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Letters to the Editor

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An Attempt at Finding the Relationship Between the Nuclear Force and the Gravitational Force

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THE best we know about the nuclear force is that it is of short range type. Its analytic form is still unknown. The meson theory of nuclear force is, up to the present at least, inconclusive.[1] On the other hand, the gravitational force is explained by the theory of general relativity. If we temporarily disregard the theory of general relativity and pay attention to the important fact that both the nuclear force and the gravitational force are attractive, we may assume that these two forces are of the same origin. Let us tentatively take the function

$$V=-Ae^{K/r} \tag{1}$$

as the mutual potential between any two nuclear particles, i.e., between two protons, two neutrons, or one proton and one neutron, with A and K as constants. Then, as the distance r between the particles becomes much larger than K, Eq. (1) turns out to be

$$V=-A-(AK/r)-\cdots. \tag{2}$$

In this expression, the first term on the right-hand side is a constant, and therefore is of no consequence. Thus

$$V(r)=-AK/r. \tag{3}$$

On the other hand, the gravitational potential between the two nuclear particles of masses M and M' should be given by

$$V=-G(MM'/r). \tag{4}$$

If the nuclear force and gravitational force are really of the same origin, we must have, from (3) and (4),

$$AK=GMM'=1.83\times10^{-55}\text{ erg cm}, \tag{5}$$

since $G=6.66\times10^{-8}$ and $M=M'=1.66\times10^{-24}$. Recently, Ragan, Kanne, and Taschek,[2] from the proton-proton scattering experiment, found that the potential between two protons can be represented by a rectangular well of width $2e^2/mc^2$ and depth 10.5 Mev. Now if from our equation (5), we put K as the Compton wave-length of electron, i.e., $K=h/mc=3.83\times10^{-11}$ cm, we get $A=4.80\times10^{-45}$, and if we substitute these values of K and A into (1), we find the potential $V=10.5$ Mev at $r=1.51e^2/mc^2$ which is only a little smaller than the experimental value of $2e^2/mc^2$. In fact, if the potential is not a straight rectangular well but a slightly curved one, for the same depth of potential, a smaller value of r is expected. If, instead of Eq. (1), we take

$$V=-(B/r)e^{K/r}=-(AK/r)e^{K/r} \tag{6}$$

as the nuclear potential function, we get the result $V=10.5$ Mev at $r=1.62\ e^2/mc^2$ which checks even better with the experimental value. Thus we may tentatively state that:

$$\begin{aligned} V&=-(B/r)e^{K/r} \quad \text{for } r>a \\ V&=-(B/a)e^{K/a} \quad \text{for } r\leqq a \end{aligned} \tag{7}$$

for a certain value of a, the exact value of which is of no great importance at present. Since the value of K is *not* purely arbitrary, but is chosen as the Compton wave-length of electron, the agreement between the experimental and the calculated value is perhaps not accidental, and may indicate that the electron, as has long been suggested, plays an important role in nuclear interactions. If it is required to avoid the rather artificial way of "cutting off" of the expression (7) at $r=a$, we give an alternative expression

$$V=-A\exp\left[\frac{K}{r}-\left(\frac{K'}{r}\right)^n\right], \tag{8}$$

with n lying between 1 and 2, and K' a new constant which may tentatively be put as the Compton wave-length of meson, i.e., $K'=h/m'c\approx h/180mc$, but this makes the width of the potential well smaller than $1.51\ e^2/mc^2$. It will be seen in a paper by M. S. Wang[3] that good results for the binding energy of deutron and the scattering cross section of protons by fast neutrons can actually be obtained by calculations in employing either the potential function (1) or (6). In conclusion, we express our gratitude to discussions with our colleague, Professor H. P. Soh.

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[1] H. A. Bethe, Phys. Rev. **57**, 260, 390 (1940).

[2] G. L. Ragan, W. R. Kanne, and R. F. Taschek. Phys. Rev. **60**, 628 (1941). See also T. H. Osgood, J. App. Phys. **14**, 53 (1943);

[3] M. S. Wang, Phys. Rev. **66**, 103 (1944).