It is of course the case that μ, or more accurately μ/A, measures the ratio of magnetic induction to magnetising force, the permeability of the medium, while K, or rather $K/4\pi$, is a measure of its permittivity, the ratio of electrical displacement to electric force, but these facts are consequences of theory rather than fundamental definitions of the coefficients μ and K. The object of this note is to direct attention to the fact that many other coefficients used in physics share this role with μ and K.

Hooke's law, "Ut tensio sic vis", might be made the basis of a definition of force; indeed, it is used in the spring balance as a measure of force. A coefficient, Young's modulus, gives us the link by means of which we can express the stretch (tensio, extension) of a spring or piece of elastic in dynamical measure. This is true of all coefficients of compressibility or rigidity. By means of them we are enabled to express dynamically the pressures or tractions required to change the volume or shape of a body by a given amount.

Nor is this use of a coefficient limited to cases in which force is one of the quantities measured. Heat is properly measured as energy; it can also be measured by the rise of temperature produced in a given mass of water. Joules' equivalent is a coefficient which enables us to express a rise of temperature as the ratio of energy to the mass of water; the result is not completely 'absolute', for it involves certain properties of water.

Or again, to take a case involving, no doubt, the properties of a quantity of electricity, the electron, Planck's constant gives us the ratio of a quantity of energy to the frequency of an electron and thus enables us to express the frequency of an electron in dynamical units.

R. T. GLAZEBROOK.

Ballards Oak,
Limpsfield,
Surrey.
Dec. 2.

Production of Neutrons by Annihilation of Protons and Electrons According to Fermi's Theory

IN the theory of β-decay as proposed by Fermi[1], one assumes the existence of elementary processes in which a neutron is transformed into a proton by simultaneous creation of an electron and a neutrino. For the inverse process, which is also naturally contained in Fermi's theory, one needs the previous existence of an electron and a neutrino. It might therefore be thought that a proton cannot be transformed into a neutron without the presence of a neutrino source. Such a source, however, is not necessary if it be admitted that in empty space all negative neutrino states are occupied in the same way as the negative energy states of the electron in Dirac's theory of the positron. In this case, for example, the presence of an electron alone is sufficient since the neutrino can be furnished from a negative state.

The transformation of protons into neutrons by positron emission has already been treated by Uhlenbeck and Wolfe[2]. Of course, it could only occur if for the masses M_P, M_N and m of proton, neutron and electron respectively, the relation

$$D = M_N c^2 - M_P c^2 < -mc^2 \qquad (1)$$

were valid. Recent data for the neutron mass seem to exclude such a relation.

By a process of the kind mentioned above, however, the proton in the hydrogen atom together with the electron can be transformed into a neutron, if

$$D < mc^2 - J, \qquad (2)$$

J being the ionisation energy.

Since, at present, relation (2) cannot be excluded with certainty, we have calculated the rate of transition of a hydrogen atom into a neutron. The result depends somewhat on the form of the interaction between the heavy particle and the electron-neutrino field. We have used two such forms, that proposed originally by Fermi (l.c.), the other by Konopinski and Uhlenbeck[3], and we find in the former case:

$$R' = \frac{\Delta^2}{T}; \qquad (3a)$$

and in the latter,

$$R'' = \frac{\Delta^4}{T}; \qquad (3b)$$

$$\text{where } T = \frac{2\pi^2\hbar^4}{g^2\alpha^3 m^2 c} = 8 \cdot 8 \times 10^{10} \text{ sec.} \qquad (4)$$

$$\text{and } \Delta = \frac{mc^2 - J - D}{mc^2} \qquad (5)$$

g is the universal constant as determined by the β-decay with the value $g = 4 \times 10^{-50}$ cm.³ erg; $2\pi\hbar$ is Planck's quantum of action; α is the reciprocal of the Bohr radius; c is the velocity of light; and J is the ionisation energy of the hydrogen atom.

If by a very cautious estimation we assume that the lifetime of hydrogen is certainly longer than 10^{13} sec., we find as a lower limit of D from (3a):

$$D > 0 \cdot 9\ mc^2 = 4 \cdot 5 \times 10^5 \text{ e.v.}; \qquad (5a)$$

from (3b):

$$D > 0 \cdot 6\ mc^2 = 3 \times 10^5 \text{ e.v.} \qquad (5b)$$

Since it is very likely that not only are the relations (5) satisfied but also that D is considerably larger than mc^2, a transformation of protons into neutrons could only occur by bombardment with electrons of high energy. We have also treated this case neglecting the Coulomb interaction between the proton and the electron. For the cross-section we obtain with

$$\Gamma = \frac{E - D}{mc^2},$$

in the Fermi case

$$\Phi' = A \frac{c}{v} \Gamma^2; \qquad (6a)$$

in the Uhlenbeck case

$$\Phi'' = A \frac{c}{v} \Gamma^4. \qquad (6b)$$

E and v are energy and velocity of the incident electron; A is the universal area

$$A = \frac{g^2 m^2}{2\pi\hbar^4} = 1 \cdot 7 \times 10^{-44} \text{ cm.}^2 \qquad (7)$$

The smallness of the value (7) will scarcely permit detection of our effect, although it increases rapidly with the electron energy. Our calculations have been carried out on the assumption that the mass of the neutrino is small compared with the mass of the electron. In addition, for simplicity, terms of the order m/M have been neglected.

F. BLOCH.
C. MØLLER.

Universitetets Institut for
Teoretisk Fysik,
København.
Oct. 26.

[1] E. Fermi, *Z. Phys.*, **88**, 161; 1934.
[2] *Phys. Rev.*, **46**, 237; 1934.
[3] *Phys. Rev.*, **48**, 7; 1935.