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About Nature of Nuclear Forthes

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

After the discovery of the proton-neutron composition of nuclei, the problem of nuclear forces nature became especially urgent.

Nowadays, nuclear forces are explained by the action of a special strong interaction that occurs when nuclear nucleons exchange special particles - gluons.

This article proves that the attraction between protons and neutrons can be explained by the well-known quantum mechanical effect, which was first described about a hundred years ago. This is the attraction between two protons that occurs when they are exchanged by electron (in this case relativistic). This makes it possible, abandoning the gluon model, to obtain quantitative estimates of the magnitude of the mass defect of both light and heavy nuclei.

Keywords: Proton; neutron; nuclear forth; electron; light nuclei; heavy nuclei; defect of mass.

1 INTRODUCTION

British scientist William Gilbert formulated about 400 years ago a postulate that can be considered the main postulate of the natural sciences [1]. According to Gilbert, all theoretical constructions claiming to be scientific should be tested and confirmed experimentally.

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Despite the fact that nowadays it is apparently impossible to find a researcher who would disagree with this statement, a number of modern physical theories do not satisfy this principle [2].

In the physics of the microcosm, this refers to those theories from which it is impossible to calculate the main characteristic parameters of the objects under study. These include existing models of nuclear physics, which do not make it possible to calculate the masses of atomic nuclei.

An alternative approach to solving this problem is discussed below.

This new approach to the problem of the nature of strong interaction is based on the effect of attraction described by the classics of quantum mechanics almost a hundred years ago. This attraction occurs between protons during the exchange of electron [3]. To describe the attraction of nuclear objects, it is necessary to take into account that electrons in this case must be relativistic [4, 5].

In this case, neutron is considered as a composite particle consisting of proton and relativistic electron, which makes it possible to fairly accurately estimate the mass of neutron, its magnetic moment and decay energy.

What are the features of the forces acting between nucleons inside nuclei?

The enormous binding energy of nucleons indicates that these inter-nucleon forces are created by a very intense interaction. This interaction has the character of attraction if the nucleons are at short distances from each other, despite the strong electrostatic repulsion between the protons.

Nuclear forces are short-acting - at distances between nucleons exceeding about $2 \cdot 10^{-13}$ cm, their action is no longer detectable. At distances less than 10^{-13} cm, the attraction of nucleons is replaced by repulsion.

The intra-nuclear interaction is not Coulomb, it does not depend on the charge of the nucleons.

The nuclear forces depend on the mutual orientation of spins of interacting nucleons. For example, neutron and proton are held together to form deuteron only when their spins are parallel to each other.

Nuclear forces have a saturation property (which means that each nucleon in the nucleus interacts with a limited number of nucleons). This property follows from the fact that the binding energy per nucleon is approximately the same for all nuclei, starting from ^4_2He. In addition, the saturation of nuclear forces is also indicated by the proportionality of the volume of the nucleus to the number of nucleons forming it.

The dependence of the binding energy (in MeV) per nucleon on the mass number of the nucleus is shown in Fig.1.

From this figure it can be seen that there are two different mechanisms that determine the nuclear forces in light and heavy nuclei differently.

In solving these problems, the first important step is to build a neutron model that makes it possible to predict its main observable properties.

2 ELECTROMAGNETIC MODEL OF NEUTRON

2.1 Neutron and the Quark Model

There are several theoretical constructions of the twentieth century that need to be revised due to their incompleteness or disagreement with the measurement data [2]. Apparently, the quark model of elementary particles can be replaced by a description of their excited states [6].

The formation of the quark model in the chain of the science of the structure of matter seems to be quite consistent: all substances consist of molecules and atoms. The central elements of atoms are nuclei. Nuclei consist of protons and neutrons, which in turn consist of quarks.

The quark model assumes that almost all elementary particles consist of quarks. The quark structure of nucleons is of particular interest in this case.

It seems that experts in elementary particle physics initially proceeded from the assumption that at the creation of the world, suitable parameters were individually selected for each elementary particle: charge, spin, mass, magnetic moment, etc.

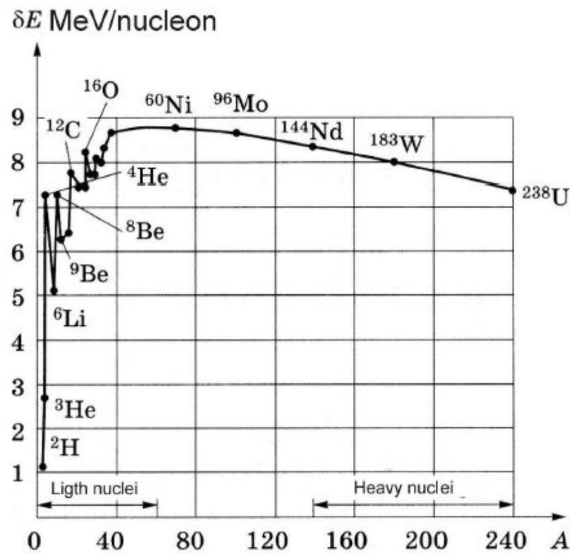

Fig. 1. The binding energy per one nucleon of the nucleus

Gell-Mann simplified this work somewhat. He developed a rule according to which a set of quarks determines the total charge and spin of the formed elementary particle but masses and magnetic moments of these particles do not fall under this rule.

The Gell-Mann quark model assumes that quarks, which make up all elementary particles (with the exception of the lightest), must have a fractional (equal to 1/3 e or 2/3 e) electric charge.

In the 60s, after the formulation of this model, many experimenters tried to find particles with a fractional charge but without success.

In order to explain this, it was assumed that quarks are characterized by a confinement, i.e. a property that prohibits them from somehow manifesting themselves in a free state. At the same time, it is clear that confinement removes quarks from subordination to the Gilbert principle. In this form, the model of quarks with fractional charges claims to be scientific without confirmation by measurement data.

It should be noted that the quark model successfully describes some experiments on the scattering of particles at high energies, for example, the formation of jets or the feature of scattering of high-energy particles without destruction. However, this does not seem to be enough to recognize the real existence of quarks with a fractional charge.

In the 30s of the last century, theoretical physicists, due to the lack of necessary experimental data, formed the opinion that neutrons, like protons, are elementary particles [7]. In the Gell-Mann quark model, the neutron is also assumed to be an elementary particle in the sense that it consists of a different set of quarks than proton.

However, the fact that neutron is an unstable particle and decays into proton and electron (+ antineutrino) gives reason to attribute it to non-elementary composite particles.

The quark model does not aim to predict the basic properties of neutron, such as its mass, magnetic moment and decay energy. The electromagnetic model of neutron makes it possible to successfully evaluate these parameters [4].

Suppose that neutron, as well as a Bohr hydrogen atom, consists of proton around which electron rotates at a very small distance from it. Near proton, the electron's motion must be relativistic.

2.2 The Interaction of Relativistic Electron with Proton

Consider a composite particle in which an electron having a rest mass m_e and a charge $-e$ is moving around a proton in a circle of radius R_e with a speed $v_e \to c$ (Fig. 2).

Since we initially assume that the motion of the electron is likely to be relativistic, it is necessary to take into account the relativistic effect of the growth of its mass:

$$m_e^* = \gamma m_e, \tag{1}$$

where the relativistic factor

$$\gamma = \frac{1}{\sqrt{1-\beta^2}} \tag{2}$$

and $\beta = \frac{v}{c}$.

The rotation of the heavy electron m_e^* does not allow to consider the proton as at rest. The proton will also move, revolving around the center of mass common with the heavy electron.
Let's introduce a parameter characterizing the ratio of the mass of a relativistic electron to the mass of proton:

$$\vartheta = \frac{\gamma m_e}{M_p/\sqrt{1-\beta_p^2}}. \tag{3}$$

It follows from the condition of equality of momenta that $\beta_p = \vartheta$ therefore the radii of the orbits of the electron and proton can be written as:

$$R_e = \frac{R_{ep}}{1+\vartheta}, \qquad R_p = \frac{R_{ep}\vartheta}{1+\vartheta}. \tag{4}$$

Where $R_{ep} = R_e + R_p$.

The relativistic factor characterizing the electron in this case is equal to

$$\gamma = \frac{\vartheta}{\sqrt{1-\vartheta^2}} \frac{M_p}{m_e}. \tag{5}$$

2.2.1 Larmor's theorem

To describe the characteristic feature of proton motion along a circle of radius R_p, we can use Larmor's theorem [8]. According to this theorem, in a reference frame rotating with proton at a frequency of Ω, a magnetic field is applied to it. This field is determined by its gyromagnetic ratio

$$H_L = \frac{\Omega}{\xi \frac{e}{2M_p c}}. \tag{6}$$

Where ξ =2.79 is the magnetic moment of the proton in units of Bohr magnetons.

As a result of the action of this field, the proton magnetic moment turns out to be oriented perpendicular to the plane of rotation. In other words, we can say that due to the interaction with this field, the rotation of the electron should occur in the plane of the "equator" of proton.

2.2.2 Quantization of equilibrium orbit

It can be assumed that, as in the formation of a stable orbit in a hydrogen atom, the orbit of a relativistic electron will be stable if an integer number of de Broglie wavelengths λ_{dB} fits on the circumference of the electron ring $2\pi R_e$, that is:

$$2\pi R_e = n\lambda_{dB}. \tag{7}$$

Where n is integer number
and

$$\lambda_{dB} = \frac{2\pi\hbar}{\gamma m_e c}. \tag{8}$$

That is, in accordance with this assumption, the stability condition of the electronic orbit takes the form:

$$\frac{r_c}{R_e} = \frac{\vartheta}{n\sqrt{1-\vartheta^2}} \frac{M_p}{m_e} = \frac{\gamma}{n} \tag{9}$$

Where $r_c = \frac{\hbar}{m_e c}$ is Compton radius.

2.2.3 The kinetic energy of rotating electron

The kinetic energy of a relativistic electron is expressed by the equality:

$$\mathcal{E}^e_{kin} = (\gamma - 1) \cdot m_e c^2 \tag{10}$$

Due to the assumption of the electron to be ultrarelativistic

$$\mathcal{E}^e_{kin} \approx \gamma \cdot m_e c^2 \tag{11}$$

In this case, the centrifugal force acts on the electron:

$$\mathcal{F}_1 = \gamma m_e[\omega[\omega, R_e]] = \frac{\gamma m_e c^2}{R_e} \tag{12}$$

The kinetic energy of proton is equal to:

$$\mathcal{E}^p_{kin} = \left(\frac{1}{\sqrt{1-\vartheta^2}} - 1\right) \cdot M_p c^2 \tag{13}$$

An additional contribution to the kinetic energy of electron creates a magnetic field that occurs when it rotates. The energy of this field is equal to

$$\mathcal{E}_\Phi = \frac{\Phi I}{2c}, \tag{14}$$

Due to the fact that the electron motion in the orbit is quantized, the magnetic flux penetrating the ring of radius R_e must be equal to the quantum of the magnetic flux Φ_0:

$$\Phi = \Phi_0 = \frac{2\pi\hbar c}{e}. \tag{15}$$

Since the current in the electronic ring

$$I = \frac{ec}{2\pi R_e}, \tag{16}$$

we have

$$\mathcal{E}_{\Phi_e} = \frac{e^2}{R_e}\frac{1}{2\alpha}\frac{r_c}{R_e} = \frac{1}{2n}\gamma m_e c^2. \tag{17}$$

The force arising at the same time, tending to break the current ring, turns out to be equal

$$\mathcal{F}_2 = \frac{\gamma}{2n}\frac{m_e c^2}{R_e}. \tag{18}$$

The magnetic energy created by the rotation of a proton is much less:

$$\mathcal{E}_{\Phi_p} = \frac{\sqrt{2}\cdot\vartheta^2}{\sqrt{1-\vartheta^2}}\cdot M_p c^2. \tag{19}$$

The force corresponding to this energy is applied to proton and does not directly affect the electron equilibrium orbit.

Thus, the total kinetic energy of the electron, taking into account the energy of the magnetic field that it creates when rotating:

$$\mathcal{E}_{kin}^{\Sigma} = \mathcal{E}_{kin}^{e} + \mathcal{E}_{\Phi_e} = \left(1+\frac{1}{2n}\right)\gamma m_e c^2. \tag{20}$$

2.2.4 The Coulomb interaction in the system of relativistic electron + proton

The energy of Coulomb attraction between a proton and a relativistic electron is [8],§24:

$$\mathcal{E}_C = -\gamma\frac{e^2}{R_{ep}} = -\gamma\frac{\alpha r_c}{R_e(1+\vartheta)}m_e c^2. \tag{21}$$

Where $\alpha = \frac{e^2}{\hbar c}$ is the fine structure constant.

Therefore, the Coulomb attraction force acting between these particles is equal to

$$\mathcal{F}_3 = -\gamma\frac{e^2}{R_{ep}^2} = -\gamma\frac{\alpha}{(1+\vartheta)^2}\frac{r_c}{R_e}\frac{m_e c^2}{R_e}. \tag{22}$$

2.2.5 Interaction of electron with magnetic field of proton

In the present case a proton possesses two magnetic moments. This is its own internal magnetic moment:

$$\mu_p = \frac{\xi e\hbar}{2M_p c} \tag{23}$$

and the orbital magnetic moment which occurs due to the fact that proton rotates in an orbit of radius R_p:

$$\mu_{0p} = \frac{e\vartheta R_p}{2} \tag{24}$$

Therefore, the energy of interaction of rotating electron with the proton magnetic field consists from two components:

$$\mathcal{E}_\mu = \frac{\gamma e}{2R_e^2}\left(\mu_{0_p} - \mu_p\right). \tag{25}$$

In order for the system energy to be less, the magnetic moments μ_p and μ_{0_p} must be oppositely directed.

The force that acts on the rotating electron can be written as:

$$\begin{aligned}\mathcal{F}_4 &= \gamma e\beta\left(\frac{\mu_{0_p}}{R_e^3} - \frac{\mu_p}{R_{ep}^3}\right) = \\ &= \gamma e\left(\frac{\mu_{0_p}}{R_e^3} - \frac{\mu_p}{R_e^3(1+\vartheta)^3}\right) = \\ &= \gamma\frac{m_e c^2}{R_e}\left(\frac{\vartheta^2}{2} - \frac{\xi_p}{(1+\vartheta)^3}\frac{\vartheta}{2n\sqrt{1-\vartheta^2}}\right)\frac{\vartheta}{2n\sqrt{1-\vartheta^2}}\alpha\frac{M_p}{m_e}.\end{aligned} \tag{26}$$

The magnetic moment of electron is not considered because, as will be shown below, the generalized momentum (spin) of the electron orbit is equal to zero and there is no direction for the selected orientation of the electron magnetic moment in the system.

2.2.6 Equilibrium electron orbit

The equilibrium condition for the electron orbit is:

$$\sum_{i=1}^{4}\mathcal{F}_i = 0. \tag{27}$$

At summing of Eq.(12), Eq.(22),Eq.(18) and Eq.(26)

$$\gamma\frac{m_e c^2}{R_e} - \gamma\frac{e^2}{R_{ep}^2} + \gamma\frac{m_e c^2}{2R_e} - \gamma e\left(\frac{\mu_{0p}}{R_e^3} - \frac{\mu_p}{R_{ep}^3}\right) = 0. \tag{28}$$

and after simplifying transformations taking into account Eq.(9) we get:

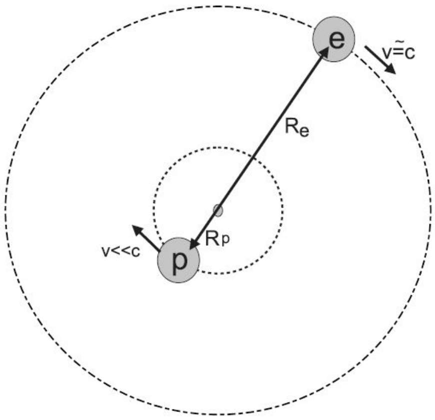

Fig. 2. A system consisting of a proton and a heavy (relativistic) electron, revolving around a common center of mass

$$1+\frac{1}{2n}-\left(\frac{\vartheta}{n\sqrt{1-\vartheta^2}}\frac{\alpha M_p}{m_e}\right)\left[\frac{1}{(1+\vartheta)^2}+\frac{\vartheta^2}{2}-\frac{\xi}{2n(1+\vartheta)^3}\frac{\vartheta}{\sqrt{1-\vartheta^2}}\right]=0. \quad (29)$$

2.3 The Basic State of Neutron

The basic state of this system with the minimal energy is realised at n=1, that is, the length of the electron orbit is equal to the de Broglie wavelength.

We need to find a solution of Eq.(29) under this condition:

$$\frac{3}{2}-\alpha\gamma\left[\frac{1}{(1+\vartheta)^2}+\frac{\vartheta^2}{2}-\frac{\xi\gamma}{2(1+\vartheta)^3}\frac{m_e}{M_p}\right]=0. \quad (30)$$

As the result we have

$$\vartheta=0.1991 \quad (31)$$

and

$$R_e=1.2413\cdot 10^{-13}cm \quad (32)$$

2.4 Equilibrium Electron Orbit. Approximate Solution

The complex Eq.(30) defining the parameter ϑ can be simplified. Its decomposition gives an approximate expression

$$\vartheta_1\approx\frac{3\sqrt{\pi}}{2}\frac{m_e}{\alpha M_p}\approx 0.1985. \quad (33)$$

We can introduce the value of the new fundamental length R_*, expressed in terms of the Compton radius r_c or the Bohr radius a_B:

$$R_*=\alpha r_c=\alpha^2 a_B=\frac{e^2}{m_e c^2}=2.8183\cdot 10^{-13}cm \quad (34)$$

The radius of the electron orbit is equal in order of magnitude to the fundamental length R_*:

$$R_e=r_C\frac{\sqrt{1-\vartheta^2}}{\vartheta}\frac{m_e}{M_p}\approx\frac{R_*}{\sqrt{8}}=9.9\cdot 10^{-14}cm. \quad (35)$$

This value is consistent with the estimate obtained earlier [4]:

$$R_e=\frac{\hbar}{c}\sqrt{\frac{\alpha\xi}{2m_e M_p}}=9.1\cdot 10^{-14}cm \quad (36)$$

2.4.1 Spin of neutron

The total generalized electron momentum can be written as

$$S_{0e}=\left[R_e\times\gamma\left\{m_e c-\frac{e}{c}A_e\right\}\right] \quad (37)$$

Or in the scalar form

$$S_{0e}=\gamma m_e c R_e\left\{\frac{3}{2}-\alpha\gamma\left(\frac{1}{(1+\vartheta)}-\frac{1-\vartheta^2}{2}+\alpha\gamma\frac{\xi_p}{(1+\vartheta)^2}\frac{m_e}{\alpha M_p}\right)\right\}. \quad (38)$$

Substituting the values of ϑ and R_e calculated above into this equality, we come to the conclusion that

$$S_{0e} = 0. \tag{39}$$

For this reason, the total spin of particles in question is 1/2 because it is created by the spin of proton.

The equality to zero of the spin of this electron ring plays an important role in the formation of the equilibrium state of system. Due to the fact that $S_0 = 0$ the electron's own spin and its magnetic moment are devoid of orientation direction in space and fall out of the balance equations, and therefore out of consideration in this problem altogether.

2.4.2 Mass of neutron

The mass of a composite particle is determined by the sum of the rest masses of the particles, their relativistic kinetic energy and the mass defect arising from the potential energy of their internal interaction. Calculate these contributions

Kinetic energy of electron and proton Summing Eqs.(11),(13),(17) and (19) at n=1 we obtain

$$\mathcal{E}(kin) = \frac{\vartheta}{\sqrt{1-\vartheta^2}}\left[1 + \left(\frac{1}{\sqrt{1-\vartheta^2}} - 1\right)\frac{\sqrt{1-\vartheta^2}}{\vartheta} + \left(\frac{1}{2} + \sqrt{2}\vartheta\right)\right] \cdot M_p c^2 \tag{40}$$

Potential energy of electron and proton Summing Eqs.(21) and (25) at n=1 we obtain

$$\mathcal{E}(pot) = \frac{\alpha M_p}{m_e}\left[\frac{1}{1+\vartheta} + \frac{\vartheta^2}{2}\left(1 - \frac{1}{(1+\vartheta)^3} \cdot \frac{\xi_p}{\cdot\vartheta\sqrt{1-\vartheta^2}}\right)\right]\left(\frac{\vartheta}{\sqrt{1-\vartheta^2}}\right)^2 \cdot M_p c^2. \tag{41}$$

The neutron mass The total mass of proton and electron is equal to:

$$\mathcal{M}^{e+p} = m_e + M_p + \frac{E_0}{c^2} \tag{42}$$

Here E_0 is the total energy possessed by a relativistic electron+proton

$$\begin{gathered} E_0 = \mathcal{E}(kin) - \mathcal{E}(pot) = \\ = \frac{\vartheta}{\sqrt{1-\vartheta^2}}\left[1 + \left(\frac{1}{\sqrt{1-\vartheta^2}} - 1\right)\frac{\sqrt{1-\vartheta^2}}{\vartheta} + \left(\frac{1}{2n} + \sqrt{2}\vartheta\right)\right] \cdot M_p c^2 - \\ -\frac{\alpha M_p}{n m_e}\left[\frac{1}{1+\vartheta} + \frac{\vartheta^2}{2}\left(1 - \frac{1}{(1+\vartheta)^3} \cdot \frac{\xi}{n \cdot \vartheta\sqrt{1-\vartheta^2}}\right)\right]\left(\frac{\vartheta}{\sqrt{1-\vartheta^2}}\right)^2 \cdot M_p c^2 \end{gathered} \tag{43}$$

Hence it turns out

$$E_0 = 2.04 \cdot m_e c^2 \tag{44}$$

The sum of kinetic and potential energy thus obtained must correspond to the energy released during the decay of the particle. This estimate is in qualitative agreement with the measured data (Table.1).

2.4.3 The neutron magnetic moment

The particle magnetic moment is the sum of the proton magnetic moment and magnetic moments of orbital currents of electron and proton.

The total magnetic moment generated by of both circular currents

$$\mu_0 = -\frac{e\beta_e R_e}{2} + \frac{e\beta_p R_p}{2} = \frac{eR_{ep}}{2}\frac{(1-\vartheta^2)}{(1+\vartheta)} = \frac{eR_{ep}}{2}(1-\vartheta). \tag{45}$$

If to express this moment in the magnetons of Bohr μ_B, we get

$$\xi_0 = \frac{\mu_0}{\mu_B} = -\frac{(1-\vartheta^2)\sqrt{1-\vartheta^2}}{\vartheta}. \quad (46)$$

At $\vartheta = 0.1991$ we have

$$\xi_0 \approx -4.7269 \quad (47)$$

Summing it with the proton magnetic moment, we get

$$\xi_{total} = \left[-\frac{(1-\vartheta^2)\sqrt{1-\vartheta^2}}{\vartheta} + 2.79\right] \approx -1.9341. \quad (48)$$

It agrees well with the tabular value

$$\xi_{neutron} = -1.91304273. \quad (49)$$

2.5 The Excited States of Neutron

Just like the Bohr atom, a neutron, in addition to the ground state, can have excited states with $n > 1$.

2.5.1 The excited state with n=2

Under this condition Eq(29) transforms to:

$$1 + \frac{1}{2\cdot 2} - \left(\frac{\vartheta}{2\sqrt{1-\vartheta^2}}\frac{\alpha M_p}{m_e}\right)\left[\frac{1}{(1+\vartheta)^2}\right] + \\ + \left(\frac{\vartheta}{2\sqrt{1-\vartheta^2}}\frac{\alpha M_p}{m_e}\right)\left[\frac{\vartheta^2}{2} - \frac{\xi}{2\cdot 2(1+\vartheta)^3}\frac{\vartheta}{\sqrt{1-\vartheta^2}}\right] = 0. \quad (50)$$

The solution to this equation is

$$\vartheta = 0.263. \quad (51)$$

2.5.2 The excited state with n=3

At that the equation is

$$1 + \frac{1}{2\cdot 3} - \left(\frac{\vartheta}{3\sqrt{1-\vartheta^2}}\frac{\alpha M_p}{m_e}\right)\left[\frac{1}{(1+\vartheta)^2}\right] - \\ - \left(\frac{\vartheta}{3\sqrt{1-\vartheta^2}}\frac{\alpha M_p}{m_e}\right)\left[\frac{\vartheta^2}{2} - \frac{\xi}{2\cdot 3(1+\vartheta)^3}\frac{\vartheta}{\sqrt{1-\vartheta^2}}\right] = 0 \quad (52)$$

and its solution is

$$\vartheta = 0.479. \quad (53)$$

For comparison, the calculated and measured values of masses and magnetic moments of neutron and its excited states are given in Tables 1 and 2.

Based on this comparison, we conclude that neutral Λ- and Σ-hyperons are excited states of neutron [6].

3 DISCUSSION

The consent of estimates and measured data indicates that the neutron is not an elementary particle [5]. At that neutron is unique object of microcosm. Its main peculiarity lies in the fact that the proton and electron that compose it are related to each other by a (negative) binding energy. The neutron mass is greater than the sum of the rest masses of proton and electron despite the presence of a mass defect. This is because proton and electron, forming neutron, are relativistic and their masses are much higher than their rest masses. In result the bound state of neutron disintegrates with the energy releasing.

This structure of neutron must change our approach to the problem of nucleon-nucleon scattering. The nuclear part of an amplitude of the nucleon-nucleon scattering should be the same at all cases, because in fact it is always proton-proton scattering (the only difference is the presence or absence of the Coulomb scattering). It creates the justification for hypothesis of charge independence of the nucleon-nucleon interaction.

The above considered electromagnetic model of neuron is the only theory that predicts the basic properties of the neutron. According to Gilbert's postulate, all other models (and in particular the quark model of neutron) that can not describe properties of neutron can be regarded as speculative and erroneous. The measurement confirmation for the discussed above electromagnetic model of neutron is the most important, required and completely sufficient argument of its credibility.

Nevertheless, it is important for the understanding of the model to use the standard theoretical apparatus at its construction. It should be noted that for the scientists who are accustomed to the language of relativistic quantum physics, the methodology used for the above estimates does not contribute to the perception of the results at a superficial glance. It is commonly thought that for the reliability, a consideration of an affection of relativism on the electron behavior in the Coulomb field should be carried out within the Dirac theory. However that is not necessary in the case of calculating of the magnetic moment of the neutron and its decay energy. In this case, all relativistic effects described by the terms with coefficients $\left(1 - \frac{v^2}{c^2}\right)^{-1/2}$ compensate each other and completely fall out. The neutron considered in our model is the quantum object. Its radius R_0 is

Table 1. The comparison of calculated particle mass values with measurement data

n	$\frac{\varepsilon_{kin}}{c^2}$	$\frac{\varepsilon_{pot}}{c^2}$	M_{total} Eq.(43)	experimental data	$\Delta = \frac{M_{exp}-M_{calc}}{M_{exp}}$
n=1	$702m_e$	$700m_e$	$1839m_e$	$M_{n_0} = 1837m_e$	0.001
n=2	$879m_e$	$778m_e$	$1938m_e$	$M_{\Lambda^0} = 2183m_e$	0.11
n=3	$2103m_e$	$1740m_e$	$2200m_e$	$M_{\Sigma^0} = 2335m_e$	0.06

Table 2. Comparison of calculated values of magnetic moments with measurement data

n	ϑ	μ_0 Eq.(46)	μ_{total} Eq.(48)	experimental. data
n=1	0.1991	-4.727	-1. 9367	$\mu_{n_0} = -1.9130427 \pm 0.0000005$
n=2	0.263	-3.4147	-0.6247	$\mu_{\Lambda^0} = -0.613 \pm 0.004$
n=3	0.479	-1.4121	1.3779	$\mu_{\Sigma^0_{\Sigma\Lambda}} = 1.61 \pm 0.08$

proportional to the Planck constant $\hbar$. But it can not be considered as relativistic particle, because coefficient $\left(1 - \frac{v^2}{c^2}\right)^{-1/2}$ is not included in the definition of R_0. In the particular case of the calculation of the magnetic moment of the neutron and the energy of its decay, it allows to find an equilibrium of the system from the balance of forces, as it can be made in the case of non-relativistic objects. The another situation arises on the way of an evaluation of the neutron lifetime. A correct estimation of this time even in order of its value do not obtained at that.

4 THE ONE-ELECTRON BOND OF TWO PROTONS

4.1 The Heitler-London Effect

Let us consider a quantum system consisting of two protons and one electron. If protons are separated by a large distance, this system consists of a hydrogen atom and the proton. If the hydrogen atom is at the origin, then the operator of energy and wave function of the ground state have the form:

$$H_0^{(1)} = -\frac{\hbar^2}{2m}\nabla_r^2 - \frac{e^2}{r}, \qquad \varphi_1 = \frac{1}{\sqrt{\pi a^3}} e^{-\frac{r}{a}} \tag{54}$$

If hydrogen is at point R, then respectively

$$H_0^{(2)} = -\frac{\hbar^2}{2m}\nabla_r^2 - \frac{e^2}{|\overrightarrow{R} - \overrightarrow{r}|}, \qquad \varphi_2 = \frac{1}{\sqrt{\pi a^3}} e^{-\frac{|\overrightarrow{R} - \overrightarrow{r}|}{a}} \tag{55}$$

In the assumption of fixed protons, the Hamiltonian of the total system has the form:

$$H = -\frac{\hbar^2}{2m}\nabla_r^2 - \frac{e^2}{r} - \frac{e^2}{|\overrightarrow{R} - \overrightarrow{r}|} + \frac{e^2}{R} \tag{56}$$

At that if one proton removed on infinity, then the energy of the system is equal to the energy of the ground state E_0, and the wave function satisfies the stationary Schrodinger equation:

$$H_0^{(1,2)}\varphi_{1,2} = E_0\varphi_{1,2} \tag{57}$$

We seek a zero-approximation solution in the form of a linear combination of basis functions:

$$\psi = a_1(t)\varphi_1 + a_2(t)\varphi_2 \tag{58}$$

where coefficients $a_1(t)$ and $a_2(t)$ are functions of time, and the desired function satisfies to the energy-dependent Schrodinger equation:

$$i\hbar\frac{d\psi}{dt} = (H_0^{(1,2)} + V_{1,2})\psi, \tag{59}$$

where $V_{1,2}$ is the Coulomb energy of the system in one of two cases.
Hence, using the standard procedure of transformation, we obtain the system of equations

$$\begin{aligned} i\hbar\dot{a}_1 + i\hbar S\dot{a}_2 &= E_0\Big\{(1 + Y_{11})a_1 + (S + Y_{12})a_2\Big\} \\ i\hbar S\dot{a}_1 + i\hbar\dot{a}_2 &= E_0\Big\{(S + Y_{21})a_1 + (1 + Y_{22})a_2\Big\}, \end{aligned} \tag{60}$$

where we have introduced the notation of the overlap integral of the wave functions

$$S = \int \phi_1^* \phi_2 dv = \int \phi_2^* \phi_1 dv \tag{61}$$

and notations of matrix elements

$$\begin{aligned} Y_{11} &= \frac{1}{E_0} \int \phi_1^* V_1 \phi_1 dv \\ Y_{12} &= \frac{1}{E_0} \int \phi_1^* V_2 \phi_2 dv \\ Y_{21} &= \frac{1}{E_0} \int \phi_2^* V_1 \phi_1 dv \\ Y_{22} &= \frac{1}{E_0} \int \phi_2^* V_2 \phi_2 dv \end{aligned} \tag{62}$$

Given the symmetry

$$Y_{11} = Y_{22} \qquad Y_{12} = Y_{21}, \tag{63}$$

after the adding and the subtracting of equations of the system (60), we obtain the system of equations

$$\begin{aligned} i\hbar(1+S)(\dot{a}_1 + \dot{a}_2) &= \alpha(a_1 + a_2) \\ i\hbar(1-S)(\dot{a}_1 - \dot{a}_2) &= \beta(a_1 - a_2) \end{aligned} \tag{64}$$

Where

$$\begin{aligned} \alpha &= E_0 \Big\{ (1+S) + Y_{11} + Y_{12} \Big\} \\ \beta &= E_0 \Big\{ (1-S) + Y_{11} - Y_{12} \Big\} \end{aligned} \tag{65}$$

As a result, we get two solutions

$$\begin{aligned} a_1 + a_2 &= C_1 exp\left(-i\frac{E_0}{\hbar}t\right) exp\left(-i\frac{\epsilon_1}{\hbar}t\right) \\ a_1 - a_2 &= C_2 exp\left(-i\frac{E_0}{\hbar}t\right) exp\left(-i\frac{\epsilon_2}{\hbar}t\right) \end{aligned} \tag{66}$$

where

$$\begin{aligned} \epsilon_1 &= E_0 \frac{Y_{11} + Y_{12}}{(1+S)} \\ \epsilon_2 &= E_0 \frac{Y_{11} - Y_{12}}{(1-S)}. \end{aligned} \tag{67}$$

From here

$$\begin{aligned} a_1 &= \frac{1}{2} e^{-i\omega t} \cdot (e^{-i\frac{\epsilon_1}{\hbar}t} + e^{-i\frac{\epsilon_2}{\hbar}t}) \\ a_2 &= \frac{1}{2} e^{-i\omega t} \cdot (e^{-i\frac{\epsilon_1}{\hbar}t} - e^{-i\frac{\epsilon_2}{\hbar}t}) \end{aligned} \tag{68}$$

and

$$\begin{aligned} |a_1|^2 &= \frac{1}{2}\left(1 + cos\Big(\frac{\epsilon_1 - \epsilon_2}{\hbar}t\Big)\right) \\ |a_2|^2 &= \frac{1}{2}\left(1 - cos\Big(\frac{\epsilon_1 - \epsilon_2}{\hbar}t\Big)\right) \end{aligned} \tag{69}$$

As

$$\epsilon_1 - \epsilon_2 = 2E_0 \frac{Y_{12} - SY_{11}}{1 - S^2} \tag{70}$$

with the initial conditions

$$a_1(0) = 1 \qquad a_2(0) = 0 \tag{71}$$

and

$$C_1 = C_2 = 1 \tag{72}$$

or

$$C_1 = -C_2 = 1 \tag{73}$$

we obtain the oscillating probability of placing of electron near one or other proton:

$$\begin{aligned} |a_1|^2 &= \frac{1}{2}(1 + cos\omega t) \\ |a_2|^2 &= \frac{1}{2}(1 - cos\omega t) \end{aligned} \tag{74}$$

Thus, electron jumps into degenerate system (hydrogen + proton) with frequency ω from one proton to another.

In terms of energy, the frequency ω corresponds to the energy of the tunnel splitting arising due to electron jumping (Fig. 3).

As a result, due to the electron exchange, the mutual attraction arises between protons. It decreases their energy on

$$\Delta = \frac{\hbar\omega}{2} \tag{75}$$

The arising attraction between protons is a purely quantum effect, it does not exist in classical physics.

The tunnel splitting (and the energy of mutual attraction between protons) depends on two parameters:

$$\Delta = |E_0| \cdot \Lambda, \tag{76}$$

where E_0 is energy of the unperturbed state of the system (ie, the electron energy at its association with one of proton, when the second proton removed on infinity), and function of the mutual distance between the protons Λ.

This function according to Eq.(70) has the form:

$$\Lambda = \frac{Y_{12} - SY_{11}}{(1 - S^2)}. \tag{77}$$

It expresses the dependence of the exchange energy on the distance between particles.

The graphic estimation of the exchange splitting $\Delta\mathcal{E}$ indicates that this effect decreases exponentially with increasing a distance between the protons in full compliance with the laws of the particles passing through the tunnel barrier.

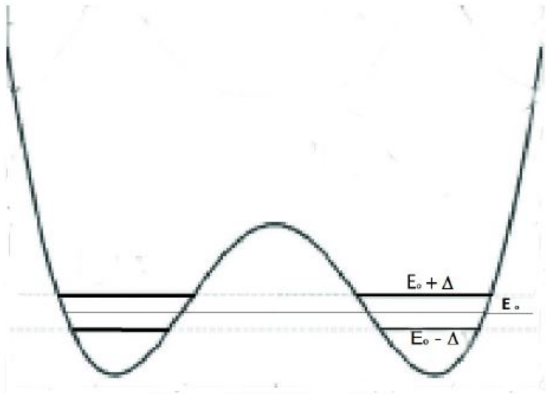

Fig. 3. The schematic representation of the potential well with two symmetric states. In the ground state, electron can be either in the right or in the left hole. In the unperturbed state, its wave functions are either φ_1 or φ_2 with the energy E_0. The quantum tunneling transition from one state to another leads to the splitting of energy level and to the lowering of the sublevel on Δ

4.2 The Molecular Hydrogen Ion

The quantum-mechanical model of simplest molecule - the molecular hydrogen ion - was first formulated and solved by Walter Heitler and Fritz London in 1927 [3].

At that, they calculate the Coulomb integral:

$$Y_{11} = \left[1 - (1+x)e^{-2x}\right], \tag{78}$$

the integral of exchange

$$Y_{12} = \left[x(1+x)e^{-x}\right] \tag{79}$$

and the overlap integral

$$S = \left(1 + x + \frac{x^2}{3}\right) e^{-x}. \tag{80}$$

Where $x = \frac{R}{a_B}$ is the dimensionless distance between the protons.
The potential energy of hydrogen atom

$$\mathcal{E}_0 = -\frac{e^2}{a_B} \tag{81}$$

and with taking into account Eq.(78)-Eq.(80)

$$\Lambda(x) = \frac{x(1+x)e^{-x} - \left(1 + x + \frac{x^2}{3}\right)\left(1 - (1+x)e^{-2x}\right)}{1 - \left(1 + x + \frac{x^2}{3}\right)^2 e^{-2x}} \tag{82}$$

At varying the function $\Lambda(x)$ we find that at

$$x \simeq 1.3 \tag{83}$$

the energy of the system has a minimum

$$\Lambda_{x=1.3} \simeq 0.43. \tag{84}$$

As a result of permutations of these values we find that in this minimum energy the mutual attraction of protons reaches a maximum value

$$\Delta_{max} \simeq 9.3 \cdot 10^{-12} erg. \tag{85}$$

This result agrees with measurements of only the order of magnitude.

The measurements indicate that the equilibrium distance between the protons in the molecular hydrogen ion $x \simeq 2$ and its breaking energy on proton and hydrogen atom is close to $4.3 \cdot 10^{-12} erg$.

The remarkable manifestation of an attraction arising between the nuclei at electron exchange is showing himself in the molecular ion of helium. The molecule He_2 does not exist. But a neutral helium atom together with a singly ionized atom can form a stable structure - the molecular ion. The above obtained computational evaluation is in accordance with measurement as for both - hydrogen atom and helium atom - the radius of s-shells is equal to a_B, the distance between the nuclei in the molecular ion of helium, as in case of the hydrogen molecular ion, must be near $x \simeq 2$ and its breaking energy near $4.1 \cdot 10^{-12} erg$.

In order to achieve a better agreement between calculated results with measured data, researchers usually produce variation of the Schrodinger equation in the additional parameter- the charge of the electron cloud. At that, one can obtain the quite well consent of the calculations with experiment. But that is beyond the scope of our interest as we was needing the simple consideration of the effect.

4.3 Deuteron

The electromagnetic model of neutron, discussed above, allows us to take a fresh look at the mechanism of the neutron-proton interaction. Neutron as proton surrounded by a electron cloud and a free proton make up together an object similar to a molecular hydrogen ion.

The difference is that in this case the electron is relativistic, and the radius of its orbit is $R \approx 10^{-13}$ cm (Eq.(34)).

The electron energy in the composition of neutron in the undisturbed state was calculated earlier (Eq.(44)):

$$E_0 = 2.04 \cdot m_e c^2 \quad (86)$$

This function expresses the dependence of the exchange energy on the distance between nucleon. According to Eq.(84), it has maximum

$$\Lambda_{max} = 0.43, \quad (87)$$

at the dimensionless distance between protons $x = \frac{R}{R_e} = 1.3$ (Eq.(83)).

The values of the binding energy between nucleons are usually expressed in terms of the magnitude of the mass defect in atomic units of mass, having the international designation u. With what

$$1u = 1.6605402 \cdot 10^{-24} g. \quad (88)$$

In these units, the magnitude of the decrease in the energy of two protons exchanging a relativistic electron has the value:

$$\Delta_0 = \Lambda_{max} \mathcal{E}_0 \simeq 10^{-3} u. \quad (89)$$

To compare this energy with the measurement data, it is necessary to calculate the mass defect of particles forming the deuteron

$$\Delta M_D = M_p + M_n - M_d \approx 2.3414 \cdot 10^{-3} u \quad (90)$$

Where
$M_p = 1.007276466621$ u, $M_n = 1.00866491560$u and $M_d = 2.0136$u are masses of proton, neutron and deuteron, respectively.

Thus, we can assume that for the deuteron quantum-mechanical rating (Eq.(89)), as in the case of molecular hydrogen ion, in order of magnitude is consistent with the experimentally measured the magnitude of the binding energy (Eq.(90)), although in both cases their a coincidence, without further amendment is not very accurate.

5 BINDING ENERGY OF LIGHT NUCLEI

5.1 Helium Isotopes

Fig.5 shows schematically the energy bonds in the nucleus of ^3_2He. From it we can seen that there are three paired interactions of protons. Therefore, it should be assumed that the binding energy of this nucleus should be equal to the triple binding energy of the deuteron (Eq.(90)):

$$\delta M_{He3} = 3 \cdot \Delta M_D \approx 7.02 \cdot 10^{-3} u. \quad (91)$$

Fig. 4. Schematic representation of deuteron. The dotted line schematically shows the possibility of a relativistic electron jumping from one proton to another

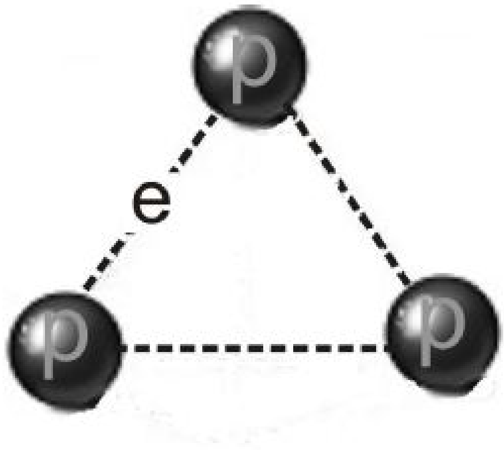

Fig. 5. Schematic representation of the ^3_2He nucleus. Dotted lines schematically represent the possibility of a relativistic electron jumping from one proton to another

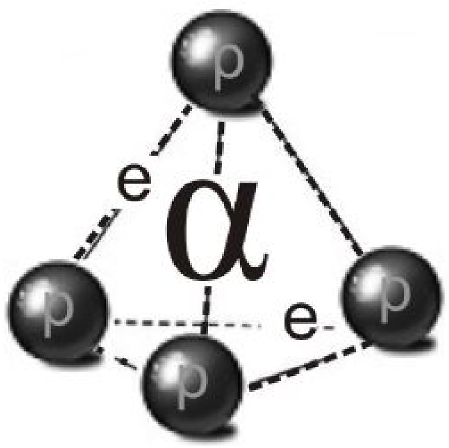

Fig. 6. Schematic representation of the nucleus ^4_2He. Dotted lines schematically represent the possibility of a relativistic electron jumping from one proton to another

The experimentally measured mass defect of this nucleus is equal to

$$\Delta M(He3) = 2M_p + M_n - M_{He3} = 8.29 \cdot 10^{-3}u. \quad (92)$$

Thus, the calculated mass defect of this nucleus can be considered quite consistent with its measured value.

As it can be seen from Fig. 6, there are bonds are formed by six paired interactions of protons ΔM_d, realized by two electrons. For this reason, it can be assumed that the binding energy of the nucleus ^4_2He should be equal to:

$$\delta M_\alpha = 2 \cdot 6 \cdot \Delta M_D \approx 28.1 \cdot 10^{-3}u. \quad (93)$$

The measured mass defect of this nucleus is equal to

$$\Delta M_\alpha = 2M_p + 2M_n - M_\alpha = 30.4 \cdot 10^{-3}u. \quad (94)$$

Such agreement of these values can be considered quite satisfactory.

5.2 Beryllium Isotopes

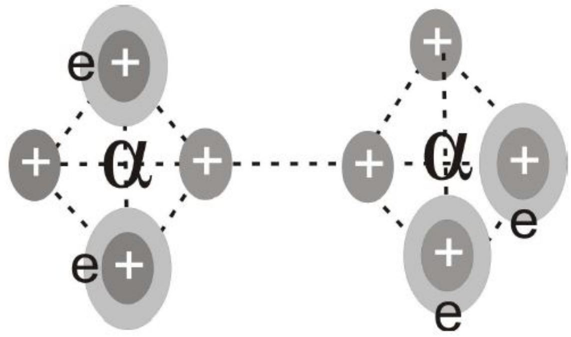

Fig. 7. The schematic representation of energy bonds in the Be-8 nucleus. Dotted lines represent the possibility of a relativistic electron jumping between protons

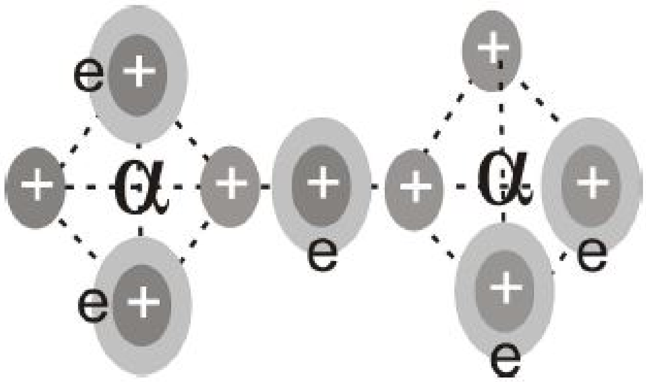

Fig. 8. Schematic representation of energy bonds in the Be-9 nucleus. Dotted lines represent the possibility of a relativistic electron jumping between protons

A comparison of the binding energies of beryllium isotopes points the way to calculating mass defects of heavy nuclei.

If we compare the binding energy of nucleus ${}^{8}_{4}Be$ with the doubled binding energy of the alpha-particle, we can conclude that this nucleus must be unstable.

When it decays into alpha particles, the energy corresponding to the mass defect, which turns out to be negative in this case, should be released:

$$\Delta M(Be8) = 2M_{\alpha} - M_{Be_8} = -2.29 \cdot 10^{-3}u \quad (95)$$

Indeed, measurements show that the ${}^{8}_{4}Be$ nucleous is very short-lived. It decays into two alpha-particles, having a lifetime of approximately 10^{-17} sec.

However, if neutron is attached to the ${}^{8}_{4}Be$ nucleus to construct the ${}^{9}_{4}Be$ nucleus (Fig. 8), the result is a stable nucleus with a mass defect:

$$\Delta M(Be9) = 4 \cdot M_p + 5 \cdot M_n - M_{Be_9} = 60.25 \cdot 10^{-3}u. \quad (96)$$

This can be explained by the fact that the total mass defect in the structure shown in Fig.(8), will increase.

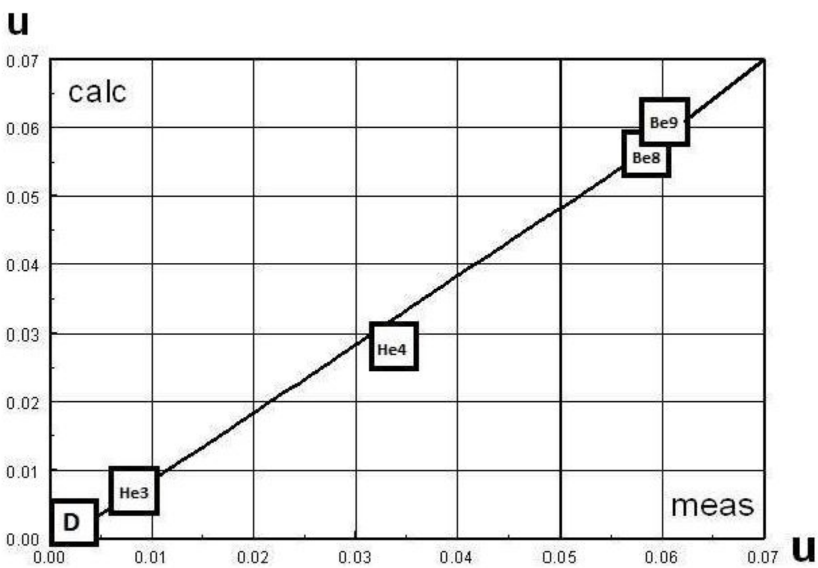

Fig. 9. Comparison of calculated values of the mass defect of light nuclei with the measurement data

Table 3. Comparison of the calculated values of the defect of the mass of light nuclei with the measurement data

isotope	M u	ΔM $10^{-3}u$	N_d	$\delta M = N_d \cdot \Delta M_D$ $10^{-3}u$	$\frac{\Delta M - \delta M}{\Delta M}$ %
${}_1^2D$	2.01355	2.3414	1	-	
${}_2^3He$	3.01493	8.2878	3	7.0242	15
${}_2^4He$	4.001506179	30.377	12	28.097	7.5
${}_4^8Be$	8.00530510	58.46	24	56.194	3.9
${}_4^9Be$	9.0121822	60.248	26	60.876	1

The mass defect of alpha-particle according to Eq.(93) is equal to $12 \cdot \Delta M_d$. Two alpha particles respectively create a mass defect $24 \cdot \Delta M_d$. To this value, we need to add a doubled deuteron defect of mass $2 \cdot \Delta M_d$, since the electron of an additional neutron connecting alpha-particles (Fig. 8) has the ability to transfer to free protons of neighboring alpha-particles. As a result, we get the total mass defect of ${}_4^9Be$

$$\delta M(Be9) = 26 \cdot \Delta M_D = 60.88 \cdot 10^{-3}u. \quad (97)$$

Good agreement of this estimate with the experimental value (Eq.(96)) suggests that neutron can bind alpha-particles together, playing the role of a kind of glue.

6 MASS DEFECTS OF HEAVY NUCLEI

6.1 Crystal Model of Heavy Nuclei

Taking into account the scheme of the structure of the nucleus ${}_4^9Be$ (Fig. 8), we can by analogy assume that, other stable heavy nuclei can be represented in the form ”crystals” , consisting of alpha-particles ”glued” each other neutrons (Fig. 10).

The elementary cell of such a ”crystal” can be represented as an alpha particle associated with six neutrons that ”glue” it with other alpha particles along the three axes of the ”crystal” (Fig. 11).

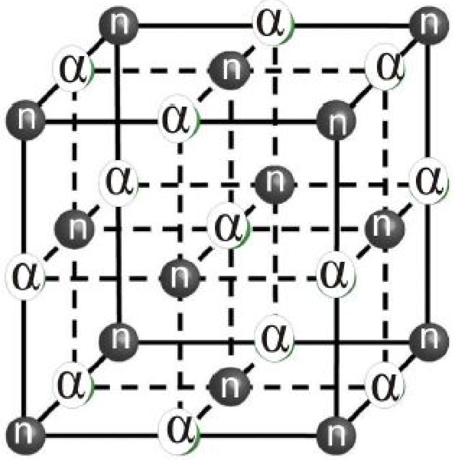

Fig. 10. Schematic representation of the "crystal" models of a heavy nucleus in which alpha-particles are "glued" together by neutrons

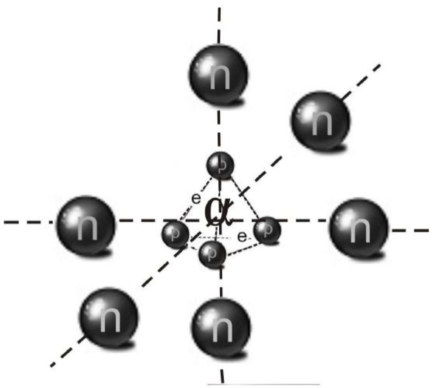

Fig. 11. "Elementary cell" three-dimensional "crystal" models of a heavy nucleus in which alpha particles are "glued" together by neutrons

To obtain a numerical estimate of the binding energy of heavy nuclei (with an even number of protons), we introduce the following notation:

A is the total number of nucleons in the nucleus,

Z is an even number of protons,

$N_n = A - Z$ is the number of neutrons,

$N_\alpha = Z/2$ is the number of alpha-particles,

$N_{glue} = N_n - Z$ - excess number of neutrons "gluing" alpha-particles.

The value of the experimentally measured mass defect for an isotope with a large number of nucleons is calculated by the formula:

$$\Delta M_{isotop} = M_p \cdot Z + M_n \cdot N_n - M_{isotop}. \quad (98)$$

Where M_{isotop} is measured mass of a isotope.
As before (Eq.90), we will assume the deuteron mass defect

$$\Delta M_D = 2.3414 \cdot 10^{-3} u. \quad (99)$$

We introduce the parameter q, which shows the difference between the number of alpha-particles in the nucleus and the number of neutrons "gluing" alpha-particles:

$$q = N_\alpha - N_{glue}. \quad (100)$$

For a number of heavy isotopes, these numbers coincide and this parameter

$$q = 0. \quad (101)$$

In this case, the mass defect of one alpha-particle together with six neutrons bound to it along the three axes of the "crystal"

$$\delta M(alpha) = \Delta M_\alpha + 6 \cdot \Delta M_D = 18 \cdot \Delta M_D \quad (102)$$

and the total defect of the mass of such a nucleus

$$\delta M(nucl) = 18 \cdot \Delta M_D \cdot N_\alpha. \quad (103)$$

Since one neutron can "glue" a different number of alpha particles, in a large "crystal" the number of alpha-particles may differ from the number of neutrons "gluing" them. Therefore, for many isotopes $q \neq 0$.

It can be assumed that in nuclei where there is a shortage of neutrons, alpha-particles lose "gluing" neutrons along one of axes of the "crystal" and for such nuclei there is a mass defect

$$\delta M(nucl) = \Delta M_D \left[18(N_{alpha} - q) + 16q\right]. \quad (104)$$

From here we get the binding energy that occurs in the nucleus between protons during the exchange of relativistic electron:

$$\delta M(nucl) = 9.3644 \cdot 10^{-3} \cdot (Z + A/2)\, u. \quad (105)$$

6.2 Correction for Coulomb Interaction

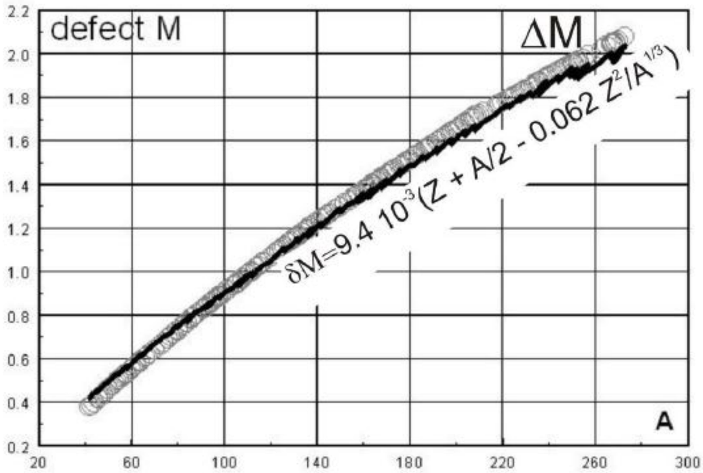

Fig. 12. Comparison of calculated mass defects of nuclei (Eq.(111)) with experimentally measured values of ΔM

For a more accurate description of the total binding energy in nuclei, it is necessary to introduce a correction for the Coulomb interaction of nucleons.

It is generally assumed that the nuclei consist of a substance with the same density

$$\gamma_n \approx 10^{14}\ g/cm^3 \quad (106)$$

The mass of a spherical body with radius R of such substance

$$\frac{4\pi}{3}\gamma_n R_n^3 = AM_N \quad (107)$$

Here M_N and A are the mass of nucleon and their number in nucleus.
From here we can determine the radius of the nucleus with constant density γ_n

$$R_n = 1.59 \cdot 10^{-13} \sqrt[3]{A} \quad (108)$$

The Coulomb energy of such spherical nucleus, taking into account the field created by it in outer space

$$\mathcal{E}_Q = \frac{3}{5}\frac{Z^2 e^2}{R_n} = 8.72 \cdot 10^{-7}\frac{Z^2}{\sqrt[3]{A}}\, erg \quad (109)$$

From here, turning to atomic units of mass, we get

$$\mathcal{E}_Q = 5.85 \cdot 10^{-4}\frac{Z^2}{\sqrt[3]{A}}\, u \quad (110)$$

Thus, the total mass defect of nuclei is equal to

$$\delta M_n = 9.36 \cdot 10^{-3}\left(Z + A/2 - 0.062\frac{Z^2}{\sqrt[3]{A}}\right) u, \quad (111)$$

which is in good agreement with the measurement data (Fig. 12).

7 CONCLUSION

The good agreement of the calculated binding energy for many nuclei with the measurement data allows us to assume that the strong interaction is the purely quantum mechanical effect described above.

This gives a physical explanation to Hideki Yukawa's hypothesis that nuclear forces should be described by a shielded potential that cuts off their action at short distances, and also allows us to calculate its magnitude.

It seems that the model discussed above, in which the nuclei consisting of protons and electrons, can be considered a kind of development of the idea of Sir Joseph John Thomson, who suggested a similar structure of the atom at the very beginning of the last century. However, after the discovery of neutrons, Thomson's model began to seem of purely historical interest.

Later, in the 30s of the last century, I.E.Tamm [10] drew attention to the possibility of explaining nuclear forces based on the effect of electron exchange. However, soon the model of exchange of π-mesons, and then gluons, became predominant in nuclear physics. The reason for this is clear. To explain the magnitude and radius of action of nuclear forces, a heavy particle with a small intrinsic wavelength is needed. A non-relativistic electron is not suitable for this. However, on the other hand, the models of π-meson or gluon exchange also did not turn out to be productive. These models could not give a quantitative explanation of the binding energy of even light nuclei.

The above simple and consistent with measurements estimate of the mass defect of nuclei is an unambiguous proof that the so-called strong interaction is a manifestation of the quantum mechanical effect of attraction between protons arising due to their exchange of a relativistic electron.

Fig. 13. Sir Joseph John Thomson, who created in 1903 a model in which atoms consisted only of positive charges and electrons, called "pudding with raisins"

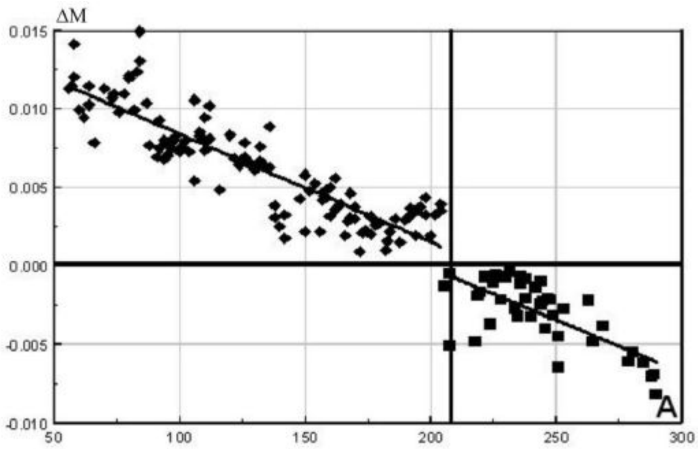

Fig. 14. Stable nuclei with $\Delta M > 0$ lie to the left of the observed stability boundary, indicated by a vertical line. In nuclei for which $\Delta M < 0$, alpha-decay is possible

The simple approach described above to calculating defects in the mass of nuclei gives a good match with the measurement data. This suggests that earlier theories of nuclear forces, such as the drip-model or the shell-model of nuclei, in terms of calculating the binding energy of nuclei can be considered of historical interest.

Using the data on the mass defect of nuclei, it is possible to raise the question of for which nuclei alpha-decay is possible and which are not.

Let the original nucleus ${}^{A}_{Z}X$ have mass $M({}^{A}_{Z}X)$.

Let's denote the difference in the masses of the products of its hypothetical alpha-decay and its mass

$$\Delta M = M({}^{A-4}_{Z-2}X) + M_\alpha - M({}^{A}_{Z}X). \qquad (112)$$

If $\Delta M > 0$, alpha-decay of such nuclei is impossible.

In Fig.(14), these nuclei lie to the left of the observed stability boundary, indicated by a vertical line.

In those nuclei for which $\Delta M < 0$, alpha-decay is possible, and they lie to the right of the stability boundary in Fig.14. At the same time, the further they lie from this boundary, the larger the modulus of ΔM is obtained, i.e., the greater the decay energy and, in accordance with the Sergent rule, the shorter their lifetime.

Therefore, there are no reasons for the emergence of stability islands beyond the specified boundary (Fig. 14), and all the activity to search for them among superheavy nuclei looks devoid of a physical basis.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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