Nuclear Power and the Structure of a Nucleus According to J.Wheeler's Geometrodynamic Concept

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In this paper on a unified basis in terms of mechanistic interpretation of J.Wheeler's geometrodynamic concept the attempt to explain the nature of nuclear forces as the result of the complex nucleons structure and to submit the model of the structure of atomic nuclei is done. It is shown that the assumption of the existence of closed contours, including electron and proton quarks leads to a conclusion about the existence of W, Z-bosons and also the Higgs boson whose mass is calculated. Values of the coupling constants in the strong and weak interactions are calculated, and it is shown that they do not indicate the strength of the interaction, but indicate only the strength of bonds between the elements of nucleon structure. The binding energy of the deuteron, triton and alpha particles are defined. Dependence of the nucleon-nucleon interaction of the distance is explained. The structural scheme of nuclei is proposed, the inevitability of presence of envelopes in nuclei is proved, the expressions allowing to estimate the features of nuclear structure, as well as correctly to assess the binding energy of nuclei and their mass numbers are obtained. The results of calculations at the level of the model suggest the possibility to use this model for the construction of an appropriate theory.

1 Introduction

At present there is no a complete theory of the nuclear structure, which would explain all properties of atomic nuclei. To describe properties and behavior of atomic nuclei different models are used, each of which is based on various experimental facts and explains some allocated properties of the nucleus. One reason for this is that the analytical dependences for the interaction forces between nucleons are until now not derived.

In the quantum theory, the interaction between the microparticles is described as an exchange of specific quanta (photons, pions, gluons, and vector bosons) associated with these types of interactions. The dimensionless parameter determining the relative strength of any interaction (an interaction constant or coupling constant α) is assumed proportional to the source interaction charge by analogy with the charge of an electron in the electromagnetic interaction:

$$\alpha_e = e^2/\hbar c = 1/137, \tag{1}$$

where e is the electron charge (in the CGSE).

But the problem consists in that for both strong and weak interactions the mechanism of interaction and, accordingly, a coupling constant strongly depend on the interaction energy (distance) and are determined experimentally.

In terms of the developed model based on the mechanistic interpretation of J.Wheeler's geometrodynamic concept [1], such a variety of types and mechanisms of interaction seems strange and unreasonable. In contrast to the quantum theory, which states that microphenomena in no way can be understood in the terms of our world scale, the mechanistic interpretation of J.Wheeler's idea above all assumes the existence of common or similar natural laws, which are reproduced at the different scale levels of matter that, in particular, allows using of macroscopic analogies in relation to the objects of microworld.

The proposed model of nuclear forces and nuclear structure as well as previous works [2-5] is based on the general conservation laws and balances between main interactions: electrical, magnetic, gravitational and inertial - with no additional coefficients or any arbitrary parameters introduced. Without using complicated mathematical apparatus, this work is not physical and mathematical one, but rather is the physical and logical model. However, application of Wheeler's ideas to this area of microphenomena give the opportunity to clarify the cause and nature of nuclear forces and give a reasonable scheme of nuclear structure, which is confirmed by some of the examples of successful calculations made on the basis of the model.

2 Initial conditions

Recall that in this article, as well as in the earlier works, the charges in accordance with Wheeler's idea treated as singular points on the three-dimensional surface, connected by a"worm-hole" or vortical current tube similar to the source-drain principle, but in an additional dimension of space, constituting a closed contour as a whole.

The closest analogy to this model, in the scale of our world, could be the surface of ideal liquid, vortical structures in it and their interactions which form both relief of the surface and sub-surface structures (vortex threads and current tubes).

In this model, there is no place for a *charge* as a specific matter, it only manifests the degree of the nonequilibrium state of physical vacuum; it is proportional to the momentum of physical vacuum in its motion along the contour of the vortical current tube. Respectively, the *spin* is proportional to the angular momentum of the physical vacuum with respect to the longitudinal axis of the contour, while the *magnetic interaction* of the conductors is analogous to the forces acting among the current tubes.

In such a formulation the electric constant ε_0 makes sense the linear density of the vortex current tube

$$\varepsilon_0 = m_e/r_e = 3.233\times10^{-16}\ \text{kg/m}, \tag{2}$$

and the value of *inverse magnetic constant* makes sense the centrifugal force

$$1/\mu_0 = c^2\varepsilon_0 = 29.06\ \text{n}, \tag{3}$$

appearing by the rotation of a element of the vortex tube of the mass m_e and of the radius r_e with the light velocity c; this force is equivalent to the force acting between two elementary charges by the given radius, and electron charge makes sense the momentum of the vortex current tube (counter) with a mass of $m_e c_0^{2/3}$ and with velocity of $c_0^{2/3}\times$ [m/sec], the energy of which is equal to the maximum energy of the electron $m_e c^2$, i.e.

$$e = m_e c_0^{4/3} \cos q_w \times [\text{m/sec}] = 1{,}603\times10^{-19}\ \text{kg m/sec}, \tag{4}$$

where c_0 is the dimensionless light velocity c / [m/sec], q_w is the Weinberg angle of mixing of the weak interaction, it equals 28.7^0.

Vortex formations in the liquid can stay in two extreme forms — the vortex *at the surface* along the *X*-axis (let it be the analog of a fermion of the mass m_x) and the vortical current tube *under the surface* of the peripheral velocity v, the radius r and the length l_y along the *Y*-axis (let it be the analog of a boson of the mass m_y). These structures oscillate inside a real medium, passing through one another (forming an oscillation of oscillations). Probably, fermions conserve their boson counterpart with half spin, thereby determining their magnetic and spin properties, but the spin is regenerated up to the whole value while fermions passing through boson form. The vortex thread, twisting into a spiral, is able to form subsequent structures (current tubes). The possibility of reciprocal transformations of fermions and bosons forms shows that a mass (an energy) can have two states and pass from one form to another.

In paper [2] proceeding from conditions of conservation of charge and constancy parameters μ_0 and ε_0, parameters of the vortex thread m_y, v, r, for an arbitrary $p^+ - e^-$-contour defined as a proportion of the speed of light and electron radius as:

$$m_y = (an)^2, \tag{5}$$

$$v = c_0^{\,1/3}/(an)^2, \tag{6}$$

$$r = c_0^{\,2/3}/(an)^4, \tag{7}$$

where n is quantum number, a is inverse fine structure constant.

Wherein, referring to the constancy ε_0 (linear density), it is clear that the relative length of the tube current in the units of r_e is equal boson mass m_y in the units of m_e, i.e.

$$l_y = m_y = (an)^2. \tag{8}$$

In the model the particles themselves are a kind of a contour of subsequent order, formed by the intersection of the X- surface with the current tube, and they have their own quantum numbers defining the zone of influence of these microparticles. In [3] determined that for the proton

$$n_p = (2c_0 /a^5)^{1/4} = 0.3338, \tag{9}$$

for an electron $n_e = (n_p)^{1/2} = 0.5777$, and for the critical contour, when $r \to r_e$ and $v \to c$, $n_c = c_0^{1/6}/a = 0.189$.

Hereinafter all the numerical values of the mass, size and speed are given in dimensionless units: as a proportion of mass of the electron m_e, its radius r_e and speed of light c.

It is important to note that the contour or vortex tube, which the vortex thread fills helically, can be regarded as completely "stretched", i.e. elongated proportional to $1/r$ or, on the contrary, extremely "compressed", i.e. shortened proportional to $1/r$ and filling all the vortex tube of radius r_e. In the latter case its compressed length $L_p = l_y r$ is numerically equal to the energy of the contour boson mass in units of mass-energy.

Indeed, since $r = v^2$, then the above quantities values in dimensionless units are in all cases identical:

$$L_p = l_y r = m_y r = m_y v^2 = c_0^{\,2/3}/(an)^2 . \tag{10}$$

It is obvious that an arbitrary boson mass in the units of mass-energy will match of its own value m_y only in the case of ultimate excitation of the vortex tube when $r \to r_e$ and $v \to c$.

Here are some of the parameters for mentioned three particular contours. Substituting in the formula (7) and (8) the parameters n_e, n_p, and n_c one can find the characteristic sizes of the vortex tubes: for an electron vortex thread radius $r = 0.0114$, the length of the vortex thread $l_y = 6267$, for the proton $r = 0.1024$, $l_y = 2092$, for a critical contour $r = 1$, $l_y = 670$.

As for the accepted *scheme of the nucleons structure*, in [3] it is shown that the proton has a complex structure, which is revealed in process of transition to smaller scales with increasing the interaction energy, i.e., as if its "deepening" along the *Y*-axis; so to the outside observer the nuclear forces manifest themselves in a complex manner.

In the *inner area of the proton* there are three critical section (quarks), each of which is crossed by three force lines (charges 1, 1, -1). The presence of inverse circulation currents forming three closed contours leads to the fact that the intersection of the critical section by the lines of force inside the proton will for an outside observer be projected on *the outer proton surface* in the form of 2/3, 2/3, -1/3 of the total charge.

Along the *Y*-axis the proton boson vortex tube is located having parameters m_{py} = 2092 and r_p = 0.1024. The most "deep" along the *Y*-axis the quark vortex tubes are located with the parameters defined in [3]: the quantum number n_k = 0.480, the total fermion mass m_{kx} = 12.9, the total boson mass m_{ky} = 4324, the radius of the vortex tube r_k = 0.024.

It should be noted that the value of the parameter r_k is confirmed by works on studying of *neutron polarizability*. In [6] the lower limit the polarizability coefficient is specified of a_p = 0.4×10^{-42} cm^3. This means that the linear inhomogeneity parameter in the structure of the neutron coincides with the radius of the quark vortex tube as $(a_p)^{1/3} = 7.37\times10^{-15}$ cm or 0.026 r_e.

Neutron has three closed contour, i.e. six force lines instead of nine ones, which a proton has, and, therefore, the total neutron quark mass has the value of 12.9×2/3 = 8.6. Having in mind adopted direction and the possible distribution of the force lines in the neutron [3], one can expect that in the case of neutron polarization neutron may have the charges in the inner region of 1, -1, or -1, 2/3, 1/3, and in the projection of the outer surface of -2/3, 1/3, 1/3.

In the contour connecting the charged particles, the quarks are involved in the circulation and become an active part of the nucleon mass. It is assumed that in the critical section circulation velocity reaches the velocity of light, so quarks are actually dark matter, which is equivalent to the mass defect, reflecting the energy of bonds within nucleons or nuclei; the nominal mass-energy of a quark is 0.511×12.9/3 = 2.2 MeV.

When considering the closed contour having contra-directional currents from the balance of magnetic and gravitational forces recorded in a "Coulombless" form, the characteristic size of a contour as a *geometrical mean* of two linear values is obtained:

$$l_k = (l_i\, r_i)^{1/2} = (z_{g1}z_{g2} / z_{e1}z_{e2})^{1/2}(2\pi\, \gamma\varepsilon_0)^{1/2}\times[\text{sec}], \tag{11}$$

where z_{g1}, z_{g2}, z_{e1}, z_{e2}, r_i, l_i are gravitational masses and charges expressed through masses and charges of an electron, a distance between current tubes and theirs length.

Number of vortex thread constituting contour reflects the difference of material medium from vacuum, and their greatest value corresponds to the ratio of electrical forces to gravitational forces, i.e. value:

$$f = c^2/(\varepsilon_0\, \gamma) = 4.16\times10^{42}, \tag{12}$$

where γ is the gravitational constant.

The contour can be considered located both in the *X*-area (for example, $p^+ - e^-$ -contour in atom) and in the *Y*-area (vortex tube inside an atomic nucleus). When a proton and an electron come together (for example, when its contraction by the *e*-capture) a deformation of the contour takes place, energy and the fermion mass increase, while the boson mass decreases, but the impulse (charge) is conserved.

Formula (11) for unit charge taking z_{g2} =1, and after calculating the constants gets the form in the units of r_e and m_e:

$$m_k = z_{g1} = bl_k^2\,, \qquad (13)$$

where m_k is the proton quark mass involved in the circulation contour, $b = 5.86\times10^{-5}$.

Parameter l_k is composite. If the contour (vortex tubes) is directed along the Y-axis, then $r_i = r$, $l_i = l_y$, if the contour is directed along the X-axis, then in calculating parameters are replaced, i.e. $r_i = l_y$, $l_i = r$. Having in mind (7), (8), (11), and (13), replacing arbitrary parameters r_i and l_i by the sizes of short and long axes of the contour and calculating constants, we obtain the formulas relating the quark mass and the contour linear parameters:

$$m_k = 26.25/r = 0.0392\, l_y^{1/2}, \qquad (14)$$

and also

$$r\, l_y^{1/2} = c_0^{1/3}. \qquad (15)$$

3 On boson masses

The circuit parameters in X-region and Y-region in the general case do not match, but both include the quark mass, which depends on the size of the contour. Let us compare the parameters of these contours for some specific cases.

Let us consider X-contour of own electron at $n_e = 0.5777$. Its size along the X-axis, as follows from (8), $r_i = l_y = 6267$. From (14) we find the quark mass $m_k = 3.10$. For having of the same value of mass-energy L_p, Y-contour, as follows from (10), should have a quantum number n = 2.77. The boson mass of such a contour according to (5) $m_y = 1.44\times10^5$, that is close to the mass of W^{+-} bosons.

Let us consider the contour of own proton at $n_p = 0.3338$. Its size along the X-axis $r_i = l_y$ = 2092 and the quark mass $m_k = 1.795$. Y-contour having the same value of mass-energy has n = 3.645. Boson mass of such a contour $m_y = 2.494\times10^5$, that is almost exactly ***corresponds to the mass of the Higgs boson*** (125 GeV).

Let us consider the critical contour at $n_c = 0.189$. Its size along the X-axis $r_i = l_y = 672$ and the quark mass $m_k = 1.02$. That is, in the limiting case the ***quark mass becomes equal to the mass of an electron***. Y-contour having the same value of mass-energy has $n = 4.884$, i.e. it is a standard contour [2]. The boson mass of such a contour $m_y = 4.48\times10^5$, that is close to the total mass of W, Z - bosons.

Thus, these relations between the masses of the particles taking part in the weak interaction (quarks, bosons, protons, and electrons) to some extent clarify the nature of the weak interaction and the physical meaning of its interpretation as “the exchange of bosons”. It turns out that W, Z - bosons and the Higgs boson are the vortex tube having the value of mass-energy equal to mass-energy of the quarks included in the circulation contours corresponding to their own electron, proton, and critical contours. And in the course of the weak interaction X-contour is reduced and when performing this condition, it is reoriented to Y-region, transmitting momentum (charge) to the proton while keeping the angular momentum (spin, in the case of e-capture, for example); then it is extracted as a neutrino [3].

From the above it implies that the *Higgs boson is not a unique particle in microcosm*.

4 The coupling constants

In [5] a formula is obtained, from which it follows that the unit contour or vortex tube having a *momentum equivalent to the electron charge*, consist of three unit vortex threads. After transformation this expression can be written as:

$$n_i^3 = \frac{m_e c_0^{2/3} r_e /((2\pi)^{1/2}\times[\sec^2])}{2\pi\,\gamma m_e^2/r_e^2} = 26.25. \qquad (16)$$

This formula represents the ratio of inertial forces occurring during acceleration of the standard contour boson mass and acting toward to periphery (as the value $r_e /((2\pi)^{1/2}\times[\sec])$ is the rotational speed of the vortex thread relative to the longitudinal axis of the contour [3]) to the gravity forces acting between the masses of m_e at a distance of r_e. The numerator is constant, so the expression depends only on the force of gravity, i.e. from interacting masses and distances between them. This ratio (or its modification for arbitrary m_i and r_i) can be the equivalent of the coupling constant, as indicates the strength of the bonds between the elements of the proton structure (quarks).

4.1 Strong interaction

Suppose that quarks are located at the corners of an equilateral triangle at a distance r_e. In this case each of them is exposed of the sum of two projections forces, therefore the denominator into (16) should be corrected by multiplier $2sin60^0$. As a result, the expression (16) in the relative units of r_e and m_e after calculating of constants takes the form:

$$a_s = 15.15(r_i /m_i)^2. \qquad (17)$$

Consider the case of the strong interaction at low energies where the parameter r_i is greater than the nucleon size r_n. Let the mass of the proton quark takes a minimum value m_e (section 3), the distance between the quarks is r_e; substituting $r_i = 1$, $m_i = 1$ into (17), we obtain $a_s = 15.15$, which coincides with the known value determined at low energies $a_s \sim 15$.

It should be expected that at $a_s = 1$, there is a balance between the forces of gravity and peripheral inertia forces, which the nominal size of the proton can be determined from. Indeed, under this condition (17) it follows $r_i = 0.257$, and the size of the vortex tube, accordingly, is $0.257/sin60^0 = 0.297$ or 0.84 fm, which *coincides with the proton radius*.

Consider the case of the strong interaction with $r_i < r_n$, where the energy of the interacting particles is high (about 100 GeV), and they approach each other at the minimum distance of the vortex proton tube $r_p = 0.1023$ (section 2). In this case, the distance between the quarks inscribed in the vortex proton tube is $r_i = r_p\, sin60^0 = 0.0887$. Substituting r_i and $m_i = 1$ into (17), we obtain $a_s = 0.119$. This calculated value coincides with the experimental data. Indeed, in [7] it was found that at the given energy $a_s = 0.1176 \pm 0.0024$.

Now it becomes clear physical meaning of the great difference in magnitudes of this type interaction. At low energies of the interacting particles affecting only the outer structure of nucleons ($r_i > r_n$, low "depth" along Y-axis) the peripheral inertial forces exceed the forces of gravity, so the elements of the structure (quarks) are weakly bonded to each other, can move away from the starting position and interact with nearby nucleon quarks. At high energies ($r_i < r_n$, more "depth" along Y-axis) interaction occurs at the level where the forces of mutual attraction holds the quarks in the bound state within the nucleon size, that leads to a decrease in the efficiency of the interaction of microparticles as a whole.

Note, that in the atoms nuclei quarks may also be in a bound state due to their large masses, which they acquire when entering into the $p^+ - e^-$-contours.

4.2 Weak interaction

When the weak interaction (such as in the case of *e*-capture, for example) the bosonic part of the proton quark or vortex tubes take part (section 3).

Let us assume that the mass of each of three quark tubes $m_i = m_{ky} / 3 = 4324/3 = 1441$ (section 2). Substituting m_i and $r_i = 1$ into (17), we find $a_w = 0.73\times10^{-5}$. This value agrees with the value of a_w, defined through the constant Fermi (1×10^{-5}). At high interaction energies (about 100 GeV) the constant a_w increases to ~ 1/40. In our model this increase can also be explained.

At the limit excitation of the contour vortex tube at the quarks level when $v \rightarrow c$ and $r \rightarrow r_e$ boson mass becomes equivalent to its mass-energy, but because the parameters ε_0 and μ_0 are constant then the radius of the vortex tube increases proportional to the ratio r_e/r_k. Since $r_e/r_k = 41.7$, then in this case $r_i = 41.7$, and the parameter a_w increases proportionally to the square of this ratio, i.e. $a_w = 0.73\times10^{-5}\times41.72^2 = 1/78$, which is in agreement with the value of a_w determined at high energies.

4.3 On the electron

Suppose that the formula (17) is applied to the electron itself. Electron contains three vortex threads. Assuming $r_i = r_e$ and considering that the boson mass of an electron vortex threads is $m_i = (an_e)^2/ 3 = 2089$, and it coincides with the proton boson mass, it is obvious that the *coupling constant for the electron in the weak interaction is identical to that of the proton*.

As for the strong interaction then in this case $m_i = 1/3\ m_e$. Substituting into (17) $r_i = 1$ and $m_i = 1/3$, we find $a_s = 136.4$, which almost coincides with the value of the reciprocal fine structure. Proceeding from the enormous value of the coupling constant a_s the electron structure can not be in a bound state, and in equilibrium at $a_s = 1$ the size of the electron would be very small at $r_i = 0.086$. But having such a small radius the electron charge can not place itself according to the classical definition, by which the potential energy of the electrostatic field is completely equivalent to the rest mass of an electron.

Thus, the electron to resolve this contradiction and be able to exist itself shall continuously oscillate between these states. Its pulsations provide the motion of medium along the $p^+ - e^-$-contours thereby confirming definition of the charge as the momentum.

Summing up the results of Chapter 4 one can say that the *coupling constant* defines neither the nature of nuclear forces, nor the interaction force, but only *indicates the strength of the bonds within the complex structure of nucleons.*

5 The nucleus

When considering nuclear forces hereinafter, to take into account the Coulomb interaction at various energy levels (distances) proved sufficient, from which it can be concluded that the *introduction of any special nuclear forces is not required*, at least within the limits of this model.

As for scheme of nuclear structure, then the proposed scheme is, to a certain extent, associated with collective model (J. Rainwater, 1959, A. Bohr, and B. Mottelson, 1952). This model combines the provisions of the hydrodynamic and the envelope model and suggests that the nucleus consists of the inner stable part - the core formed the nucleons of filled envelopes and the outer nucleons moving in the field generated by the core nucleons.

5.1 Nuclear forces

Are there any special nuclear forces at all?

At high energies and short distances, i.e. when approaching nucleons to their radius r_n = 0.842 fm and overlapping of their *internal structures*, the interaction between nucleons occurs inside their total “quark bag” between oppositely quarks having inside the nucleon structure the charges of 1 and -1 at the distance of its vortex tube. Let us assume that the quark mass is minimal and equal to m_e, i.e. it is identical to an electron, then its vortex tube size is equal to the electron vortex tube size r_k = 0.0114 (section 2).

Write the formula for the potential in the units of MeV and the fractions of r_e. The depth of the attractive potential at the minimum distance for unit charges is

$$V = -\,0.511\,/\,r_k, \tag{18}$$

which gives - 44.8 MeV (see Figure 1).

With further approach of nucleons at even higher energies (greater “depth” along *Y*-axis) the interaction at the level of boson vortex nucleons tubes is added. It is understood that the unidirectional vortex tubes are repelled, and as far as “deepening” along *Y*-axis their radius *r* decreases (here the role of magnetic attraction forces is negligible). Since the mass per unit length is reduced in proportion to the square of the radius, the local value of the electrical constant (linear density) ε_0 is reduced proportional to the ratio r/r_e. Thus repulsive potential as a result increases in inverse proportion to the square of the distance, and the resulting potential-distance dependence receives the form below:

$$V = 0.511(-1/r_k + 1/r^2)\ \text{МэВ}. \tag{19}$$

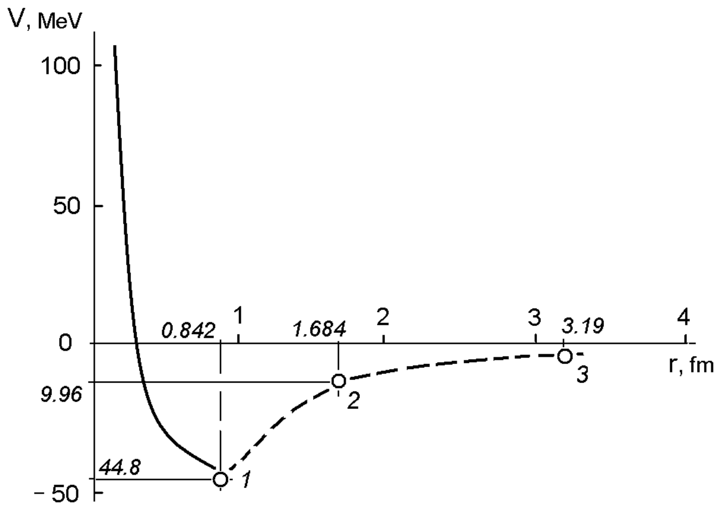

Fig. 1: The dependence of the nucleon-nucleon interaction on the distance

Beyond “quark bag”, at the distance of the nucleon diameter, the Coulomb interaction occurs between the fractional charges of different signs, located on the *outer surface* of protons. Thus, attractive potential sharply decreases, for protons it is in proportion to the product of $1/3\times2/3 = 2/9$. Namely, at the distance $2r_n = 1.684$ fm attractive potential decreases to a value $2/9\times44.8 = 9.96$ MeV.

Another reference point for plotting the dependence $V(r)$ can be found by equating the Coulomb repulsive forces between two protons at the distance between their centers to the residual attractive forces acting between the fractional charges located on the outer surface of the protons. In this case we have:

$$e^2/(\varepsilon_0 r^2) = (2/9) \times e^2/(\varepsilon_0(r - 2r_n)^2), \tag{20}$$

from which we obtain $r = 2r_n /(1- \sqrt{(2/9)}) = 3.78r_n = 3.19$ fm, i.e. distance where the attractive forces between the nucleons can be neglected. The resulting dependence $V(r)$ is shown in Figure 1, and it as a whole corresponds to actual dependence.

Thus, it may be concluded that any special nuclear forces do not exist, and complex nuclear interaction is explained by the forces of unified nature (electrical) acting between the elements of the complex structure of nucleons at different levels (the "depths" along Y-axis), which are determined by the interaction energy.

5.2 The binding energy of deuterium, tritium and alpha particles

A deuterium nucleus - the deuteron is a rather loose formation, and therefore it can be assumed that the bond of two nucleons due to Coulomb forces between the proton having on its outer surface fractional charges of 2/3, 2/3, -1/3 and the polarized neutron with charges on the surface of -2/3, 1/3, 1/3. Let us assume that the nucleons form its own contour having at $n = n_p$ the parameters $l_y = 2092$ and $r = 0.1024$ (section 2). When substituting r into (18), we obtain the binding energy (potential) in the units of MeV bonding the nucleons in the deuteron: $E_d = 0.511\times(2/3\times2/3) / 0.1024 = 2.22$ MeV that corresponds exactly to the actual binding energy of the deuteron.

Could this be an accidental coincidence? It is known that the good description of the characteristics of the deuteron provides the selection of the nucleon-nucleon n-p potential in the form of a rectangular pit of depth V~35 MeV and of width $d = 2$ fm [8]. Assuming that d is the distance between the centers of nucleons, one can find that the distance between the fractional charges on the nucleon periphery is $d - 2r_n = 0.316$ fm or 0.112 r_e. The result is in good agreement with the proton vortex tube size, i.e. with parameter r, that confirms the correctness of calculation.

The tritium nucleus - triton consists of a proton and two neutrons attached. The mean square charge radius of the triton is 1.63 fm, so, obviously, the nucleons are in contact. Let us assume that the neutrons are polarized with charges of 1, -1. Binding energy can be determined by summing the mass-energy of the four quarks involved in creating bonds. As a result, we get $E_d = 2.2\times4 = 8.8$ MeV that is close to the actual triton binding energy (8.48 MeV).

An alpha-particle is a spherically symmetric object with radius of about 2 Fermi, and it is the most stable and compact structure (cluster) that can occur inside the atomic nucleus. If we assume that nucleons are in contact with each other, then for symmetrical arrangement of four nucleons having radii $r_n = 0.842$ fm and forming a closed system as a whole, in fact, the alpha-particles radius will be 2.04 fm, Figure 2.

The alpha particle emitted from a nucleus overcomes the potential barrier and, in addition, is a surplus energy in different ranges. Apparently, in addition to the mass-energy of eight quarks involved in the interaction, there is a necessity to take into account also the mass-energy of the two protons quarks included in $p^{+} - e^{-}$-contours; this mass-energy depends on the quantum number of the contour, figure 2*a*. It was revealed that alpha-clustering is most probable in the nucleus surface region where the density of nuclear matter is reduced to about one-third of density in the nucleus central part [9]. Therefore, we can assume that the protons of alpha-particles leaving the nucleus are associated with the second electron shell (the first one has only two electrons).

From (8), (13), and (14) it follows that the masses of quarks that are constituents in a $p^{+} - e^{-}$-contour are proportional to the quantum number:

$$m_k = bac_0^{1/3} n = 5.377\, n, \tag{21}$$

i.e. for the second shell the quark mass is equal to 10.75. As a result, given the potential repulsion of two protons (~ 0.6 MeV at a specified distance 2.38 fm on the scheme), we obtain: E_a = 0.511×(4.3×8+10.75×2) - 0.6 = 28.0 MeV, which corresponds well to the actual alpha particles binding energy (28.2 MeV).

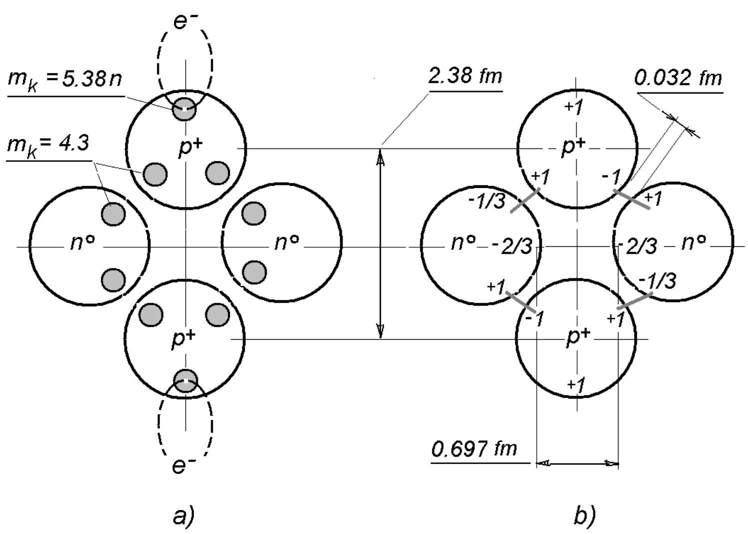

Fig. 2: Settlement scheme of the alpha particle: *a* - on the basis of the quark masses, *b* - on the basis of energy of the quarks

One can determine the binding energy from another considerations by summing the energy of bonded opposite charges, assuming that the distance between them is equal to the radius of the electron vortex tube r = 0.0114 = 0.032 fm, figure 2*b*. Other positive charges of the protons quarks are associated with the atom electrons, and the unaccounted negative neutrons charges create the repulsive potential. The bonds form a closed system, so one can assume that the alpha particle binding energy is the averaged binding energy of a link, since at destruction of a link the particle splits as a whole. Indeed, it is known that to remove of only a nucleon from alpha particles the energy about 20 MeV is required [9].

Given the above, referring to the adopted charges layout, the alpha particles geometry, and specified dimensions, one can write the final formula for the binding energy as the average energy per bond at subtracting the repulsive potentials of protons as whole units and the fractional charge repulsion potentials of neutrons:

$$E_a = (1/4)\times(1\times1+1/3\times1+1\times1+1/3\times1)\times0.511/r - 1\times1\times0.511/b - (2/3\times2/3)\times0.511/c, \qquad (22)$$

where b and c are calculated from geometrical considerations: $b = 2r_n\sqrt{2} = 2.38$ fm or 0.845, $c = 2r_n(\sqrt{2}-1) = 0.697$ fm or 0.248. Substituting the values, we obtain $E_a = 28.3$ MeV, which coincides with the actual value.

It is known that the nuclei can be seen as the system of nucleons and at the same time as the system of the large number of clusters of different nature, which are in dynamic equilibrium, i.e. they disintegrate, are again formed and exchanged both nucleons and energy [10]. The closer to the nucleus center are protons, the higher energy they have, since the proton quarks mass-energy included in the $p^+ - e^-$ -contours increases in proportion to the quantum number. When the transfer of energy from the center and from the inner envelopes to the periphery occurs, alpha-particles leaving the nucleus surface have the energy excess equal to the energy difference between the corresponding levels, i.e. referring to (22) and at changing to energy units $E_a = 2.75(n_2 - n_1)$ MeV.

Thus, when the excitation transfer from the third to the second envelope the energy of alpha-particles having two protons may be not more than 2×2.75 = 5.5 MeV, and when the excitation transfer from the fourth to the second envelope - twice as much, not more than 11 MeV.

Indeed, for the emitted alpha particles there are two energy ranges: with the upper limit of 2-4 MeV for rare earth elements and 4-9 MeV for the elements heavier than lead [11]. Not numerous long-range alpha particles with higher energy get this energy after series of collisions with protons in the center of the nucleus, which are associated with the fifth, sixth, and seventh envelopes; accordingly, their maximum energy can reach 2×2.75(7 - 2) = 27.5 MeV. The resulting value matches exactly the value of the maximum alpha particles energy, defined in during the study of heavy nucleus fission accompanied by the formation of three charged particles [12]. Moreover, in these particles energy spectrum there is no fine structure, which is understandable, since the energy of such particles is derived from protons homogeneously packed in the "quark bag" in the nucleus core, but not from the structural units in the nuclear envelopes composition having certain specificities.

It should be noted that the binding energies differences between neighboring isotopes for the nuclei of almost all elements are in the range of 20 MeV (for isotopes with the least number of neutrons) to 2 MeV (for isotopes with the greatest number of neutrons). That is, in the most cases these energy differences lie in the range from the nominal mass-energy of a cluster 2.2×8 = 17.6 MeV to the mass-energy of a quark 2.2 MeV. This means that in the first case, with the excess of protons, addition of a neutron leads to the formation of an entire cluster (alpha-particles) and in the second case, with the excess of neutrons, - to another quark be only involved in a common bound nucleus structure.

Another fact confirming that clusters are only formed in the envelopes from the first to the fourth is the amount of isotopes depleted by neutrons. Typically, for most of elements (except radioactive ones) it is close to the number of clusters. The maximum amount of such isotopes Platinum has (Pt^{195}... Pt^{166}), it is equal to the number of clusters in all four envelopes (30).

5.3 On the nucleus structure

In accordance with the model the packing density of alpha-clusters and of protons in particular increases toward the center of the nucleus, as the distance between the vortex tubes of $p^+ - e^-$-contours is reduced and the vortex tubes length increases. Therefore, the electrons located at the more distant orbits are associated with the protons located at the deeper nucleus levels; thus the *layers or envelopes are formed in the nucleus* that similarly to the electronic shells.

Suppose that the distance r_i between the vortex tubes can not be less than the size of alpha-particles (4 Fermi). This condition limits the number of the electronic shell whose electrons can associate with the protons belonging to alpha-clusters and, accordingly, the nucleus envelope which deeper alpha-clusters are not formed. From (15) and (8) implies $n <= 3.44$. Even if the diameter of the equivalent sphere equal to the volume of four alpha-particles nucleons (~ r_e) to accept for limiting size, and even then $n <5$. I.e. the electrons of the fifth and subsequent atom shells are associated with protons in the center of the nucleus; these protons are here not part of the alpha-clusters. Thus, the fourth layer (envelope) is the last in the nucleus.

It should be noted that a similar condition for the nucleon size also determines the maximum possible number of the atom electron shell. Indeed, assuming $r_i >= 2r_n$, we find $n_{max} <= 8.1$.

Consider the heavy atom nucleus, for example, $_{82}Pb^{207}$, wherein there is a fourth filled electron shell with 32 electrons and, accordingly, the fourth layer of 16 clusters in the nucleus. It is not difficult calculate the outer and inner radii of the layer, assuming that one alpha-cluster has a volume equivalent to the volume of four nucleons, i.e. $4\times(2r_n)^3 = 19.1$ fm^3. The inner radius is 2.93 fm. The remaining 22 protons are not part of the proton clusters; they are located in the center of the nucleus and have the volume equivalent to the sphere of exactly the same radius 2.93 fm. The outer diameter of the nucleus as a whole in the summation of the thickness of the four envelopes is $2.93 + 4\times2r_n = 9.66$ fm, which corresponds to the size of heavy nuclei.

Thus, it appears that for the elements heavier than lead, the protons taking part in the contours where electrons belong to the fifth and subsequent shells no longer completely go in the core of the nucleus. With increasing the number of protons the fourth nuclear envelope expands, additional neutrons are included in it, and radius of the nucleus increases.

Neutrons are not included in the cluster (for $_{82}Pb^{207}$ of such neutrons are 65) are placed in the free volume being forced out into the outer envelopes. One can assume that the average distance between them is not less r_e, accordingly, the average volume per a neutron exceeds 22.4 fm^3 that provides the nuclear attraction forces between neutrons to be absent and neutrons to move freely. Now it is possible to calculate the number of neutrons in the void volume (excluding the first envelope, which is the transition boundary structure, where the nuclear and charge density fall sharply down) and then the mass number. For lead the outer radius of the second envelope is $9.66 - 2r_n = 7.98$ fm, its volume is 2130 fm^3. Subtracting from this volume the volume of 30 clusters (120 nucleons) and subtracting the volume of 22 nucleons in the center of the nucleus, we obtain the volume 1452 fm^3, which can accommodate 65 neutrons. As a result, adding the number of protons (82) and neutrons in clusters (60), we obtain the exact mass number for the stable isotope of lead $A = 207$.

The highest density of nuclear matter exists in the nucleus center and in the inner envelopes. Assuming that the nucleons packing density in the nuclear core and in the adjoining envelope are identical, i.e. their nuclear density is the same, and on the basis of the above geometrical considerations, it is possible derive the relation between the number of nucleons in the nucleus core z_{cor} and their number in the adjoining envelope z_{env}, which provides this homogeneity condition:

$$z_{env} = c\,(1 + (z_{cor}/c)^{1/3})^3 - z_{cor}\,, \tag{23}$$

were $c = 4\pi/\,3$.

Equation (23) observed for the lead very precisely: 22 nucleons in the center correspond to 64 nucleons in the 4th envelope (32 protons and 32 neutrons), so it turns out that in the nucleus core neutrons are absent. For the lighter nuclei the inner envelope volume including protons and neutrons can be considered as the core. Condition (23) is also satisfied of about for iron (4 nucleons in 4th envelope, 28 nucleons in 3d envelope), xenon (8 nucleons in the core 36 nucleons in 4th envelope) and for a few other elements. At that, for the nuclei of these elements the observed electric quadrupole moments are close to zero. For most other elements situation may be different; in the general case part of the neutrons or go in the nucleus core, or go in the adjacent envelope, and such nuclei may take a non-spherical shape.

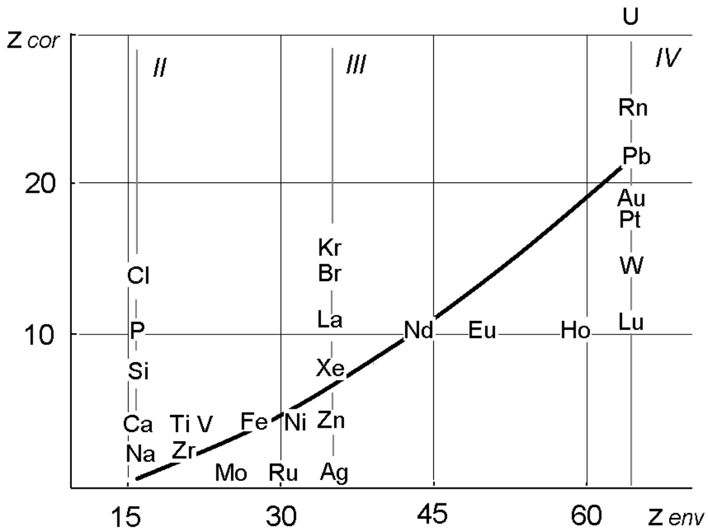

Fig.3: The condition of nucleus central part homogeneity with respect to the initial number of nucleons for the stable isotopes of some elements

Thus, for the condition (23) to be satisfied, it is necessary (for the metals heavier than iron having one or two electron at the fourth electronic shell) for the additional neutrons that are outside clusters to replenish the fourth inner nucleus envelope and (for the metals with Z = 37 ... 52, many of lanthanides, and heavy metals before lead) to instil into the nucleus core. For others, mainly non-metals and the elements heavier than lead, the neutrons must replenish the envelope adjoining to the nucleus inner part. Figure 3 shows the position of the curve $z_{cor}\,(z_{env})$ respect to the initial number of nucleons for stable isotopes of some elements.

Thus, knowing the structure of the atom electron shell and, accordingly, the number of protons in nucleus envelopes and its core, specifying the number of neutrons and having in mind the condition (23), one can try to reproduce the nucleus structure for different atoms and their isotopes. There is a question, how exactly the condition (23) should be satisfy during of additional neutrons distribution? That is whether equation (23) can be solved in integers, as it is done for lead? Perhaps this peculiarity defines some properties of the isotopes: lifetime and others.

To fill the outer nuclear envelopes neutrons there is usually no in enough. Therefore, for some nuclei its outer envelope must be squeezed, lose shape of a spherical layer and take the form of a polyhedron, in the corners of which alpha-clusters are. A similar phenomenon is starting to get a confirmation, for example, in [13].

5.4 The nuclei binding energies and the mass numbers

It is well known that nuclear binding energy E_n is calculated by the Weizsacker semiempirical formula, based on the liquid drop model and consists of five members and empirical coefficients reflecting the contribution of various components in the total binding energy.

Presented above model allows calculating the nucleus binding energy without having to empirical coefficients. As mentioned in section 5.2, the nucleus energy is ultimately determined by the mass-energy of nucleon quarks. Represent this energy as the sum of the nominal energy of eight quarks in all clusters (Figure 2*a*), included in the envelopes from the first to the fourth as 8×2.2 z_{kl}, the total energy of the proton quarks belonging to $p^+ - e^-$-contour as 2.75$(m_1 + 2m_2 + 3m_3 + ...)$, and the base energy of the first envelope as 2.75 z. The latter may be associated with a potential barrier.

Here it is denoted: z_{kl} is the clusters number, z is the protons total number, m_i is the electrons number in the i-th atom shell.

The final amount when changing the clusters number by the protons number in clusters has the form:

$$E_n = 8.8\, z_{pkl} + 2.75(m_1 + 2m_2 + 3m_3 + \ldots + z), \quad MэB \tag{24}$$

where z_{pkl} is the total protons number in the first - fourth envelopes.

Formula (23) for the binding energy does not depend on the neutrons number; this indicates that for stable isotopes a certain optimum amount of neutrons are in accordance with protons. It turns out that it is possible to calculate the neutrons number based on energy balance considerations, using the dependences previously obtained.

It is considered that the neutrons and protons are different states of nucleons. This is true for the nominal quark masses of nucleons, since their mass-energies are identical and equal to 2×2.2 = 4.4 MeV. However, the mass-energy of neutron quarks must also comply with the mass-energy of proton quarks, which are included in the circulating $p^+ - e^-$-contour 2.75$(m_1 + 2m_2 + 3m_3 + ...)$, net of the basic energy of the unfilled first shell 2.75 z and minus the nominal mass-energy of proton quarks, located in the nucleus center and not connected with neutrons 4.4 $(z - z_{pkl})$.

That is the balance of energy must be from which the neutrons number N and further the mass number $A=N+z$ can be determined:

$$2.75(m_1 + 2m_2 + 3m_3 + \ldots) - 2.75\, z - 4.4(z - z_{pkl}) = 4.4\, N, \quad MэB \tag{25}$$

$$A = z_{pkl} + 0.625(m_1 + 2m_2 + 3m_3 + \ldots - z) + (4)_{A<140}\,. \tag{26}$$

For the mass number an amendment is necessary in some cases, which, it may be supposed, is the consequence of the presence of alpha-cluster four nucleons in the first envelope, which are split off when the nucleus reaches a certain mass. Thus, for light and medium nuclei the result of formula (26) should be increased by 4. For the heavier nuclei with $A > 140$, the amendment is not necessary, that seems to be due to their natural alpha decay. For the transuranic elements nuclei, as calculations are shown, their binding energy should also be reduced by the amount of the alpha particle binding energy.

Table 1 show the actual and calculated data of the binding energy and mass number rounded to the integer for stable isotopes of certain elements according to the formulas (24) and (26). These formulas are obtained under the condition that the nuclei structure satisfies the condition (23). Existing slight variations in binding energy to the lower side for medium nuclei can be eliminated by considering their individual features, for example, with taking into account the energy bonds of additional neutrons, which replenish the core or adjoining nucleus envelope.

Table 1 Even numbered elements

Elements	$_{4}Be^{9}$	$_{8}O^{16}$	$_{14}Si^{28}$	$_{26}Fe^{56}$	$_{30}Zn^{65}$	$_{42}Mo^{96}$	$_{62}Sm^{150}$	$_{74}W^{184}$	$_{92}U^{238}$
Actual, MeV	58.2	128	237	492	567	831	1239	1473	1802
Calcul., MeV	62.6	131	244	487	566	822	1232	1479	1806
Calcul. *A*	9	16	28	56	65	99	151	184	236

Odd numbered elements

Elements	$_{5}B^{11}$	$_{17}Cl^{35}$	$_{21}Sc^{45}$	$_{29}Cu^{64}$	$_{39}Y^{89}$	$_{51}Sb^{122}$	$_{67}Ho^{165}$	$_{83}Bi^{209}$	$_{93}Np^{237}$
Actual, MeV	76.4	298	388	559	775	1033	1344	1640	1795
Calcul., MeV	79.7	303	388	544	757	1009	1344	1636	1821
Calcul. *A*	11	35	45	63	90	123	165	208	238

6 Conclusion

It seems surprising that the complex nature of nuclear forces and the structure of atomic nuclei proved possible to be largely understood without involving actual quantum concepts and complex mathematical apparatus.

The mass of equivalent to the Higgs boson mass are obtained, the coupling constants in different types of interactions, the binding energy of the deuteron, triton, and alpha particles are defined, the possible ranges of alpha particles energies are identified, and dependence of the nucleon-nucleon interaction from a distance is explained. Based only on the composition of the atom electron shells, it was possible to determine the nuclei binding energies, the nucleus neutron numbers, to reveal the important features of nuclei.

Obviously, these results indicate that the model adequately reflects the fundamental features of the atomic nucleus structure. These results give reason to believe that the foregoing model can become the basis of further theoretical developments for detailed describing the properties of nuclei and their behavior in nuclear reactions.

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