Geometric model of atomic nuclei

Ilya A.Boldov

Abstract

The article proposes a geometric model of atomic nuclei based on the homology of the structures of electronic shells and structures of nuclear layers and the assumption of anisotropy of nuclear forces and their action in six orthogonal directions $(\pm X, \pm Y, \pm Z)$. The order of filling the spatial positions of the core layers with both nucleon pairs (proton-neutron) and individual neutrons of the core surface is proposed. Based on the computer program written by the author, the structures of all known and possible nuclei up to the 160th element of the Periodic Table are modeled. An explanation of the so-called "magic" cores has been obtained. The spatial positions in which protons can be attached to the nucleus in cold nuclear fusion reactions are determined. The location of ^4He clusters in the structure of the core layers is revealed and it is shown how the fission of radioactive nuclei into unequal fragments by intercluster bonds occurs. An explanation of the stability corridor of the nuclei is given. The proposed model was verified by calculating the quadrupole moments of Lithium nuclides.
keywords:Atomic nucleus, atomic nucleus structure, nuclear forces, nuclear fission, stability of atomic nuclei, Cold nuclear fusion.

> God acts as the greatest geometer who
> prefers the best solution to problems.
> G.K.Leibniz

1 Introduction

The study of atomic nuclei began in the 30s of the XX century and continues to the present day. Modern physics knows and offers many different models based on the representation of the nucleus as a physical object with pre-known characteristic properties. Let us briefly list the main generally accepted:

1. **A drop model.**

   It was proposed by N.Bohr in 1936 as part of the theory of the composite kernel [1]. The model assumes the nucleus as a kind of incompressible drop of liquid-nuclear matter capable of "evaporation of nucleons". From this model, Karl Weizsacker obtained a semi-empirical formula for the binding energy of the atomic nucleus, named in his honor. The model describes well the proportionality of the binding energy of heavy nuclei to the mass number $A = N + Z$; the dependence of the radius of the nucleus R on A, the causes of nuclear fission and their mechanism, nuclear reactions at low energies going through the composite Boron nucleus, but does not describe some terms in the formula for the binding energy of the nucleus, for example, the pairing energy, does not explain the existence and special stability of magic nuclei.

2. **Shell model.**

   In this model, the nucleus is a system of nucleons moving independently in an averaged field created by the force action of the remaining nucleons [2]. Each nucleon is in a certain individual quantum state characterized by energy, the moment of rotation j, its projection m on one of the coordinate axes and the orbital moment of rotation $l = j \pm 1/2$. The energy of the level does not depend on the projection of the moment of rotation on the external axis, therefore, at each energy level with moments j, l there can be $(2j + 1)$ nucleons forming the shell (j, l). A set of levels close in energy forms the shell of the core. When the number of protons or neutrons reaches the magic number corresponding to the filling of the next shell, there is a possibility of abrupt changes in some quantities characterizing the nucleus (in particular, the binding energy). The physical reason for periodicity is the Pauli principle, which prohibits two identical fermions from being in the same state.

The shell model made it possible to explain the spins and magnetic moments of nuclei, the different stability of atomic nuclei, as well as the frequency of changes in their properties, applicable to the description of light and medium nuclei, as well as nuclei in the ground state.The model does not explain deformed cores.

3. **Collective model.**

   It was proposed by Oge Bohr and B. Mottelson in 1952. It is a variant of the droplet model and considers the nucleus as a backbone formed by nucleons of filled shells and external nucleons moving in the field created by the nucleons of the backbone. The model explained the nature of low-lying excitations of nuclei, which are interpreted as dynamic deformation of the surface.

4. **Generalized model.** It was also proposed in 1952 by Oge Bohr and B. Mottelson [3]. She explained the large quadrupole moments of some nuclei by the fact that the outer nucleons of such nuclei deform the skeleton, which becomes elongated or flattened.

5. **The rotational model.**

   It appeared as an explanation of experimentally established very large values of quadrupole moments of heavy nuclei at $150 < A < 190$ and $A > 200$. In this range of values A, the dependence of the energy of the lower excited states of the nuclei on the spin of the nucleus turns out to be similar to the dependence of the energy of a spinning top on its moment of rotation. According to the model, the core is assumed to be non-spherical.

   The difference of the rotational model is the representation of the nucleus as a rotating whole, with the movement of individual nucleons in a non—spherical potential field. At the same time, it is assumed that the rotation of the entire nucleus is quite slow compared to the speed of movement of nucleons. The rotational model allows us to describe a number of essential properties of a large group of nuclei, while the very fact of the occurrence of the rotational spectrum (the fact of rotation of the entire nucleus as a whole) remains unexplained.

6. **The superfluid model.** Proposed in 1958 by Oge Bohr and J. Valatin [4][5]. Nucleons with the same values of quantum numbers (j, l) and with opposite projections of the total moment of rotation of the nucleon equal to $-j, -j+1, ...j-1, j$ are supposed to pair in nuclei, which leads to the superfluidity of nuclear matter. The physical reason for pairing is the interaction of particles moving in individual orbits. The model satisfactorily explains both the absolute values of the moments of inertia and their dependence on the deformation parameter P.

7. **Cluster model.**

   It originated in the second half of the 30s [7]. The model is based on the assumption that the core consists of α-partial clusters, and is used to explain the properties of some light nuclei. It is assumed, for example, that the lithium nucleus ^6Li spends a significant part of its time in the form of a deuteron and α-particles rotating relative to the center of gravity of the nucleus.

8. **Statistical model.** It was proposed in 1936 by Yakov Frenkel[8] and in 1937 by Lev Landau[9]. At high excitation energy, the number of levels in medium and heavy nuclei is large, and the distances between levels are small. The dependence of the density of energy levels is described by methods of statistical physics, considering the excitation as heating of the Fermi liquid of nucleons. The model is applicable to describe the distribution of energy levels and the probability distribution of quantum radiation during the transition between high-lying excited states of the nucleus, it allows taking into account the corrections associated with the presence of shells in the nucleus.

9. **Optical model.**

   In 1954, K.Porter V.Weiskopf and G.Feshbach [10],[11] proposed to consider an atomic nucleus or a separate nucleon as a continuous medium that refracts and absorbs the De Broglie waves of particles incident on it. The refractive index is considered as a complex quantity, the real value of which determines scattering, and the imaginary value determines absorption. The optical model is convenient because, for example, the problem of considering the interaction of an incident neutron is reduced to a simple problem of scattering and absorption of a neutron by one force center, instead of a much more complex problem of many bodies with other models of the nucleus.

10. **Vibration model.**

    It is used to explain the spectrum of collective excitations of spherical nuclei as a result of surface and quadrupole oscillations of a liquid drop, which is understood as a nucleus.

Initial parcels

The author believes that the modern approach to the structure and study of atomic nuclei resembles the study of a bag of apples and potatoes by shelling it with apples, potatoes and cherries and studying the angles and range of rebound. Yes, the number of apples (protons) and potatoes (neutrons) in the bag is known, but we are guessing about the specific distribution. According to the author, the atomic nucleus is a rigid structure in which each nucleon has its own, strictly defined place.

The proposed geometric model of atomic nuclei is a logical continuation of the conclusions made by the author earlier :

1. The possibility of applying macrophysics concepts and approaches to microphysics objects [12];
2. The assumption that the forces holding the nucleons in the nucleus and the defect of the mass of the nucleons are not a direct cause and effect [12];
3. Comparison (proportionality) of the mass of an elementary particle to the volume it occupies in three-dimensional space [12];
4. Acceptance as quarks of leptons that are polyhedra [13];
5. Geometric model of elementary particles in which nucleons have external d quarks - cubes [13];

as well as the development of shell, cluster and rotational core models.

Coulomb forces of a proton-neutron pair

The internal structure of the proton and neutron was first experimentally investigated by R. Hofstadter [14]. The neutron consists of a heavy core (core) with a radius of $\approx 0.25 * 10^{-13}$cm, with a high density of mass and charge, which has a total charge of $\approx +0.35\ e$, and a relatively sparse shell surrounding it ("meson coat"). At a distance from $\approx 0.25 * 10^{-13}$ to $\approx 1.4 * 10^{-13}$, see this shell consists mainly of virtual ρ^-- and π^-mesons and has a total charge of $\approx -0.50\ e$. Beyond the distance $\approx 2.5 * 10^{-13}$ see from the center extends a shell of virtual ω^+ and π^+ mesons carrying a total charge of $\approx +0.15\ e$. In the proton, the middle spherical layer is also positively charged and carries $\approx +0.50\ e$ [15],[16]

The author believes that in order to study the action of the Coulomb forces of a proton-neutron pair, it is possible to simplify their internal structure by presenting distributed spherical charges as a pair of local charges at the same radius along the interaction line and of half magnitude, as shown in Fig.1.

As shown by calculations of Coulomb forces using the formula (1):

$$F = \sum_{i=1,j=1}^{n,m} K \frac{q_i * q_j}{r_{i,j}^2}; \qquad (1)$$

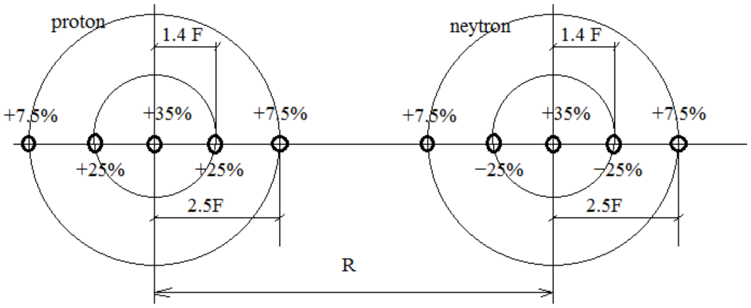
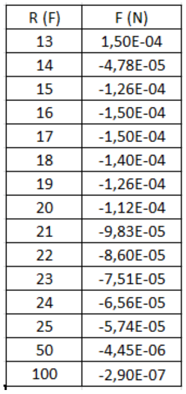


Figure 1: Internal structure of proton and neutron

where $K = \frac{1}{4\pi\epsilon_0}$, the electric constant $\epsilon_0 = 8.85418781762039 * 10^{-12} F * m^{-1}$, $q_i * q_j$ are the local charges of the proton and neutron (as a percentage of the unit charge e), and $r_{i,j}^2$ is the distance between them, with a certain distance R between the nucleon centers.

A simple calculation in Excel [17] showed the following result in the form of a table and graph Fig.2.



R (F)	F (N)
13	1,50E-04
14	-4,78E-05
15	-1,26E-04
16	-1,50E-04
17	-1,50E-04
18	-1,40E-04
19	-1,26E-04
20	-1,12E-04
21	-9,83E-05
22	-8,60E-05
23	-7,51E-05
24	-6,56E-05
25	-5,74E-05
50	-4,45E-06
100	-2,90E-07

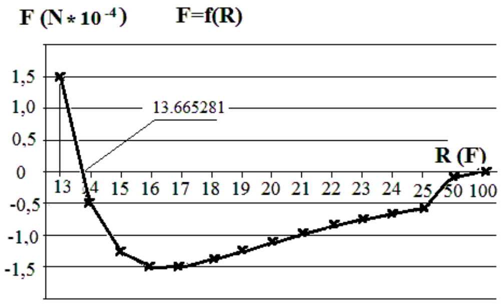


Figure 2: The obtained data and the graph of the Coulomb forces of the proton-neutron pair

As you can see, the resulting graph is a characteristic form, under which all textbooks on nuclear physics represent a graph of the so-called nuclear forces, with an equilibrium point at a distance of $\approx 13.665281F$. It is quite possible that with more complex calculations taking into account the spatial distribution of charges in nucleons, the equilibrium point will have a different meaning. Also note that in the interval between the values of $13F$ and $15F$, the graph can be considered a graph of elastic forces connecting two nucleons and striving to bring the distance between them to the equilibrium point. Which actually led to the appearance of drip and vibration models of the core.

The author conducted a study that a relatively small (about 5-10 %) change in the values of distributed charges in nucleons or the distances between them leads to the disappearance of the equilibrium point.

Also, at distances comparable to the size of nucleons, there is no appearance of attractive forces in proton-proton or neutron-neutron pairs. Only repulsion. At a distance of $\approx .15F$ between the nucleon centers, a neutron is equivalent to a negative charge of 12-15% of the value of the elementary charge e.

As an analogue to such a Coulomb interaction, a hydrogen molecule H_2 can be brought, in which the forces of attraction of one proton to the near part of a foreign electron cloud at some distance are balanced by the forces of repulsion from the second proton.

There can be only one conclusion from the above: The internucleon bonds in the atomic nucleus are exclusively of the proton - neutron type.

Geometric model of atomic nuclei

The conclusion obtained by the author in [13] that nuclear forces in atomic nuclei have spatial anisotropy in six orthogonal directions (axes $+X, -X, +Y, -Y, +Z, -Z$) gives the following form of Hydrogen nuclides $^2H ... ^7H$ is shown in Fig. 3.

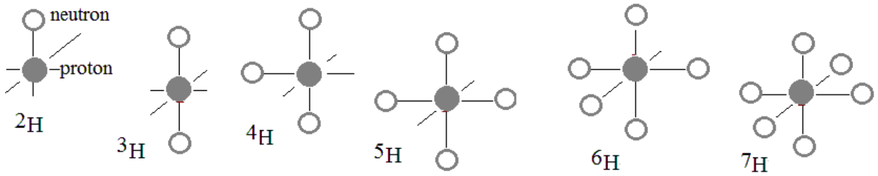


Figure 3: Structures of $^2H ... ^7H$

The figures show why the nuclide ^8H cannot exist. There is simply no place for the seventh neutron. The following assumption should be added to the above: The structure of the electron shells of the nucleus is a reflection of the structure of the nucleus itself and is homologous to it. Each layer of the nucleus (K,L,M,N...) is mirrored by its electron shell (K,L,M,N...) and is filled with nucleon pairs (proton+neutron) in the same order s1,s2,p1,p2,p3,p4,p5,p6,d1...b18 (the main algorithm) for kernels with A=2*Z. Figure4 shows the kernel of the hypothetical element $^{396}_{160}Uhn-p$. On the left side view and on the right in the section of the layer "O" in which all positions from s1 to b18 are filled with proton-neutron pairs. Black circles are protons, white are neutrons.

The formula of electronic shells for the 160th element Ks2,Lp5,Md10,Nf14,Ob18,Pf14,Qd8,Rs2. The author reminds that in the formula the big letter is the designation of the shell (core layer), and the small one with a number is the last filled subshell (position in the layer). The formula of the nuclear layers looks exactly the same.

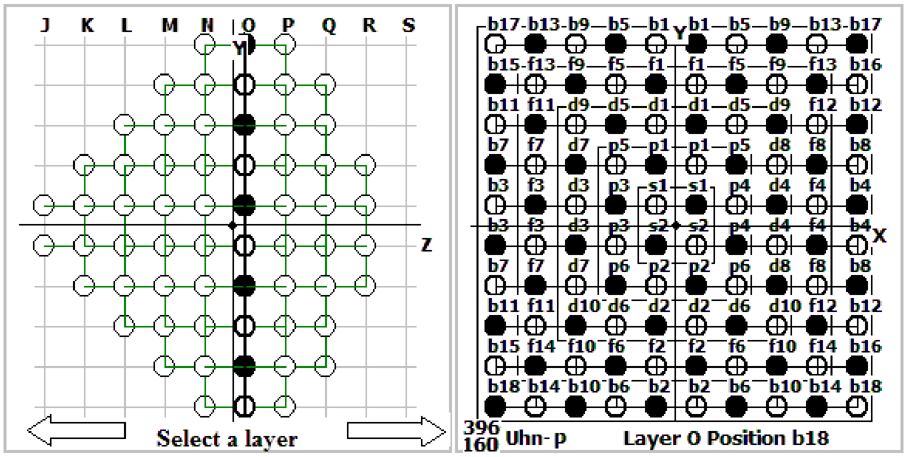


Figure 4: The structure of the O core layer $^{396}_{160}Uhn-p$

The figure below shows the algorithm for filling the core layers for nuclides A=2*Z. Since neutrons can be attached before the K layer, the author added a J layer for them. Neutron removal in neutron-deficient nuclei will take place in the same order of positions, but in the reverse order of the algorithm. That is, for the nucleus A=2*Z-1, a neutron in the K layer of position s2 will be removed. For A=2*Z-2, a neutron in the K layer of position s1 will be removed. Then Lp6, Lp5, Lp4... and so on, starting from the last filled position in the next layer. This is how the ^{8}C core layers look like, for example.

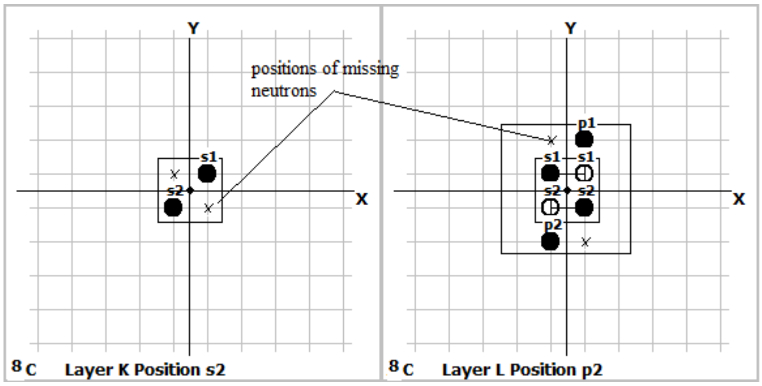


Figure 5: Structures of layers K,L of the kernel ^{8}C

Since neutrons can attach to the nucleus only next to protons, the author suggests designating such spatial positions as t-positions indicating the rank, i.e. the quantity of bonds with protons that a neutron attached to this position will receive. Accordingly, they are denoted as $t4, t3, t2, t1$. In neutron-surplus nuclei, the filling of t-positions with neutrons proceeds again according to the basic algorithm, taking into account the fact that the t-positions of the higher ranks are filled first. Fig.6 shows the layers J,K,L of the core ^{28}O in which all positions t2 and t1 are filled.

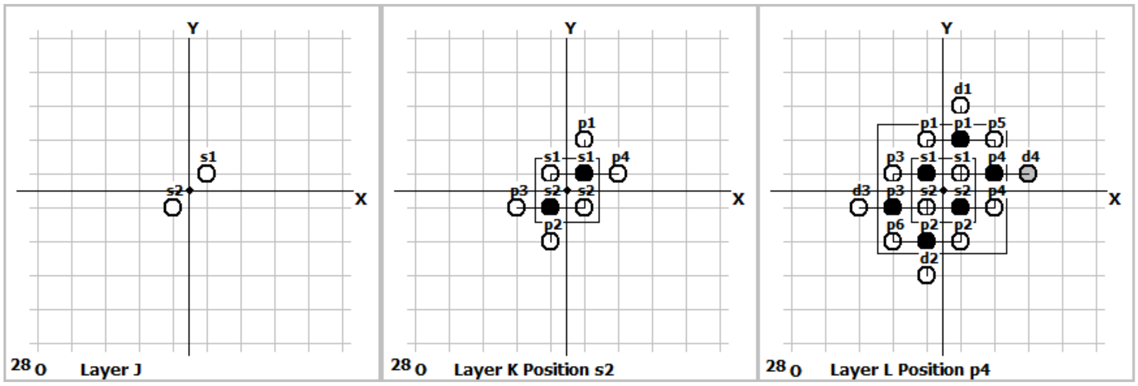


Figure 6: Structures of layers J,K,L of the kernel ^{28}O

Since it is necessary to somehow understand how this nuclide differs from neighboring ones, the author suggests introducing the designation "Isomer", as the designation of the last neutron attached by the algorithm. So for the kernel ^{28}O it will be "+Ld4". So, in comparison with the nucleus ^{27}O, a neutron has been added to the layer L position d4. For nuclei that are isomers, this designation will indicate from which position of the ground state the neutron is removed and where it is attached. For example -Js1+Js2 for the nucleus of the isotope $^{8}Li - m0.981MeV$. Such neutrons are highlighted in gray in the pictures. Naturally, for neutron-deficient nuclei, it will be indicated from where the neutron is removed compared to the neighboring A+1, for example -Ks2 for the nucleus ^{5}Li. Important in the structures of the cores is the presence of clusters ^{4}He. The author analyzes the structures of nuclei obtained in a geometric model and determines the position of clusters ^{4}He in each layer of each nucleus.

For example, the layers of the nuclide ^{40}Ca are shown in Fig.7, where the cluster center is ^{4}He  A thin circle line between two protons and two neutrons is shown.

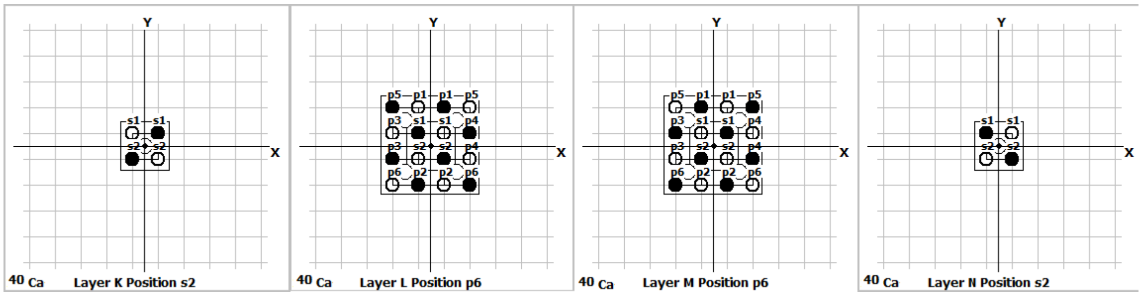
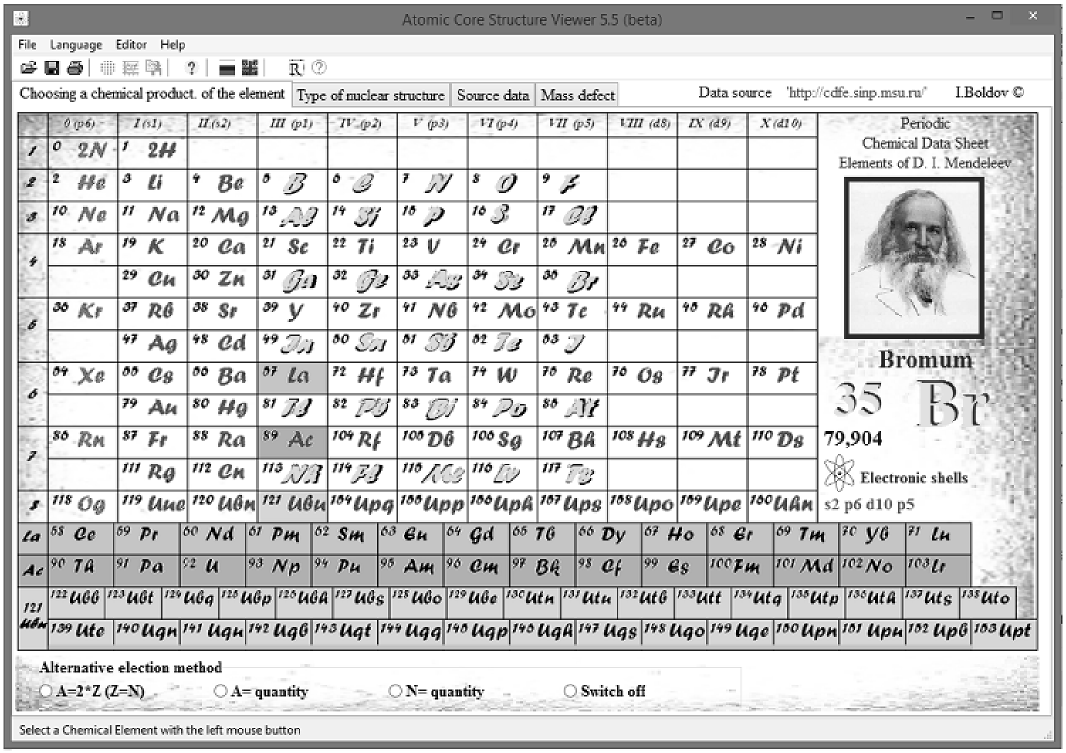


Figure 7: Location of clusters ^{4}He in layers ^{40}Ca

All the drawings of nuclear layers and graphs used in the article were obtained using a computer program written by the author for modeling the structures of atomic nuclei, available at the link [18]. Beta version 5.4 for Windows, is not installed, does not write to registries, does not create shortcuts. It is necessary to unzip and run ANV.exe .

All kernel structures are created by the program itself according to the algorithm proposed by the author . Manual editing was required only for a few light kernels (built-in structure editor). In addition to the known and experimentally discovered nuclides, the program has also created possible structures for both neutron-deficient and neutron-excess nuclides, and as yet undiscovered up to the 160th element. Such nuclides have "-p" (possible) in their name.

The nuclide series selection page is shown in Fig.8. The main choice for Z is made by selecting an element on the D.I.Mendeleev Table. At the bottom there is an alternative selection panel for A,N,A=2*Z. The structure and data view page is shown in Fig. 9. At the top left of the main



Data source 'http://cdfe.sinp.msu.ru/' I.Boldov ©

	0 (p6)	I (s1)	II (s2)	III (p1)	IV (p2)	V (p3)	VI (p4)	VII (p5)	VIII (d8)	IX (d9)	X (d10)
1	0 2N	1 2H									
2	2 He	3 Li	4 Be	5 B	6 C	7 N	8 O	9 F			
3	10 Ne	11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl			
4	18 Ar	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni
		29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br			
5	36 Kr	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd
		47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 J			
6	54 Xe	55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt
		79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At			
7	86 Rn	87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds
		111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts			
8	118 Og	119 Uue	120 Ubn	121 Ubu	154 Upq	155 Upp	156 Uph	157 Ups	158 Upo	159 Upe	160 Uhn

La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

121 Ubu	122 Ubb	123 Ubt	124 Ubq	125 Ubp	126 Ubh	127 Ubs	128 Ubo	129 Ube	130 Utn	131 Utu	132 Utb	133 Utt	134 Utq	135 Utp	136 Uth	137 Uts	138 Uto
	139 Ute	140 Uqn	141 Uqu	142 Uqb	143 Uqt	144 Uqq	145 Uqp	146 Uqh	147 Uqs	148 Uqo	149 Uqe	150 Upn	151 Upu	152 Upb	153 Upt		

Periodic
Chemical Data Sheet
Elements of D. I. Mendeleev

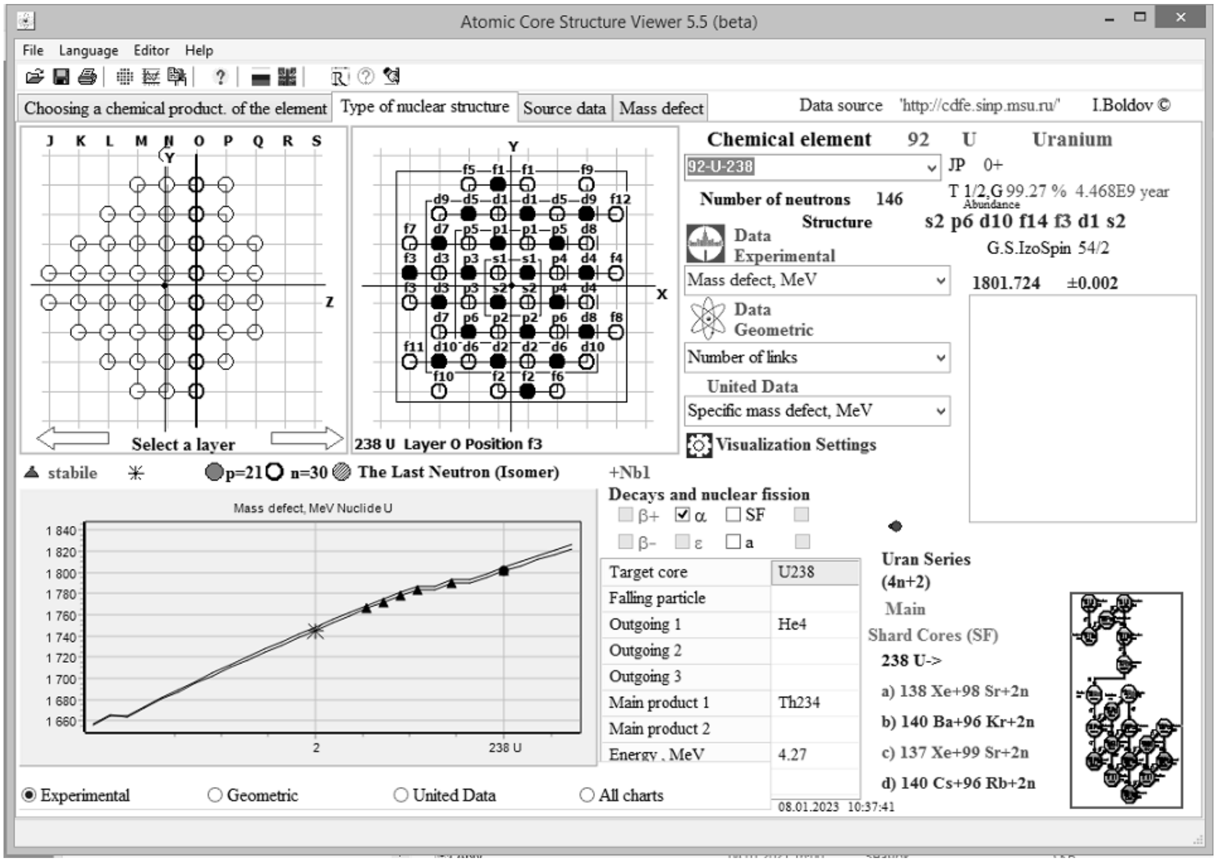
Bromum
35 Br
79,904
Electronic shells
s2 p6 d10 p5

Alternative election method
○ A=2*Z (Z=N) ○ A= quantity ○ N= quantity ○ Switch off

Select a Chemical Element with the left mouse button

Figure 8: Nuclide series selection page

panel there are images of the selected nuclide as a side view and a view of the selected layer. The layers are selected by clicking the left mouse button on the left or right half of the side view of the core. Near the top there is a drop-down list of the selected quantity of nuclides. At the top right are the basic data of the selected nuclide: Number, name, quantity of neutrons, lifetime or half-life, spin, isospin of the ground state and the structural formula of the nuclear layers.



Data source 'http://cdfe.sinp.msu.ru/' I.Boldov ©

Chemical element 92 U Uranium

92-U-238

JP 0+

T 1/2,G 99.27 % 4.468E9 year Abundance

Number of neutrons 146

Structure s2 p6 d10 f14 f3 d1 s2

G.S.IzoSpin 54/2

Mass defect, MeV

1801.724 ±0.002

Number of links

Specific mass defect, MeV

+Nb1

Decays and nuclear fission

☐ β+ ☑ α ☐ SF ☐

☐ β- ☐ ε ☐ a ☐

Target core	U238
Falling particle	
Outgoing 1	He4
Outgoing 2	
Outgoing 3	
Main product 1	Th234
Main product 2	
Energy , MeV	4.27

08.01.2023 10:37:41

Uran Series (4n+2)

Main

Shard Cores (SF)

238 U->

a) 138 Xe+98 Sr+2n

b) 140 Ba+96 Kr+2n

c) 137 Xe+99 Sr+2n

d) 140 Cs+96 Rb+2n

● Experimental ○ Geometric ○ United Data ○ All charts

Figure 9: Kernel structure view page

To the right of the drawings of the core layers , one below the other, there are three drop-down lists :

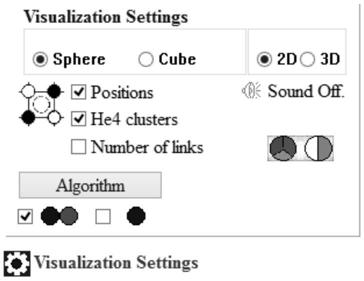
1. **Experimental data downloaded from the Website of the MSU Photonuclear Experiments Data Center**[19]:
   Atomic mass,M; Atomic mass M, MeV; Excess mass M-A, MeV; Core mass, MeV; Mass defect,MeV; BE,MeV; Bn,MeV; Bp,MeV; quadrupole moment (under development).

2. **Geometric data:**(in which the distance between nucleons is taken as a conditional unit of length. Similarly, the masses of the proton and neutron are also taken as a conditional unit of mass for simplification.)
   -t-positions are shown on the core structure with the rank designation. The text field to the right shows the quantity of t-positions by rank and their filling;
   -The center of mass of the core (in XYZ coordinates relative to the center of positions s1, s2 and the layer number) determining the position of the axis of rotation of the core;
   -Centrifugal force, as the sum of the products of the conditional unit mass of nucleons on their removal from the axis of rotation of the nucleus;
   -Total quantity of proton-neutron bonds;
   -Distribution of internuclear bonds along the XYZ axes;
   -Quantity of clusters ^4He;
   -The quantity of nucleons with different quantity of bonds (from 1 to 6) separately for protons and neutrons;

-LENR positions - places where a proton can be attached in Cold Nuclear Fusion reactions;
-Coordinates of nucleons - Determination of the position of the selected nucleon relative to the center of mass (in conditional coordinates);
-Moment of inertia (under development);
-The quantity of bonds per nucleon;
-Coulomb forces (The total value for the surface layer of the nucleus, based on the assumption that the neutron charge Q_n is equal to -0.1 charge Q_p).

3. **Combined data:**
   - A mass defect attributable to one bond;
   - The mass defect per bond, minus the mass defect of all clusters ^4He and the quantity of bonds in them.

The author believes that both Geometric and mixed data obtained by the program will help further researchers in obtaining a formula or algorithm for accurately calculating the mass defect in atomic nuclei.



Visualization Settings
◉ Sphere ○ Cube ◉ 2D ○ 3D
☑ Positions
☑ He4 clusters
☐ Number of links
Sound Off.
Algorithm
☑ ●● ☐ ●
Visualization Settings

By clicking the mouse button on the gear, the Visualization settings Panel is called, which allows you to determine the type of nucleons shown in the form of a sphere or cube, select the mode of displaying the core layers in 2D-3D modes, set the display of nucleon positions or the quantity of connections, as well as the display of clusters ^4He. It is possible to choose the visualization in color or black and white, as well as the "Algorithm" button, which will display the order of filling the layer with proton-neutron pairs, or individual neutrons.

At the bottom left there are elements for displaying graphs of the values of the selected types of the kernel parameter. It is possible to display several or all selected types of graphs simultaneously, one from each list. The obvious correlation of the mass defect graph and the graph of the quantity of internucleon bonds shown in Fig.10 and Fig.11 immediately attracts attention.

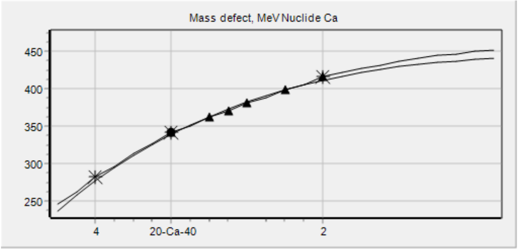


Figure 10: Defect in the mass of nuclides of the Ca series

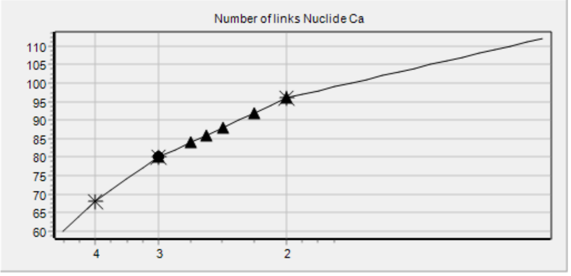


Figure 11: The quantity of bonds of nuclides of the Ca series

Moreover, this correlation can be traced on any sample of $A, Z, N, A = 2*Z$. It can be noticed that the graph of the mass defect by the end non-linearly reduces the increase in data values, and the graph of the quantity of connections at this point is linear. But it is probably necessary to take into account the nonlinear growth of the graph of centrifugal forces, which apparently reduces the mass defect with an increase in the quantity of neutrons, due to the fact that they attach to the surface of the nucleus further away from the axis of rotation.

Notation on graphs:
- The circle shows the position of the nuclide selected in the list;
- A snowflake with a number at the bottom (4,3,2) denotes a nuclide for which all t-positions of the corresponding rank are filled;
- The triangle indicates stable nuclides, or for which the T/2 time is more than a year.

The graphs slightly differ in general appearance, since there are no data for nuclides from ${}^{58}Ca-p$ to ${}^{64}Ca-p$, since they have not been detected yet. Also a very remarkable graph is the graph of the quantity of bonds per nucleon, closely related to the filling of t-positions. Below are graphs for the Ca series (Fig.12) and the Ni series (Fig.13). As we can see, for the so-called "magic" cores, there is an inflection point of the graph. This is observed for almost all "magic" and other relatively stable nuclei, for example, for the only stable ${}^{197}Au$.

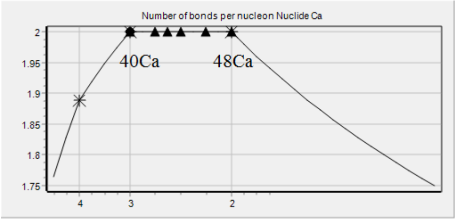


Figure 12: Graph of bonds per nucleon of the Ca series

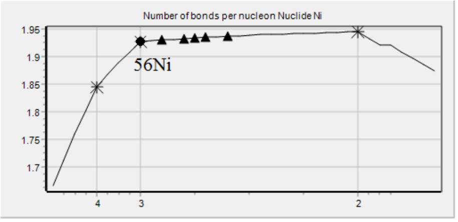
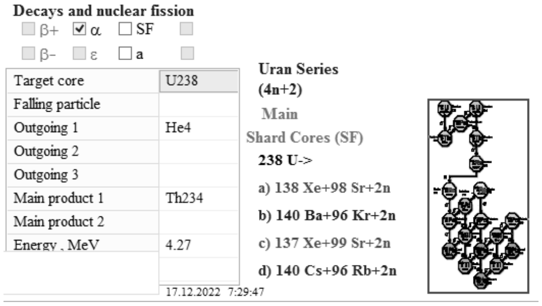


Figure 13: Graph of bonds per nucleon of the Ni series

To the right of the graph panel is the decay and fission panel. In the upper left part there are checks for choosing the types of decay. Under which there is a table with the results of the decays. In the middle part there are formulas for dividing radioactive nuclei into unequal fragments (the main ones are indicated).
In the right part, a table of radioactive series is shown in a reduced form (if the selected nuclide is included in it). When pressed, it unfolds into a large view indicating the position of the selected nuclide in it.



Decays and nuclear fission

☐ β+ ☑ α ☐ SF ☐
☐ β- ☐ ε ☐ a ☐

Target core	U238
Falling particle	
Outgoing 1	He4
Outgoing 2	
Outgoing 3	
Main product 1	Th234
Main product 2	
Energy , MeV	4.27

17.12.2022 7:29:47

Uran Series
(4n+2)
Main
Shard Cores (SF)
238 U->
a) 138 Xe+98 Sr+2n
b) 140 Ba+96 Kr+2n
c) 137 Xe+99 Sr+2n
d) 140 Cs+96 Rb+2n

Since the author has already touched on the topic of fission of radioactive nuclei, it is worth dwelling on it in detail on the example of the nucleus ${}^{238}U$. The layered structure of this nuclide is shown in Fig.14.

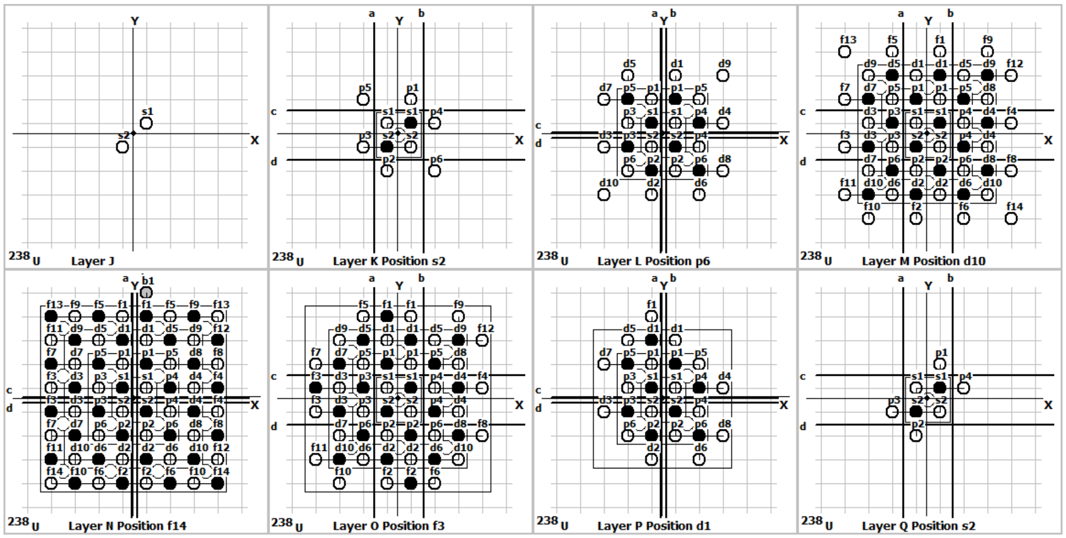


Figure 14: Layered structure ${}^{238}U$

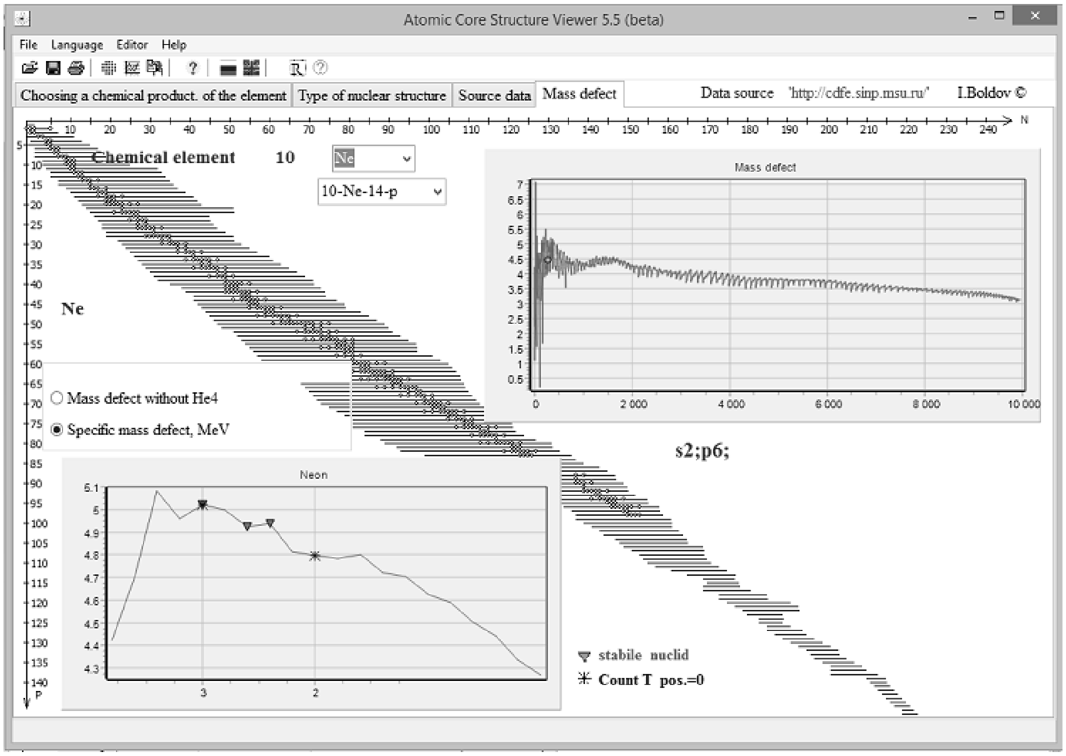
The figures show the fission lines along the intercluster connections a, b, c, d. A simple calculation of the quantity of nucleons on different sides of the lines shows that the leading fission fragments ^{238}U will be the following :
a) $^{138}Xe + ^{98}Sr + 2n$;
b) $^{140}Ba + ^{96}Kr + 2n$;
c) $^{137}Xe + ^{99}Sr + 2n$;
d) $^{140}Cs + ^{96}Rb + 2n$;

Thus, for the fission of nuclei, there is no stretching of the spherical or ellipsoidal shape of the nucleus and the formation of bridges. Radioactive nuclei simply divide under the action of centrifugal forces, like a rotating toy assembled from elements of a designer "Lego".

In this case, radioactive nuclei can be considered as a set of layers of clusters of ^4He and other nucleons connected by elastic bonds, which can fall apart under the external influence of incoming neutrons, or other disturbing factors.

The author believes that until a formula (or algorithm) has been obtained for calculating the exact value of the mass defect of atomic nuclei, it is incorrect to use the formulation "binding energy" of atomic nuclei in relation to the mass defect. Moreover, the author has shown above that it is possible in principle to consider Coulomb forces as forces holding nucleons in a nucleus with elastic bonds.

For a more detailed study of the obtained patterns in relation to the mass defect, the author has allocated to a separate section of the program viewing graphs of the values of the mass defect divided by the quantity of connections, and similar values without clusters ^4He, which is shown in Fig. 15. It is very interesting to compare graphs for sampling series of neighboring chemical elements, where their symmetry or asymmetry clearly affects the mass defect and the stability of the nuclei.



Chemical element 10 Ne

10-Ne-14-p

○ Mass defect without He4

● Specific mass defect, MeV

s2;p6;

Figure 15: Graphs of specific mass defect

The author assumes that the size of the defect of the mass of the nuclei (and the stability factor) is affected by the rotation of the nucleus as a whole, which, with asymmetry, has the influence of precession and nutation.

The author believes that it is the consideration of a neutron as having a weak negative charge at a distance comparable to its size that has a great influence on the stability of nuclei.

Thus, nuclei with a small number of neutrons on the outer surface, with their total positive proton potential, pull electrons from the lower electron shells, leading to beta capture.

The addition of a neutron outside the nucleus with its weakly negative charge reduces this potential, leading the nucleus to the lower limit of the "stability range". That is why ^{7}Li, ^{9}Be,^{11}B,^{13}C,^{15}N, ^{17}O,^{19}F,^{21}Ne are stable,^{23}Na,^{25}Mg,^{27}Al,^{32}Si,^{31}P,^{33}S,^{35}Cl,^{39}K, etc.

The upper (in terms of the mass of the nuclei) boundary of the stability range is determined by the fact that with the growth of N, neutrons joining further and further from the axis of rotation of the nucleus, receive a smaller mass defect, which allows them to perform beta decay, or other forms of decay.

Quadrupole moment Li

As a test of the proposed model of nuclei, the author calculated the quadrupole moment for Li nuclides.

Below is the Table 1 and graphs of experimental and calculated data (Fig.16). The core structure in this case is constructed in a three-dimensional matrix $X(1...12), Y(1...12), Z(1...12)$ with the distance between the centers of neighboring nucleons $l = 13.665281 * 10^{-13} cm$. The coordinates of the nucleons for ^{6}Li (X,Y,Z): p(5,5,2),n(5,6,2),p(6,6,2),n(6,5,2),n(5,5,3),p(5,6,3). The electric quadrupole moment of the nucleus will be the sum of the quadrupole moments of the spatial distribution of protons and neutrons (**??**).

$$Q_0 = K * l^2 (Q_p + Q_n) = K * l^2 \left(\sum_{1}^{k} (3z^2 - r^2) q_p + \sum_{1}^{k} (3z^2 - r^2) q_n \right); \tag{2}$$

where the position of the nucleon is calculated from the center of mass with coordinates x_0, x_0, z_0. $z^2 = (z_k - z_0)^2$; $r^2 = (x_k - x_0)^2 + (y_k - y_0)^2$, proton charge $q_p = +1$, neutron charge $q_n = -0.15$, correction dimensionless coefficient $K = 0.05$.

Table 1: Quadrupole moment Li

Nuclide	Experimental data, $10^{-24} sm$	Calculations data, $10^{-24} sm$	Center of mass			Isomer
			x_0	y_0	z_0	
^{6}Li	-0,000825	-0,04629	5,5	5,3333	2,3333	-
^{7}Li	-0,037	-0,05049	5,42857	5,42857	2,42857	+Ls2
^{8}Li	0,03103	0,02399	5,5	5,375	2,25	+Js1
^{9}Li	0,03065	0,03181	5,4444	5,4444	2,1111	+Js2
^{10}Li	-	-0,00144	5,5	5,3	2,1	+Kp1
^{11}Li	-0,031	-0,04506	5,45454	5,45454	2,0909	+Kp2

Thus, the quadrupole moment of the nucleus consists of a constant value introduced by protons that do not change their location in the nuclides of one row of a chemical element and a variable value introduced by neutrons that attach to the nucleus from the outside, and as a rule, in positions moving further away along the X, Y axes from the Z axis.

As the simulation program shows, the external shape of atomic nuclei is mostly far from both the sphere and any ellipsoids, and is more similar to the pyramid for astinoids and lanthanides, and with the growth of Z it is increasingly approaching the shape of an octahedron, as close as possible to it at the 120th element, the structural formula of which is $s2, p6, d10, f14, f14, d10, p6, s2$. This may explain the large values of the quadrupole moment of heavy nuclei.

Service functions of the program

At the first launch, the program asks for user registration with the country, name and email address. In the future, this function is disabled. Then the initial page with the selection of the chemical element is loaded. It is possible to change the user's language in the future by clicking

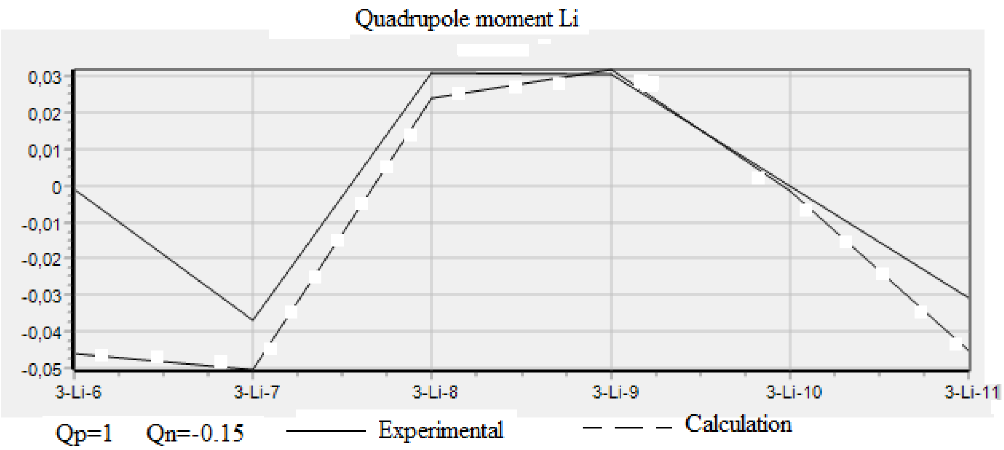


Figure 16: Graphs of the quadrupole moment of nuclides Li.

the buttons with images of state flags on the top panel, or by selecting positions in the drop-down text menu ¡¡Language¿¿.

Buttons "Open File", "Save File", "Print" , allow you to open, save and print (disabled in this version) data and graphs. Duplicated in the "File" menu.

The buttons "Save Layer", "Save Graph", "Save Data", allow you to save the selected layer to the PICTURE folder, charts to the CHART folder, and data to the DATA folder. Duplicated in the "Editor" menu.

Thanks

The author is very grateful to Yuri L. Ratis, who supported the publication of the first developments of Geometric Theory in the scientific journal of Samara Aerospace University in 2005.[20]

Cooperation

The author invites research teams and individual researchers to cooperate to finalize the computer program "Modeling Of Atomic Nucleus Structures". I am ready to consider all proposals for the correction and improvement of the program, the introduction of new functions, calculations. It is possible to finalize the program to order. The program is written in "Delphi", contains about 11 thousand lines in Pascal. The author develops a Geometric model independently, without the support of any scientific organizations and collectives, and will gratefully accept financial assistance from sponsors.

Conclusions

In the Geometric model of atomic nuclei proposed by the author, it is concluded that the forces holding the nucleons in the nuclei can be Coulomb and act in six orthogonal directions ($\pm X, \pm Y, \pm Z$). Based on the proposed order of filling the spatial positions of the core layers with both nucleon pairs (proton-neutron) and individual neutrons of the core surface, the structures of all known and possible nuclei up to the 160th element of the Periodic Table are obtained. The order of filling the core layers in positions b1-b18 for the nuclei of superactinoids from the 122nd to the 153rd elements is proposed. On the basis of experimental and geometric data, the correlation of the graphs of the mass defect and the number of internucleon bonds (taking into account centrifugal forces) is revealed An explanation of the so-called "magic" cores has been obtained. A theoretical justification for the passage of cold nuclear fusion reactions is given. The location of ${}^4He$ clusters in the structure of the core layers is revealed and it is shown how the division of radioactive nuclei into unequal fragments by intercluster bonds occurs. The substantiation of the existence of the lower and upper limits of the stability of the nuclei is proposed. The model was tested on calculations of the quadrupole moment of Lithium nuclides.

References

[1] Bohr N. Neutron capture and the structure of the nucleus // UFN. — 1936. — Vol. 14, issue 4, No. 4. — pp. 425-435.

[2] Gapon E., Iwanenko D., Zur Bestimmung der isotopenzahl, Die Naturwissenschaften, Bd.20, p.792-793, 1932.

[3] Bohr O., Mottelson B. Structure of the atomic nucleus. M., 1977. Vol. 2.

[4] Vohg A.,Motte1son V. R.,Pines D., Possibleanology between the excitation spectra of nuclei and those of the superconducting metals slate, "Phys. Rev.", 1958, v. 110, No. 4, p. 936

[5] Berezin F.A. The method of secondary quantization. M.: Nauka, 1965 – 236 p.

[6] Valentin L. Subatomic physics: Nuclei and particles, vol. 2. Moscow: Mir, 1986 -336 p.

[7] Wildermuth, K., Tan, Ya. Unified theory of the nucleus. Translated from the English by Yu.F. Smirnov. – M.: Mir, 1980. – 502 p. Wildermuth K., Tang Y. C. A unified theory of the nucleus. N.Y.: Academic Press Inc., 1977. 399 p. (Russ. ed.: Wildermuth, K., Tang, Y.C. Edinaya teoriya yadra. Moscow: Mir Publ., 1980. 502 p.).

[8] Frenkel Ya.I. Statistical Physics. M.-L.: Publishing House of the USSR Academy of Sciences, 1948. 760 p.

[9] Landau L. D.,Lifshits E. M. Theoretical physics: Textbook: For universities. In 10 vols. V. Statistical Physics. Ch. I. — 5th ed., stereot. — M.: FIZMATLIT, 2002.-616 p.

[10] Shirokov Yu. M., Yudin N. P. Nuclear physics. — M.: Nauka, 1972. — 670 p.

[11] Feshbach H. Porter C.E. Weisskopf V.F. Phys.Rev.,1954,vol. 96,p. 448

[12] Boldov I.A. Mass as geometry of space, Mathematical structures and Modeling, Omsk : Omsk State University, 2022. №3(63).
DOI 10.24147/2222-8772.2022.3.12-23
URL: http://msm.omsu.ru/jrns/jrn63/boldov.pdf (date of request: 25.11.22)

[13] Boldov I.A. Geometry of elementary particles, Mathematical structures and Modeling, Omsk : Omsk State University, 2022. №4(64).
DOI 10.24147/2222-8772.2022.4.5-21
URL: http://msm.omsu.ru/jrns/jrn64/boldov.pdf (date of request: 25.11.22)

[14] Hofstadter P. The structure of nuclei and nucleons // UFN. — 1963. — Vol. 81, issue 1. — pp. 185-200.

[15] Shchelkin K. I. Virtual processes and the structure of the nucleon // Physics of the microcosm. — M.: Atomizdat, 1965. — p. 75.

[16] Zhdanov G. B. Elastic scattering, peripheral interactions and resonons // High-energy particles. High energies in space and laboratories. — M.: Nauka, 1965. — p. 132.

[17] Excel file with calculations.
URL:https://disk.yandex.ru/i/hCAQ1lDdDyg7-g (date of request: 25.11.22)

[18] A program for modeling the structures of atomic nuclei ANV.exe , Beta version 5.4
URL: https://disk.yandex.ru/d/DmBl0dwEoUcjKg (date of application: 25.11.22)

[19] MSU Photonuclear Experiment Data Center
URL:http://cdfe.sinp.msu.ru/index.ru.html (date of request: 25.11.22)

[20] Boldov I.A. "Geometric Theory of the structure of matter and space" Interuniversity collection of scientific papers Special issue "Actual problems of natural science" Vol.1, Samara Aerospace University 2005 70-92.