12} cm^{-1}$, g should be about 10 times smaller than g, which means that the energy liberated by the transition o of a heavy particle from the neutron to the proton state, for instance, is almost always taken up by another heavy particle, which in turn makes the inverse transition, without the aid of the intermediary transition of the light particle, in contrast to the assumption of the current theory. These conclusions are not altered essentially, if we modify the mathematical formulation so as to be in accord with the result of Konopinsky and Uhlenbeck.

The above theory should be extended further, so that it can include the interaction of the U-field with the electromagnetic field.[3)] A noticeable result, which can be predicted without lengthy calculations, is that the above field should be accompanied by quanta obeying Boses statistics with the elementary charge either +e or -e and the proper mass $m_U = \frac{\lambda \hbar}{c}$, which is about 200 times as large as the electronic mass, if we take the above value for λ. Nevertheless, we can hardly expect the creation of such quanta by ordinary nuclear reactions, since at least an energy of the order of 10 eV is ~~always~~ needed. On the contrary, if they ever exist, their tracks may be found in the cloud chamber photographs of cosmic ray. Now it is not altogether impossible that the anomalous tracks discovered by Anderson and Neddermeyer,[4] which are likely to belong to unknown rays with $\frac{e}{m}$ larger than tha of the proton, are really due to such quanta, as the range-curvature relations of these tracks are not in contradiction to this hypothesis. At present, much reserve is, of course, indispensable owing to the scantiness of the experimental information.

Complete account of the theory will be given in the later issue of the Proc. Phys.-Math. Soc., Japan.

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1) See for example, Bethe and Bacher, Rev. Mod. Phys. 8, 82, 1936 and further Weizsacker, Zeits. f. Phys. 102, 572, 1936~~,~~; Iwanenko and Sokolow, ibid. 102, 119, 1936.

2) Proc. Phys.-Math. Soc. Japan 17,~~4~~ 48, 1935.

3) The mathematical development in this case follows on much the same line with that of Pauli and Weisskopf, Helv. Phys. 7, 709, 1934.

4) Phys. Rev. 50, 263, 1936.

Summary of the Preceeding Letter

The current view of coonecting the β-disintegration directly with the exchange force between the neutron and the proton was modified so as to give correct value for the latter without essentially affecting the theory of the β-decay. As an important conclusion of the theory, the existence in cosmic ray of the quanta with the elementary charge either positive or negative and the mass several times smaller than that of the proton was expected.