

Nuclear Geometry: from Silicon to Argon

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Abstract. The nuclear geometry has been developed by analogy with the fullerene geometry. On the basis of this geometric approach, it is possible to design the structure of silicon, phosphorus, sulfur, chlorine and argon isomers as well as their isotopes, which can be obtained by means of nuclear synthesis. The nuclei can be classed into two groups: basic nuclei having equal number of protons and neutrons, and isotopes having one or two more neutrons. The neutrons decompose into protons and electrons; the latter creating the coat of mail which ensures mechanical stability of the nuclei with respect to shear stresses and thermal vibrations.

1. HISTORICAL INTRODUCTION

The nuclear models are approximate representations used for description of some properties of the nuclei. They are based on the identification of a nucleus with one of physical systems, which properties are well studied. These models often contradict each other; however they describe different features of a nucleus and therefore supplement each other. There are various models of nuclear structure, but all the nuclear models play the role of more or less probable working hypotheses. At the same time, the consistent explanation of the most important properties of atomic nuclei on the *firm basis of general physical principles* is one of unsolved fundamental problems of nuclear physics [1].

The question arises how to find “the firm basis”. Let us follow the advices of the outstanding scientists of the past. The specific advice was given by Sergei Ivanovich Vavilov (1891-1951), the founder of the Soviet school of physical optics, the President of the Academy of Sciences of the USSR from 1945. He stated: “For the true judgment on the present state of any science and about its perspectives, it is useful to look back at its past, sometimes at its even very remoteness” [2].

What one can see in the past?

In 1815 William Prout (1785-1850) stated that the atomic weights of chemical elements are numerical multiples of hydrogen atomic weight, hydrogen being a primary matter [3]. According to Prout’s hypothesis, all the elements were produced by *condensation of this primary matter*. In 1886 William Crookes (1832-1919) rekindled Prout’s hypothesis. He suggested that elements were complex bodies that had developed by an inorganic process of Darwinian evolution, by the effort of two forces, electricity and heat [4]. Before evolution had commenced, there existed a primary matter. Definite quantities of electricity were given to each element at its genesis; and this electricity determined the element’s valence and its chemical properties. The radiant heat from ponderable elementary matters in the center of the universe flowed towards periphery; yielding loss of temperature with time. Atomic weight was only a measure of the cooling conditions that had prevailed at the moment of the element’s birth. Therefore it is not, as Mendeleev had implied, a measure of properties. The atomic weights determined by chemists really represented an *average weight of several slightly different atoms*.

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In 1897 Joseph John Thomson (1856-1940) established that cathode rays consisted of negatively charged particles which were soon called ‘*electrons*’ (νλεκτρον – amber). It was the first elementary particle discovered in physics; the bearer of the least mass and the least of electric charge in nature. In 1911 an atomic nucleus was discovered by Ernst Rutherford (1871-1937), who studied scattering α -particles by thin metallic plates. He came to conclusion that almost all the atomic mass is accumulated in a small core, charged positively. In 1914 Rutherford introduced the term ‘*proton*’ (πρωτος – first, initial); the latter being a core of hydrogen. In 1906-1910 it was found that when the nuclear decay of radioactive elements took place, there appeared new elements which had similar properties, but can’t be separated by chemical methods. Frederick Soddy (1877-1956) established that such elements had equal electric charge of a nucleus, but different mass. In 1910 he suggested the term ‘*isotope*’ (ισος – equal+ τοπος – place) and said that the isotopes are equal on the outside, but different in the interior. In some respect this is a remake of Crookes’ hypothesis.

The notion “*isomerism of atomic nuclei*” appeared in 1921 [1], when Otto Hahn (1879-1968) discovered a new radioactive substance, uranium-Z, which has the same chemical properties and mass number as the known substance, uranium-X₂. Later it was established that both substances had different energies and half-life periods. By analogy with the molecular isomerism they were named nuclear isomers. It was postulated that they are *two states, ground and excited, of one and the same nucleus*.

In the beginning of the twentieth century only two elementary particles, electron and proton were known. For this reason, it was a wide-spread opinion that the nuclei of all elements consist of protons and electrons (*proton-electron conception*). After discovering a *neutron* (neuter “neither”) in 1932 by James Chadwick (1891-1974), it was replaced with the *proton-neutron conception*, according to which a nucleus consists of protons and neutrons. In 1932 George Gamov (1904-1968) wrote: “The absolutely new assumption about the constituents of a nucleus is the assumption, according to which each nuclear electron is connected with one of nuclear protons forming a neutron”.

The proton-neutron conception allows unite mass and electricity. Really, the isotopism consists in the existence of nuclei having an equal number of protons but different number of neutrons. The isotopes take one and the same place in the Mendeleev periodic system of chemical elements and have identical structure of the electron shells of atoms.

The existing nuclear models, developed in the framework of the proton-neutron conception, are *spaceless*, i.e. they describe only quantum states but not the space structure of nuclei. What is the reason? The reason is that here one deals with the form of *scientific despotism* known as *specialization despotism* [2]. “A hundred years ago, there were no such scientists as Leibniz, but there were such as Gauss, Faraday, Darwin. Today only few scientists are able to name themselves mathematicians or physicists or biologists. The scientist has become a specialist in topology, acoustics or coleoptera. He is packed with the professional jargon of his special discipline, knows all the references. But any question going out of the narrow bounds of his speciality, he will consider as something which refers to his colleague who works three rooms further” (Norbert Wiener, 1895-1964).

How to find the firm basis for nuclear physics? The general advice was given by Friedrich Engels (1820-1895). He wrote: “In the diverse forms of Greek philosophy there are already in the bud all the posterior types of Weltanschauung. So the theoretical natural science, if it wants to know the generation and development of general foundations is compelled to returning to ancient Greeks” [2]. According to Aristotle (384-322 BC), all essential originates and consists of two principia: *matter and form*; the form being the leading principle. The matter in itself is the passive principle of nature; it is the possibility for appearance of a real thing. In order the thing became the reality; it must receive the form, which transforms the possibility into the reality [2]. In the modern language “form” means shape and structure simultaneously.

2. PARALLELS: FULLERENE C₄ AND HELIUM ₂He⁴

Tetrahedral fullerene C₄ can be inscribed into a sphere (Fig. 1a). The atoms and shared electron pairs, forming covalent bonds, are located on one and the same sphere [5]. It should be emphasized that in molecular geometry [6] the covalent bond can be represented not only as a straight line, but as a small arc on a geodesic line (great circle). Being less than a semicircle, it is the least path between the ends of the arc [7].

According to the theory by Sidgwick and Powell [6,8], each shared electron pair can be considered as a point charge; all the charges repelling each other and arranging themselves into such configuration, which ensures their maximal removing from each other. For tetrahedral fullerene C₄ one has four atoms and six point charges, all the charges being located on the great circles, which pass through any two atoms connected by a respective electron pair. It is interesting to note that

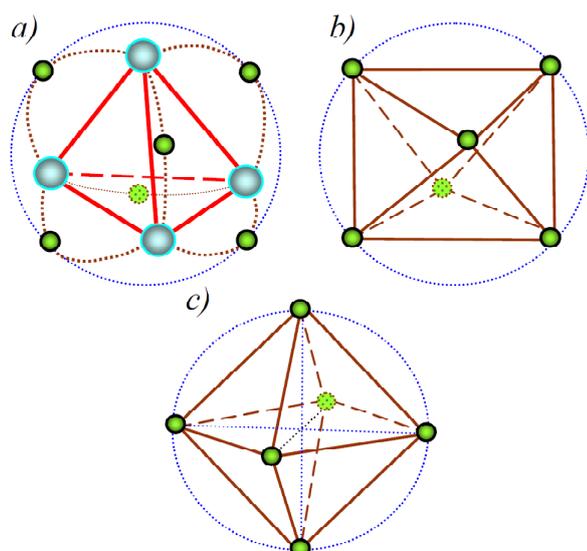


Fig. 1. Tetrahedral fullerene C_4 ; large turquoise spheres are atoms and small green spheres are shared electron pairs. Here: (a) position of the shared electron pairs on geodesic lines; (b) point charge octahedron corresponding to (a); (c) usual form of an octahedron.

six point charges form an octahedron inscribed into the same sphere (Figs. 1b and 1c).

Consider a nucleus of helium ${}^4_2\text{He}$. The name derives from the Greek $\nu\lambda\iota\omicron\varsigma$ for “sun”. The element was discovered by spectroscopy during a solar eclipse in the sun’s chromosphere by the French astronomer Pierre-Jules-Cesar Janssen in 1868. It was independently discovered and named helium by the English astronomer Joseph Norman Lockyer. It was thought to be only a solar constituent until it was later found to be identical to the helium in the uranium ore cleveite by the Scottish chemist William Ramsay in 1895. Ramsay originally called his gas krypton, until it was identified as helium. The Swedish chemists Per Theodore Cleve and Nils Abraham Langet independently found helium in cleveite at about the same time [9].

According to the proton-neutron conception, it has 2 protons and 2 neutrons. Similar to fullerene C_4 , they can form a tetrahedron; however such tetrahedron is asymmetric from the physical and geometric standpoint. Since it does not look aesthetically beautiful, it cannot be veritable one from an aesthetic point of view.

In order to conserve the symmetry of proton-neutron tetrahedron, one is compelled to accept for a fact that

- All the apices of tetrahedron are equivalent and therefore they are protons,
- Each neutron in a nucleus decomposes into a proton and negatively charged particles. For helium 4, the number of particles is equal to the number of the tetra-

hedron edges, so they have the charge $1/3$ that of an electron; the particle being named a tertion (tertia “one third”).

- Interaction of tertions leads to appearance of the hidden symmetry of special electronic pattern (tertion net) which symmetry does not coincide with that of proton one, but, similar to molecules [10], determines it.

On the basis of these postulates, it is also possible to design the structure of other nuclei; some simple ones are shown in Fig. 2.

The numerical values are taken from Ref [11]. Designing the structures, it is necessary to bear in mind that the structures obtained must satisfy “the principle of least complexity”, i.e. they are the simplest among all possible. For hydrogen, deuterium, tritium and helium 3, one has a point, a linear and a plane structure respectively. Helium 4 has tetrahedral symmetry. The name hydrogen derives from the Greek $\upsilon\delta\rho\omicron$ for “water” and $\gamma\epsilon\nu\epsilon\sigma\tau\iota\varsigma$ for “origin” because it burned in air to form water. It was discovered by the English physicist Henry Cavendish in 1766. The major stable isotope ${}^1_1\text{H}$ is also known as protium. The minor stable isotope ${}^2_1\text{H}$ is known as deuterium, with symbol D. The low concentration of ${}^2_1\text{H}$ in normal sources of H may have delayed its discovery until 1931 when hydrogen isotope fractionation was demonstrated by distillation, electrolysis, evaporation, and in environmental samples [9].

The radioactive isotope ${}^3_1\text{H}$, also known as tritium with symbol T, decays by negative beta emission to ${}^3_2\text{He}$ with a half-life of 12.3 years. Tritium is formed naturally in the atmosphere by cosmic-ray reactions such as

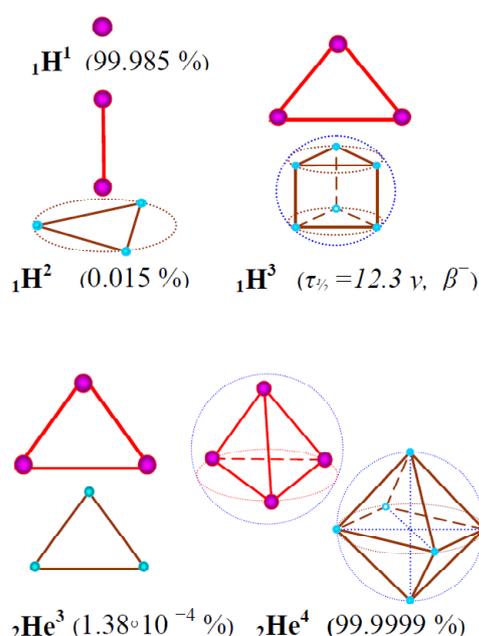


Fig. 2. Proton cells (red) and tertion nets (brown) of hydrogen, helium and isotopes.

${}^7\text{N}^{14}$ (n, t) ${}^6\text{C}^{12}$ and artificially in nuclear reactors. Large quantities of ${}^1\text{H}^3$ were injected into the atmosphere as a by-product of thermonuclear bomb tests, mostly in the 1950s and 1960s [9].

The question arises as to whether postulate 2 is formulated on legal ground. It is known that a free neutron is unstable and decays according to the scheme $n \rightarrow p + e^- + \bar{\nu}_e$ into proton, electron and antineutrino (β -decay), the average life time being approximately 15.3 min [12]. It seems very illogical that the neutron becomes stable being inside a nucleus in the strong electric field created by surrounding protons. Apparently “the absolutely new assumption according to which each nuclear electron is connected with one of nuclear protons forming a neutron,” needs to be reformulated. To my mind, neutron electrons are similar to valence electrons in solids, having a possibility to be removed from their parent neutrons and to create “covalent” bonds. At that both subsystems, nuclear protons and nuclear electrons, produce their own patterns of different symmetry.

3. THERMONUCLEAR REACTION

Contrary to the usual “algebraic approach”, when the nuclear reactions are written down simply as in chemistry, the “geometric approach” will be used. In other words, the reactions are considered, if the reacting nuclei are compatible from the geometric standpoint. Consider, for example, one of the thermonuclear fusion reactions [13,14]



It is assumed that the first generation of thermonuclear reactors will operate on the deuterium-tritium fuel because this combination of their nuclei has the largest synthesis cross-section at the rather low energy of interacting nuclei ($> 10 \text{ keV}$).

Fig. 3 illustrates the reaction geometry; only the protons are shown, the tertions are omitted.

Here deuterium and tritium are moving each to other. According to the postulate by Svante August Arrhenius (1889) a chemical reaction goes in the following way [15]. At first there forms an intermediate compound and afterwards a usual chemical reaction is going on. In our case the new proton-proton bonds are shown by lilac lines, the bond to be broken by a dot red line. It should be emphasized that the nature of nuclear forces is beyond the scope of this consideration. Henceforth only electron-proton interactions and electronic ones will be discussed. A greater body of information one obtains if to include the electrons (tertions) into consideration (Fig. 4).

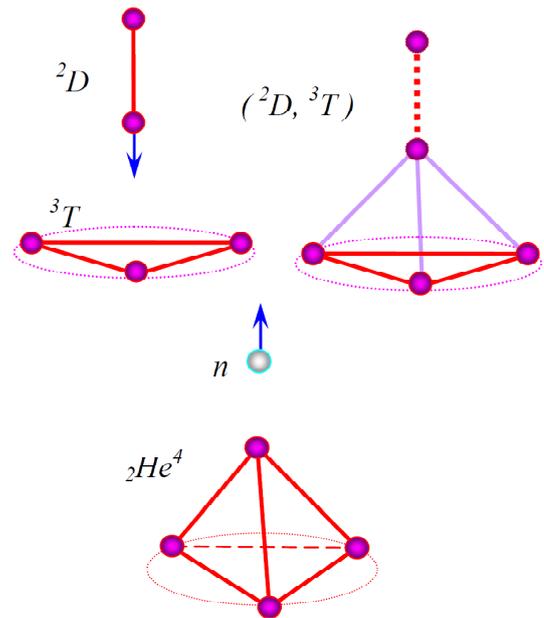


Fig. 3. Geometric scheme of the nuclear reaction; electrons (tertions) are omitted.

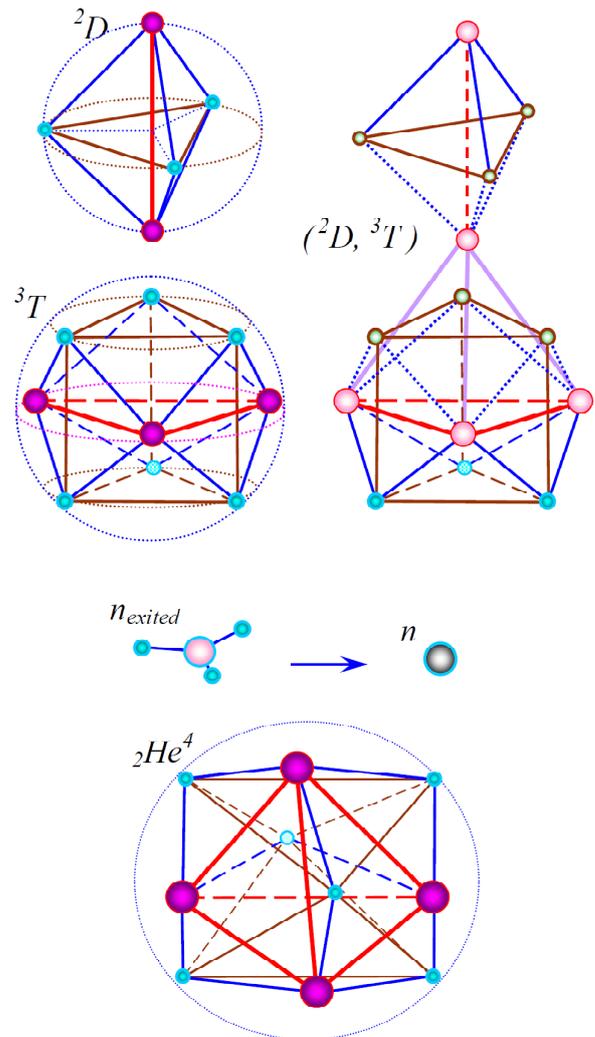


Fig. 4. Geometry of the nuclear reaction; tertions are included.

From the figure it follows that all the protons take part in the reactions; they are marked in pink. As for electrons (tertions), only 3 tertions of triton from 6 really participate in the reaction. They are specially marked in brown-green. The tertion-proton bonds destroyed are shown using dot blue lines.

4. LITHIUM, BERYLLIUM AND BODY-CENTERED CRYSTALS

The name lithium derives from the Latin *lithos* for “stone” because lithium was thought to exist only in minerals at that time. It was discovered by the Swedish mineralogist Johan August Arfwedson in 1818 in the mineral petalite $\text{LiAl}(\text{Si}_2\text{O}_5)_2$. Li was isolated in 1855 by the German chemists Robert Wilhelm Bunsen and Augustus Matthiessen [9]. There are two stable isotopes of lithium: ${}^6_3\text{Li}$ (7.5%) and ${}^7_3\text{Li}$ (92.5%) [11].

On the basis of the postulates considered above, it is possible to design the structure of these nuclei (Fig. 5) and to explain also their stability.

The radioactive isotope ${}^3_1\text{H}$ is also known as tritium with symbol T; its nucleus being named triton. If to combine helium 3 and triton using reaction ${}^3_1\text{H} + {}^3_2\text{He} \rightarrow {}^6_3\text{Li}$, one can obtain lithium ${}^6_3\text{Li}$. The further reaction $n + {}^6_3\text{Li} \rightarrow {}^7_3\text{Li}$ gives lithium 7. Here a neutron penetrates into lithium ${}^6_3\text{Li}$, where it decays producing a proton and an electron. It is reasonable to accept that a neutron inside lithium 6 is similar to a hydrogen atom. It is known that spectral-line splitting in an electric field (Stark effect) depends on the principal quantum number n . For hydrogen, if $n=1$, there is no splitting at all; if $n=2$, there appear three states of an equal energy [16]. By analogy with the hydrogen atom, it is valid to say that formally the neutronic electron give rise to $2s$, $2p_x$, $2p_y$ orbitals, producing a ‘valent state’ of the neutron. This state corresponds to the excited sp^2 state, where each of three valent tertions is not in s - or p -state, but in a hybridized state, which can be obtained by mixing a single $2s$ -state with two $2p$ -states. The latter is described by a wave function being a linear combination of s - and p -functions. At that, three sp^2 orbitals are located on a plane normal to the three-fold axis of symmetry of lithium. The negatively charged particles (tertions) corresponding to three sp^2 orbitals are painted brown-green in Fig. 5. They are incorporated in the existing tertion net. As a result, there forms the denser tertion net. The proton cell, having before a shape of a regular triangle prism, becomes a body-centered one.

The name beryllium derives from the Greek word βηρυλλος for a gemstone “beryl” ($3\text{BeO} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$), in which it is found. It was discovered by the French chemist and pharmacist Nicholas-Louis Vauquelin in beryl and emerald in 1797. The element was first sepa-

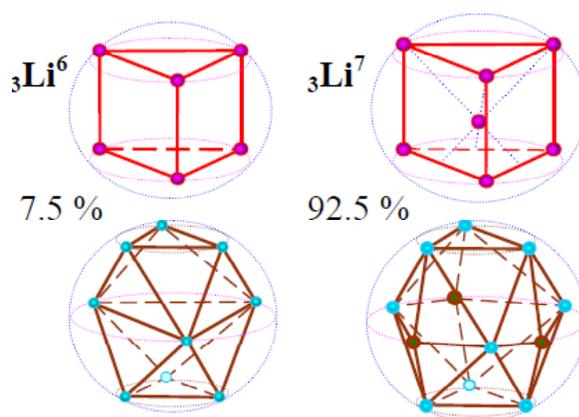


Fig. 5. Proton cells (red) and tertion nets (brown) of lithium isotopes.

rated in 1828 by the French chemist Antoine-Alexandre-Brutus Bussy and independently by the German chemist Friedrich Wöhler. Because the salts of beryllium have a sweet taste, the element was also known as glucinum from the Greek γλυκυς for “sweet”, until IUPAC selected the name beryllium in 1949 [9]. There is only one stable isotope of beryllium: ${}^9_4\text{Be}$ (100%) [11].

By analogy with the algorithm developed for lithium, which allows obtain a more abundant isotope, consider the reaction for beryllium $n + {}^8_4\text{Be} \rightarrow {}^9_4\text{Be}$. Here a neutron penetrates into beryllium ${}^8_4\text{Be}$, where it decays. As a result, there forms a denser tertion net, and the proton cell, having before a shape of a cube, becomes a body-centered cube (Fig. 6). Since the abundance of ${}^9_4\text{Be}$ is 100%, such structure has super stability.

To my mind, the stability is ensured by two factors. The first is the packing density of the proton cell; the second is the density of coat of mail (tertion net). Contrary to unstable beryllium 8, both factors take place in the case of beryllium 9, giving its structure super stability and abundance of 100%.

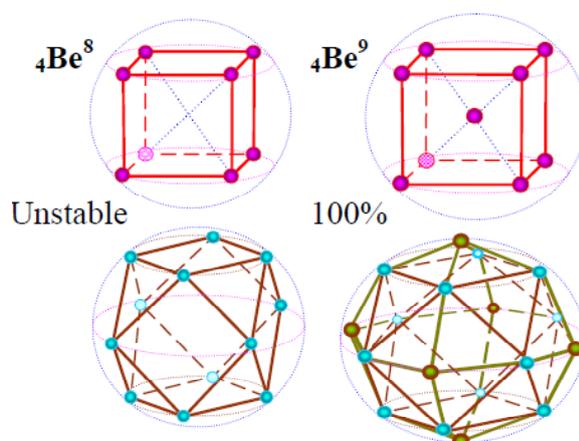


Fig. 6. Proton cells (red) and tertion nets (brown) of beryllium isotopes.

One further comment should be made. Hitherto it was assumed that the negative particle charge is $1/3$. From the results obtained, it follows that the neutron decays into a proton and six negatively charged particles, having charge $1/6$. The difference may be attributed again to the Stark effect, where spectral-line splitting depends on the principal quantum number n . If $n=2$, there are three states of an equal energy, for $n=3$, the number of states becomes six [16]. Formally the neutron electron gives rise to $2p_x$, $2p_y$, and $2p_z$ orbitals, producing a ‘valent state’ of the neutron.

5. NUCLEAR ISOMERISM: MODELS

The main principles of nuclear geometry are briefly considered above. The nuclear geometry has been developed by analogy with fullerene geometry [5]. One of the most important consequences of this model is that it allows give the *clear definition of nuclear isomerism* of the known isotopes, which is *in consent with the generally recognized definition of space isomerism* of molecules, crystals, etc.

Hitherto it is accepted that nuclear isomers are “two states of one and the same nucleus, having both different energies and half-life periods” [1]. By analogy with electrons, one considers an energetic structure of nucleons (not geometric-space structure!) employing quantum numbers. It is assumed that there are nucleon shells, one system for protons Z and another for neutrons N . The both shell systems are filled up *independently*. The nuclei with the completely filled up shells are the most stable. They occur more frequently in nature. At the same time there are nuclei with the same mass number $A=Z+N$ but having another character of filling up the shells. They are considered as isomers.

Designing the nuclear geometry, I have used instead of the vague quantum-shell “nuclear isomerism”, the clear notion accepted for the molecules. In other words, it was assumed that the *space isomerism of nuclei* is the phenomenon which consists in the existence of nuclei having an equal mass number but different positions of the nuclear constituents in the *geometric space*. It should be emphasized that this geometric approach had explained not only the generation of elements from *hydrogen to aluminum*, but also that of *their isomers and isotopes* in the framework of one and the same unified approach [17-19].

I hope that after this rather detailed explanation a reader can more easily catch the author’s meaning.

6. SILICON: ISOMERS AND ISOTOPES

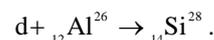
The name derives from the Latin *silex* and *silicis* for “cobble, flint”. Amorphous silicon was discovered by

the Swedish chemist Jöns Jacob Berzelius in 1824. Crystalline silicon was first prepared by the French chemist Henri Sainte-Claire Deville in 1854 [9]. There are three stable isotopes of silicon: ${}_{14}\text{Si}^{28}$ (92.23%), ${}_{14}\text{Si}^{29}$ (4.67%), ${}_{14}\text{Si}^{30}$ (3.10%) and an unstable isotope ${}_{14}\text{Si}^{32}$, having a comparatively large half-decay period being equal to 330 y [11].

The crucial question is how to obtain them and their space isomers in the framework of one and the same assumptions. Previously [17-19] it was suggested that the nuclei can be separated into two main types: the basic nuclei having equal number of protons and neutrons, and the isotopes having one, two or more additional neutrons.

6.1. Joining deuteron to aluminum

Begin with basic nucleus ${}_{14}\text{Si}^{28}$. It can be obtained through the use of the geometrically compatible one-stage reaction



Here a deuteron is incorporated into the basic nucleus of aluminum having three-fold symmetry (Fig. 7). From the figure it follows that for aluminum only 4 protons from 26 take part really in the reaction. They are specially marked in the figure; the new proton-proton bonds are lilac, the old bonds, which were destroyed, are shown using red dot lines. The reaction shown is consistent with the postulate by Svante August Arrhenius (1889) according to which at first

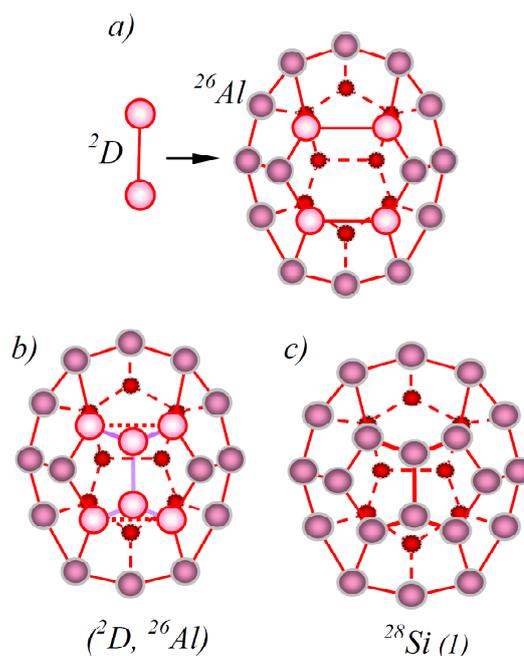


Fig. 7. Attachment of deuteron to aluminum: a) separate particles; b) intermediate compound; c) silicon 28 (90°) after relaxation.

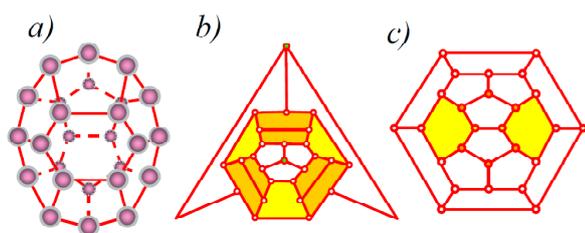


Fig. 8. Aluminum 26 (a) and its graphs showing common three fold symmetry (b) and topological six-fold one (c).

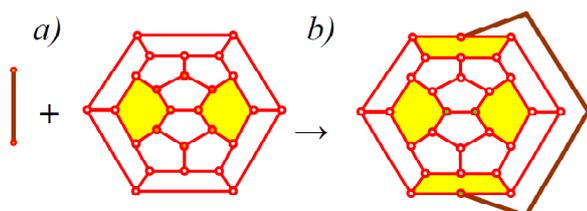


Fig. 9. Embedding the graph of aluminum into the graph of deuteron: a) separate graphs of deuteron and aluminum b) graph of silicon.

there forms an intermediate compound and afterwards a usual chemical reaction is going on [15]. The starting perfect nucleus has three-fold symmetry. Embedding a dimer into the hexagon in front, parallel to the three-fold axis, transforms aluminum ^{26}Al into silicon ^{28}Si . It is a perfect nucleus having rotation-reflection two-fold symmetry. The nucleus obtained contains twelve pentagons and four hexagons forming the penta₁₂-hexa₄ polyhedron of silicon 28 (90°).

One can consider aluminum 26 from two standpoints: first, as a polyhedron having ordinary three-fold symmetry and second, as a polyhedron having topological six-fold symmetry (Fig. 8). To gain a better understanding of the reaction mechanism, the topological symmetry is best suited. Graph of nuclear reaction $d + {}_{13}\text{Al}^{26} \rightarrow {}_{14}\text{Si}^{28}$ is shown in Fig. 9.

Another geometrically possible reaction is shown in Fig. 10. The initial perfect nucleus is the same as before, but incorporating is done at an angle of 60° to the three-fold axis of symmetry of the initial nucleus. As a

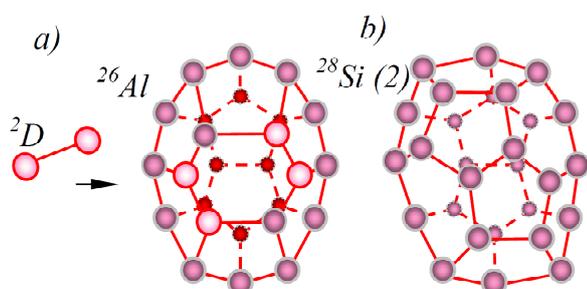


Fig. 10. Another way of the attachment of deuteron to aluminum: a) separate particles; b) silicon 28 (30°) after relaxation.

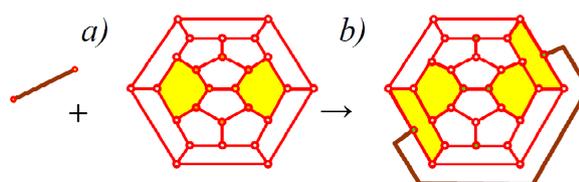


Fig. 11. Another way of embedding the graph of aluminum into the graph of deuteron: a) separate graphs; b) graph of silicon.

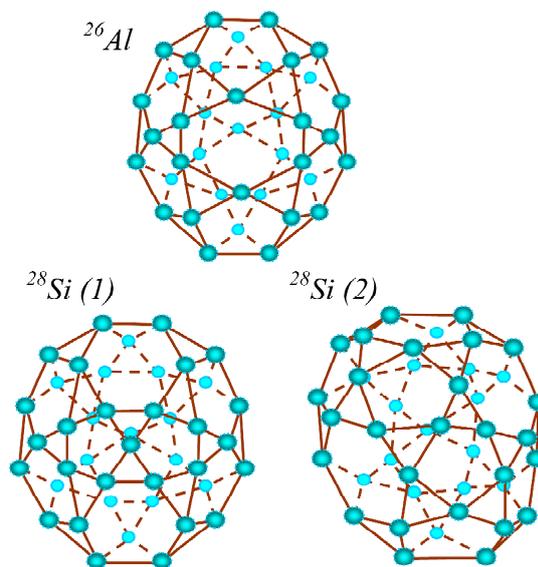


Fig. 12. Electronic structure of aluminum 26, silicon 28 (1) and silicon 28 (2).

result, one has also a perfect nucleus but having rotation-reflection two-fold symmetry. Contrary to the previous case, where the initial-nucleus half is needed to be rotated through 90 degrees to get a mirror image, here the rotation is done only through 30 ones.

The nucleus obtained also contains twelve pentagons and four hexagons and therefore it refers to the penta₁₂-hexa₄ polyhedron (30°). The symmetry can be discovered by looking at its graph (Fig. 11).

To fully appreciate the nuclear reaction, the electronic structure of the constituents is presented in Fig. 12.

It should be mentioned that for the first time the mechanism of embedding a dimer into a hexagon was suggested for fullerenes by M. Endo and the Nobel Prize winner in chemistry (1996) H.W. Kroto [20].

Graph theory and topology. The nuclear reactions above are described with the help of graph theory and topology. This is unusual for nuclear physics and so needs comments. The application of graph theory to fullerenes was discussed in detail in Ref [21]. Now consider only the notions which are necessary for understanding why application of graphs is benefit for nuclear geometry. The name graph derives from the Greek word γραφω for “write” [6]. Graph is defined as a set of

Series	Symmetry of Fullerenes (Groups)				
	3-fold S $\Delta m=6$	3-fold T $\Delta m=6$	4-fold $\Delta m=8$	5-fold $\Delta m=10$	6-fold $\Delta m=12$
$\Delta n=6$	C₁₄ C ₁₆ C ₁₈	C₁₈ C ₂₀ C ₂₂	C₂₄ C ₂₆ C ₂₈ C ₃₀	C₃₀ C ₃₂ C ₃₄ C ₃₆ C ₃₈	C₃₆ C ₃₈ C ₄₀ C ₄₂ C ₄₄ C ₄₆
$\Delta n=8$	C₂₀ C ₂₂ C ₂₄	C₂₄ C ₂₆ C ₂₈	C₃₂ C ₃₄ C ₃₆ C ₃₈	C₄₀ C ₄₂ C ₄₄ C ₄₆ C ₄₈	C₄₈ C ₅₀ C ₅₂ C ₅₄ C ₅₆ C ₅₈
$\Delta n=10$	C₂₆ C ₂₈ C ₃₀	C₃₀ C ₃₂ C ₃₄	C₄₀ C ₄₂ C ₄₄ C ₄₆	C₅₀ C ₅₂ C ₅₄ C ₅₆ C ₅₈	C₆₀ C ₆₂ C ₆₄ C ₆₆ C ₆₈ C ₇₀
$\Delta n=12$	C₃₂ C ₃₄ C ₃₆	C₃₆ C ₃₈ C ₄₀	C₄₈ C ₅₀ C ₅₂ C ₅₄	C₆₀ C ₆₂ C ₆₄ C ₆₆ C ₆₈	C₇₂ C ₇₄ C ₇₆ C ₇₈ C ₈₀ C ₈₂
$\Delta n=14$	C₃₈ C ₄₀ C ₄₂	C₄₂ C ₄₄ C ₄₆	C₅₆ C ₅₈ C ₆₀ C ₆₂	C₇₀ C ₇₂ C ₇₄ C ₇₆ C ₇₈	C₈₄ C ₈₆ C ₈₈ C ₉₀ C ₉₂ C ₉₄
$\Delta n=16$	C₄₄ C ₄₆ C ₄₈	C₄₈ C ₅₀ C ₅₂	C₆₄ C ₆₆ C ₆₈ C ₇₀	C₈₀ C ₈₂ C ₈₄ C ₈₆ C ₈₈	C₉₆ C ₉₈ C ₁₀₀ C ₁₀₂ C ₁₀₄ C ₁₀₆
$\Delta n=18$	C₅₀	C₅₄	C₇₂	C₉₀	C₁₀₈

vertices and vertex pairs (arcs, edges). There are different ways of graph representations (algebraic, geometric). However, “graphs are acting attractive and possess esthetic allure due to their representation in the form of diagrams” ($\Delta\alpha\gamma\rho\alpha\mu\mu\alpha$ - drawing, picture) [22]

In our case one can define a graph more specifically as a projection of a space figure on a plane, the number of vertices and edges being the same, but the edge lengths can be variable. This leads automatically to conserving the number of figure constituents: trigons, tetragons, pentagons, hexagons etc; however their shape can be variable. As a result, the graph theory is tightly connected with topology.

The name topology derives from the Greek words $\tau\omicron\lambda\omicron\varsigma$ - place + $\lambda\omicron\gamma\omicron\varsigma$ - doctrine [6]. Topology is a branch of mathematics having the aim to formulate the idea of continuity in the frameworks of mathematics. Here by a figure is meant a set of points which satisfies to some axioms. In many respects these axioms are similar to those of graph theory. In particular, topology does not use such geometric notions as distance, rectilinearity. Any figure of other geometry (projective, analytical) is considered as topological space. The aim of topology is to find the topological invariants, i.e. the properties that are conserved in going from one topological space to another.

In our case the term “*topological symmetry*” was used [23]. The reason is as follows. It is known that in real crystals a long-range order is impossible, because of such defects as dislocations which violate translational symmetry. Nevertheless, the long-range order is observed experimentally, so this order is referred to as *topological long-range order* [24]. In other words, since

in topology there is no the notion “distance”, it is assumed that dislocations have no influence on topological space and the long-range order is conserved.

Periodic system of fullerenes. Modeling the growth of fullerenes from C_{24} (D_{3h} symmetry) to C_{48} , we have obtained the perfect fullerenes C_{30} and C_{36} conserving three-fold symmetry [25]. Modeling the growth of fullerenes from C_{32} (D_{4h} symmetry) to C_{60} , we found perfect fullerenes C_{40} and C_{48} conserving four-fold symmetry [26]. Modeling the growth of fullerenes from C_{40} (D_{5h} symmetry) to C_{68} , we found perfect fullerenes C_{50} and C_{60} conserving five-fold symmetry [27]. In Ref. [23] starting from fullerene C_{48} (D_{6h} symmetry), we have obtained perfect fullerenes C_{60} and C_{72} . The mass difference between successive perfect fullerenes in the first case is $\Delta m=6$, in the second case $\Delta m=8$, in the third case $\Delta m=10$ and in the fourth case $\Delta m=12$. It should be emphasized that in all the cases the mass difference is equal to a double degree of symmetry. On the basis of these investigations, as well as others, we have submitted the periodic system for fullerenes [23].

Here all the fullerenes form five vertical columns (groups), having different symmetry. Two groups of three-fold symmetry differ by the structure of fullerene apices. The fullerenes of three-fold S-symmetry group have two sharp apices, the third-order axis going through them. The fullerenes of three-fold T-symmetry group have two truncated apices, the third-order axis going through the centers of triangles. We suppose that the fullerenes of one and the same group have similar physical and chemical properties.

Strictly speaking, only the fullerenes denoted by bold symbols have the symmetry of a corresponding

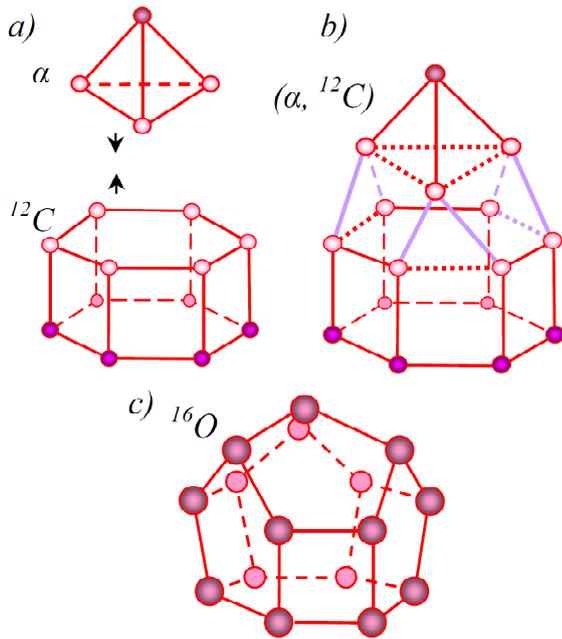


Fig. 13. *a)* Joining α -particle to carbon 12; *b)* intermediate compound: old bonds to be destroyed (red dot lines), new bonds formed (lilac firm lines), *c)* oxygen 16.

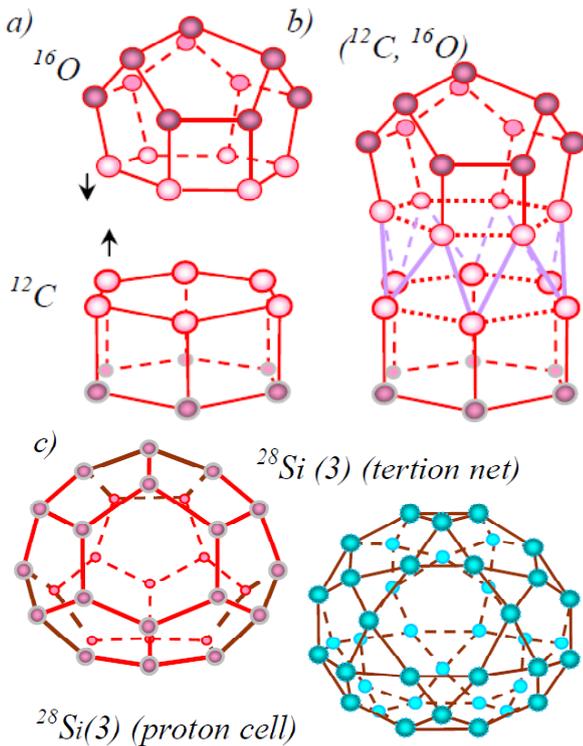


Fig. 14. *a)* Joining oxygen 16 to carbon 12; *b)* fusion of two nuclei; *c)* nucleus ^{28}Si : proton cell at the left and tertion net at the right.

column. They are ideal (perfect) fullerenes. The others (intermediate) are imperfect or semi-perfect.

As noted in Ref [23] by analogy with crystal physics, the imperfection is connected with extra 'interstitial' dimers, playing the role of defects. Let us continue this analogy. Similar to the notion *topological long-range*

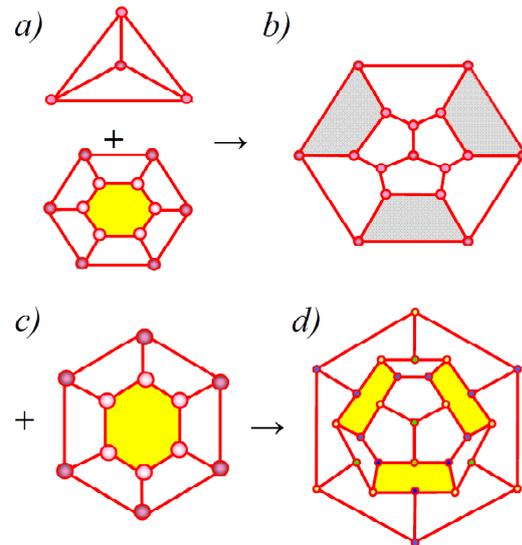


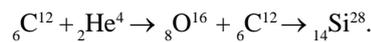
Fig. 15. Graph of the nuclear reaction $^{12}\text{C} + ^4\text{He} \rightarrow ^{16}\text{O} + ^6\text{C}^{12} \rightarrow ^{14}\text{Si}^{28}$: *a)* graph of α -particle and carbon (hexagonal prism); *b)* graph of oxygen (cupola); *c)* graph of carbon (hexagonal prism); *d)* graph of silicon (tetrahedral symmetry).

order, we have defined the imperfect fullerenes conserving the main symmetry axis as having *topological symmetry*.

I hope that after this rather detailed explanation a reader can more easily catch the author's meaning.

6.2. Fusion of two compatible nuclei

Consider the two-stage reaction



The first stage is presented in Fig. 13 and consists in joining α -particle (tetrahedron) with carbon 12 (hexagonal prism). The second stage shown in Fig. 14 illustrates joining carbon 12 (hexagonal prism) to oxygen 16 (cupola of three-fold symmetry). The graph of the reaction is illustrated in Fig. 15.

6.3. One-neutron-core isotopes

There is only one stable isotope of aluminum, $^{27}_{13}\text{Al}$ (100%) [11]. It has the shape of body centered polyhedron having three-fold symmetry. Its structure is shown in Fig. 16.

Let us replace aluminum 26 in the reaction $d + ^{26}_{13}\text{Al} \rightarrow ^{28}_{14}\text{Si}$ by aluminum 27. Then we obtain the two different isotopes of silicon 29 (Fig. 17). It should be noted that in the case of aluminum additional tertions delegated by an internal neutron to the external set have the charge of $1/3 e$. However, for silicon the charge is equal to $1/4 e$. It was shown previously that the difference can be attributed to the Stark effect [15].

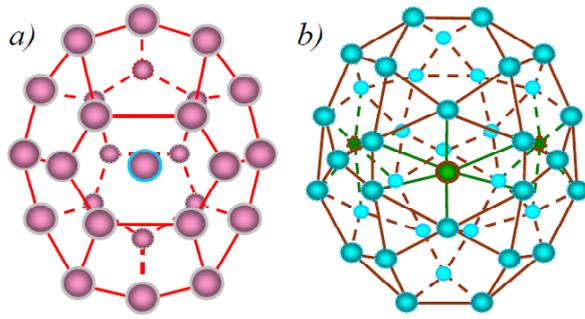


Fig. 16. Structure of isotope ^{27}Al : *a*) proton cell; *b*) tertion net; the tertions of an internal neutron are specially marked in grass green.

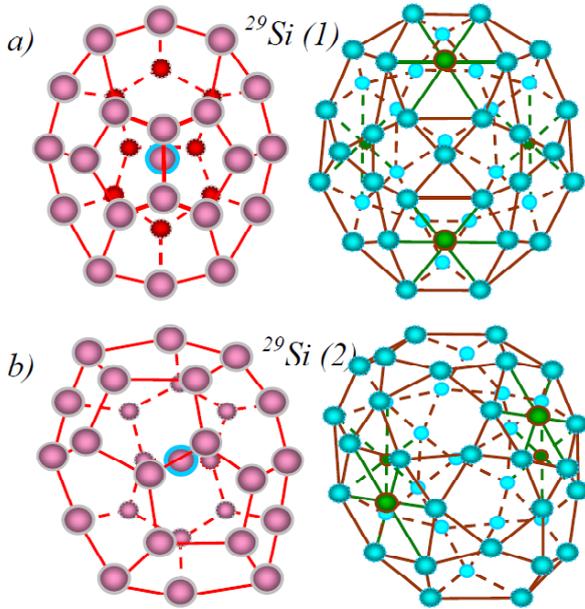


Fig. 17. Isomers of isotope ^{29}Si : *a*) proton cell and tertion net of Si (1); *b*) that of Si (2).

Examine the two-stage reaction with carbon ${}_6\text{C}^{12} + {}_2\text{He}^4 \rightarrow {}_8\text{O}^{16} + {}_6\text{C}^{12} \rightarrow {}_{14}\text{Si}^{28}$. There are two stable isotopes of carbon: ${}_6\text{C}^{12}$ (98.90%), ${}_6\text{C}^{13}$ (1.10%), and an unstable isotope ${}_6\text{C}^{14}$, having a comparatively large half-decay period being equal to 5730 y [11]. Let us replace one carbon 12 (hexagonal prism) with carbon 13 (body centered hexagonal prism) at any stage of the reaction, i.e. think over the reactions



In both cases we obtain the tetrahedral isotope of silicon 29 presented in Fig. 18.

6.4. Two-neutrons-core isotopes

Three reactions of silicon 29 with neutrons give silicon isotopes having different symmetry (Fig. 19).

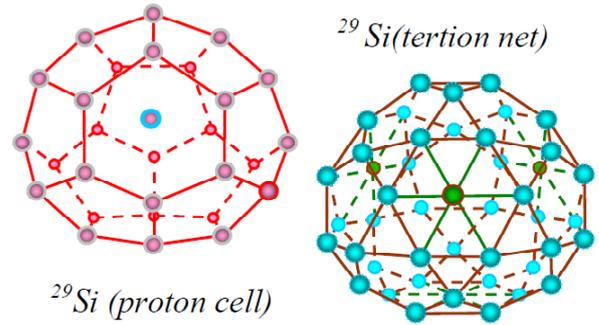


Fig. 18. Structure of isotope ^{29}Si of tetrahedral symmetry: proton cell and tertion net.

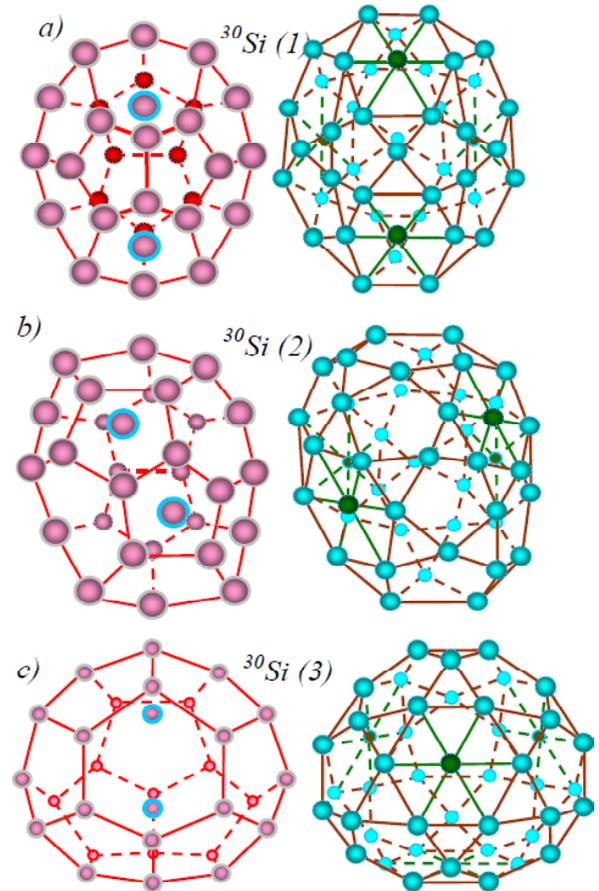
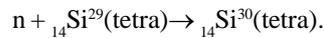
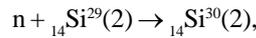
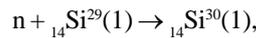


Fig. 19. Isomers of isotope ^{30}Si : *a*) proton cell and tertion net of Si (1); *b*) that of Si (2); *c*) that of Si (tetra); the tertions of two neutrons are specially marked in dark green.



These reactions are worthy of consideration. From the figure it follows that two internal neutrons are removed from one another at the distance larger than the

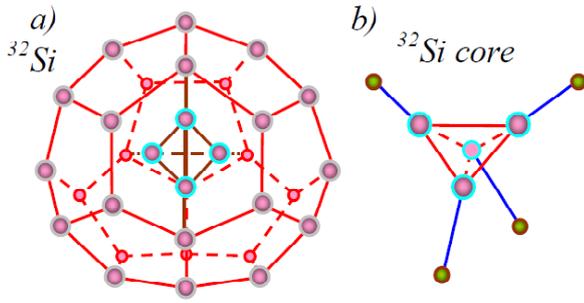


Fig. 20. Structure of isotope ^{32}Si having tetrahedral symmetry: a) proton cell; b) core of the nucleus with nearest binding tertions.

parameter of proton cell. They are localized in the minima of the double-well potential directed along the main symmetry axis. When they decompose into protons and tertions by the external field, created by the proton cell and the tertion net, one is inclined to think that the protons, only slightly connected with one another, behave themselves independently sending their tertions into the coat of mail. So the shape of tertion net doesn't change but the neutron's tertions now have double charge $1/2 e$.

6.5. Four-neutrons-core isotope

Silicon isotope ^{32}Si can be obtained through the use of the geometrically compatible reaction



The result of reaction is shown in Fig. 20.

Here only the tetrahedral silicon is considered because other silicon isomers have no room for incorporating four neutrons. Here one runs into a new phenomenon. Up to now, when there were two internal neutrons, they were decomposed into protons and tertions by the external surroundings, the protons being tightly connected with the electronic coat of mail and maybe only slightly connected, if are connected at all, one another. Now the internal protons form the tetrahedral core, they being tightly connected one another. In this respect the core structure resembles that of α -particle (Fig. 20).

Four internal neutrons give four electrons and four protons, the protons creating the tetrahedral core. It is reasonable to assume that two electrons are incorporated by the internal α -particle. They form the core net of six tertions of charge $1/3 e$. (Fig. 21). The other two electrons must be sent to the external electronic coat of mail. They connect the core and the external tertion net forming the bond net. In our case there are four hexagonal faces of the coat of mail. So the corresponding tertions have charge $1/2 e$.

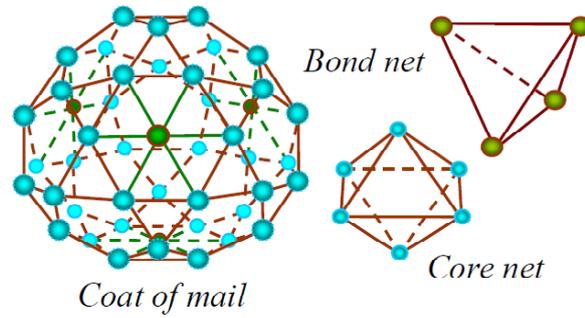


Fig. 21. Electronic structure of tetrahedral silicon isotope ^{32}Si : core net (octahedron), bond net (tetrahedron); c) external coat of mail (tetrahedron). Tertions having the charge $1/3 e$ are marked in turquoise; those of charge $1/2 e$ are grass green.

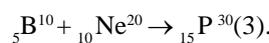
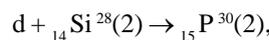
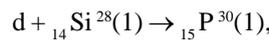
As a result the tertion net is the same as in the case of isotope ^{29}Si of tetrahedral symmetry, but the additional tertions now have the double charge equal to $1/2 e$.

6.6 Summary

The basic nucleus ${}^{14}\text{Si}^{28}$ has three isomers. They have the following forms: ^{28}Si (1) and ^{28}Si (2) of three-fold topological symmetry, ^{28}Si (3) of tetrahedral symmetry. The one-neutron and two-neutron isotopes have also three isomers of the same symmetry. The four-neutron isotope has no isomers.

7. PHOSPHORUS: ISOMERS AND ISOTOPES

The name derives from the Greek $\varphi\omega\sigma\phi\omega\rho\omicron\varsigma$ for "bringing light" because it has the property of glowing in the dark. This was also the ancient name for the planet Venus, when it appears before sunrise (morning star) [9]. Phosphorus was discovered by the German merchant Hennig Brand in 1669. There is only one stable isotope of phosphorus: ${}^{15}\text{P}^{31}$ (100 %) [11]. However a better understanding can be gained if to begin with basic nucleus ${}^{15}\text{P}^{30}$ that can be obtained by various ways through the use of the most probable geometrically compatible reactions. All of them are one-stage reactions:



These reactions were chosen as the most probable on the basis of previous experience.

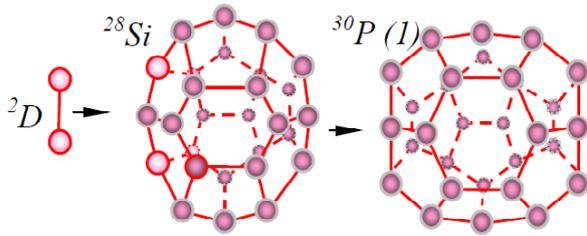


Fig. 22. Attachment of deuteron to silicon (1) and formation of phosphorus (1).

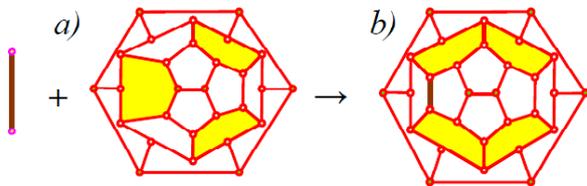


Fig. 23. Graph of the nuclear reaction $d+{}_{14}Si^{28}(1) \rightarrow {}_{15}P^{30}(1)$: a) separate graphs of deuteron and silicon; b) phosphorus graph.

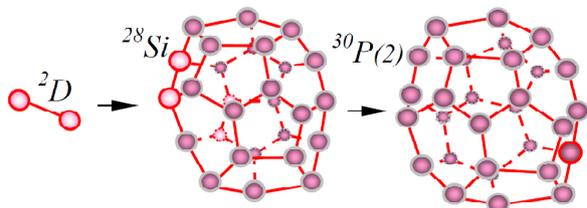


Fig. 24. Attachment of deuteron to silicon (2) and formation of phosphorus (2).

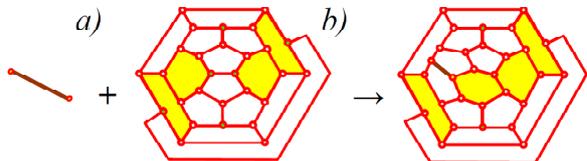


Fig. 25. Graph of the nuclear reaction $d+{}_{14}Si^{28}(1) \rightarrow {}_{15}P^{30}(2)$: a) separate graphs of deuteron and silicon; b) phosphorus graph.

7.1. Joining deuteron to silicon

The first reaction is illustrated in Fig. 22. Here a deuteron is incorporated into a basic nucleus of silicon having three-fold symmetry. For silicon only 4 protons from 28 take part really in the reaction. They are pinked. The nucleus obtained contains twelve pentagons and five hexagons. The graph representation of the reaction is presented in Fig. 23.

The second reaction, shown in Fig. 24, in many respects is similar to the previous reaction. The nucleus obtained contains also twelve pentagons and five hexagons. The graph of this reaction is shown in Fig. 25.

7.2. Fusion of boron with neon

Consider the reaction

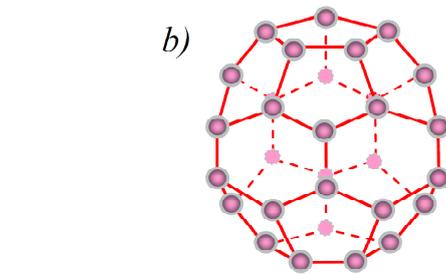
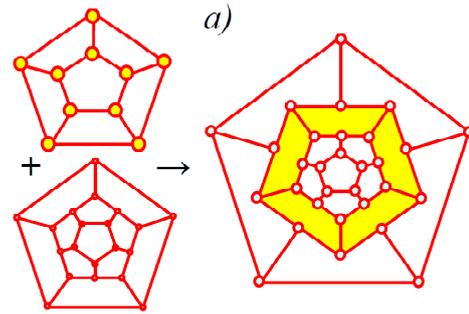
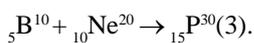


Fig. 26. Graph representation of the nuclear reaction ${}_5B^{10} + {}_{10}Ne^{20} \rightarrow {}_{15}P^{30}(3)$. Here a) graphs of a pentagonal prism and a dodecahedron, as well as their connection; b) nucleus ${}^{30}P(3)$.

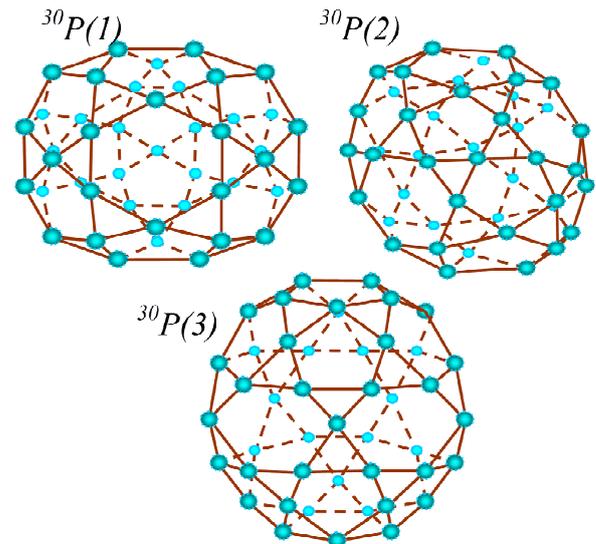
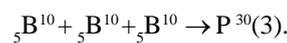


Fig. 27. Electronic structure: a) phosphorus (1); b) phosphorus (2); c) phosphorus (3).

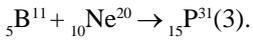
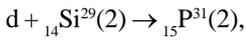
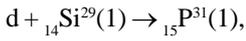
From the geometric standpoint it is attachment of a pentagonal prism to a dodecahedron. The reaction is exhibited in Fig. 26 as the connection of the corresponding graphs together with a final nucleus formed. To fully appreciate the nuclear reactions discussed, the electronic structure of the phosphorus isomers is shown in Fig. 27.

It is interesting to note that neon as a dodecahedron can be produced by the fusion of two boron nuclei [18], i.e. one can obtain phosphorus by means of nucleosynthesis using only boron



7.3. Isomers of isotope ${}_{15}\text{P}^{31}$

From the experiment [11] it follows that all the isomers of basic nuclei are unstable. The reason is that hollow structures can't resist to thermal vibrations and mechanical shear stresses. There is only one stable isotope of phosphorus: ${}_{15}\text{P}^{31}$ (100 %) [11]. By analogy with the basic nuclei, one can conclude that this isotope is able to form three isomers. They can be obtained by the following reactions



As a consequence, the proton cells of the basic-nucleus isomers transform into body centered ones. Besides, owing to delegating the neutron electrons to the coats of mail (tertion nets), the latter become denser that ensures the additional stability [18]. Their protons cells and tertion nets of body centered structures are shown in Fig. 28. What all the nuclei have in common is that their proton cells have five hexagons, so the additional tertions have the charge equal to $1/5 e$.

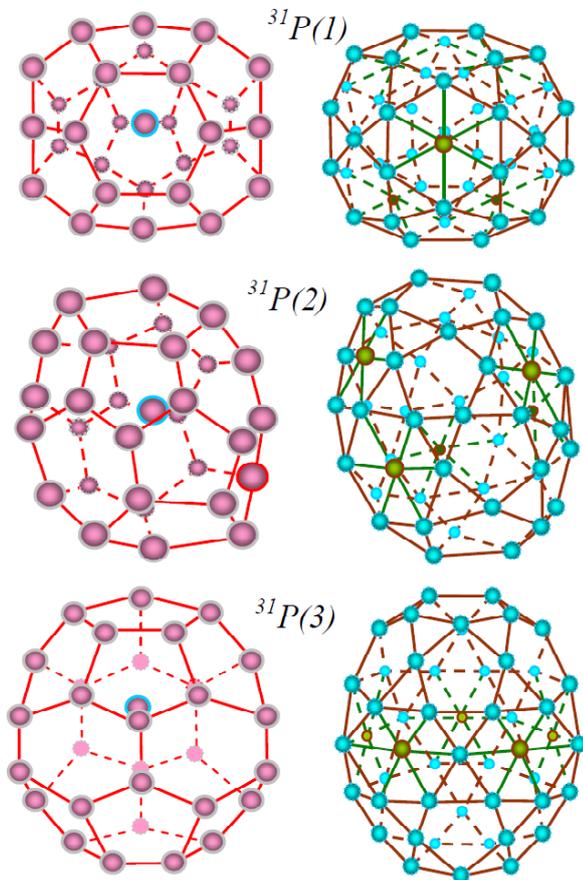
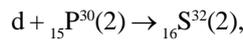
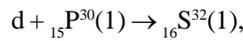


Fig. 28. Protonic and electronic structure of the isomers of phosphorus isotope ${}_{15}\text{P}^{31}$.

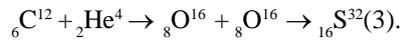
8. SULFUR: ISOMERS AND ISOTOPES

The name derives from the Latin *sulphur* and the Sanskrit *sulveri* (in Latin *sulphur sacrum* means holy celestial light, fire). Sulfur was known as brenne stone for “combustible stone” from which brim-stone is derived. It was known from prehistoric times and thought to contain hydrogen and oxygen. In 1809, the French chemists Louis-Joseph Gay-Lussac and Louis-Jacques Thenard proved the elemental nature of sulfur [9].

There are four stable isotopes of sulfur: ${}_{16}\text{S}^{32}$ (95.02%), ${}_{16}\text{S}^{33}$ (0.75%), ${}_{16}\text{S}^{34}$ (4.21%) and ${}_{16}\text{S}^{36}$ (0.02%) [11]. One may assume that all the isotopes are able to create different isomers. A better understanding can be gained if to begin again with basic nuclei having equal number of protons and neutrons. They can be obtained by various ways through the use of the most probable geometrically compatible reactions. Among them there are two one-stage reactions



and one two-stage reaction



These reactions were chosen as the most probable on the basis of previous experience and by analogy with fullerenes.

Consider the first reaction more closely.

8.1. Joining deuteron to phosphorus (1)

The reaction is illustrated in Fig. 29. Here a deuteron is incorporated into a basic nucleus of phosphorus having three-fold symmetry. From the figure it follows that

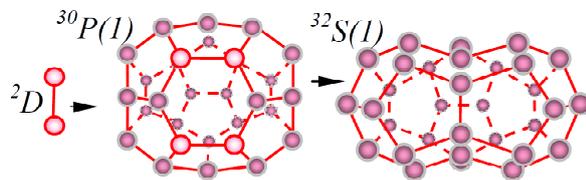


Fig. 29. Attachment of deuteron to phosphorus (1) and formation of sulfur (1).

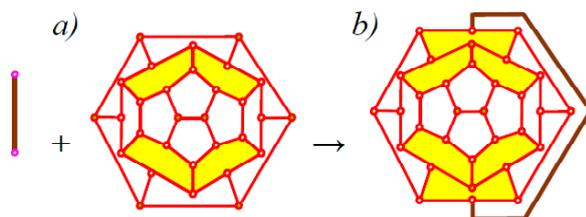


Fig. 30. Graph of the nuclear reaction shown above: a) separate graphs of deuteron and phosphorus; b) graph of sulfur.

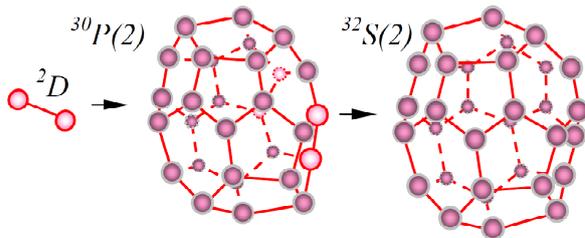


Fig. 31. Attachment of deuteron to phosphorus (2) and formation of sulfur (2).

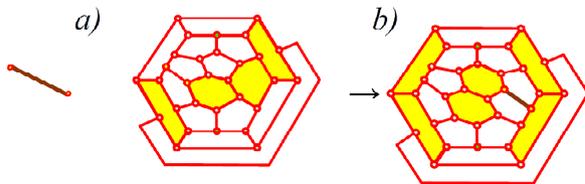


Fig. 32. Graph representation of the nuclear reaction $d + {}_{15}P^{30}(2) \rightarrow {}_{16}S^{32}(2)$: a) separate graphs of deuteron and phosphorus; b) graph of sulfur.

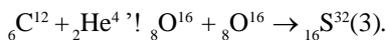
for phosphorus only 4 protons from 30 take part in the reaction. They are pinked. The nucleus obtained contains twelve pentagons and six hexagons. The graph representation of this reaction is shown in Fig. 30.

8.2. Joining deuteron to phosphorus (2)

The reaction shown in Fig. 31 in many respects is similar to the previous reaction. The nucleus obtained contains also twelve pentagons and six hexagons. The graph of this reaction is presented in Fig. 32.

8.3. Fusion of several different nuclei having compatible symmetry

Now consider the two-stage reaction which is written above as



The first stage is illustrated in Fig. 13. The second stage consists in joining two cupolas. The reaction is fully shown in Fig. 33 as connection of the corresponding graphs together with a final nucleus formed.

What all the phosphorus nuclei considered have in common is that their proton cells consist of twelve pentagons and six hexagons.

To appreciate entirely the nuclear reactions discussed, the electronic structures of the sulfur isomers are presented in Fig. 34.

8.4. Fusion of two nuclear cupolas

Consider again the parallels between fullerenes and nuclei. The periodic system of fullerenes formulated in Ref. [23] is based on symmetry principles. From the sys-

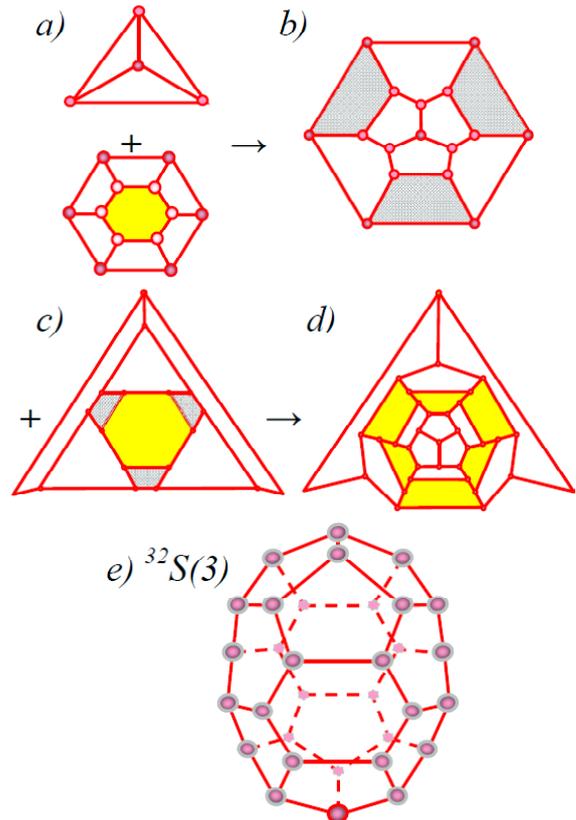


Fig. 33. Graph of the two-stage nuclear reaction: a) α -particle and carbon (hexagonal prism); b) oxygen (cupola); c) inversion graph of oxygen (cupola); d) graph of sulfur (three-fold symmetry); e) nucleus ${}^{32}S(3)$ obtained.

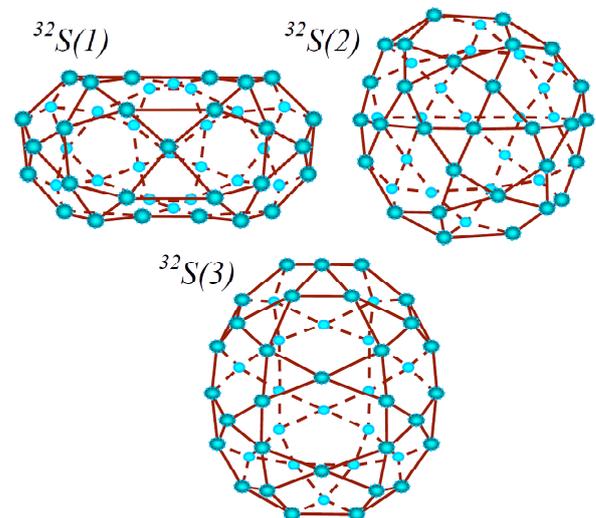


Fig. 34. Electronic structure of sulfur (1), sulfur (2) and sulfur (3).

tem it follows that there are the following fullerenes having the mass 32 and different symmetry; namely, 3-fold S-symmetry perfect fullerene, 3-fold T-symmetry imperfect fullerene having one extra dimer, 4-fold symmetry perfect fullerene and 5-fold symmetry imperfect fullerene having one extra dimer. It is reasonable to suggest that

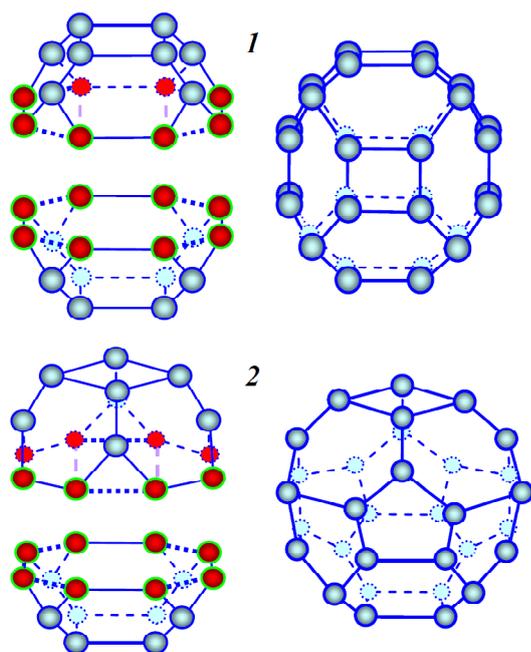


Fig. 35. Fullerene C_{32} obtained by joining two cupolas C_{16} : mirror-symmetry (1), rotation-reflection-symmetry (2).

the basic nuclei of sulfur are highly symmetric. So from these possible structures one needs to choose only the perfect fullerenes.

It should be mentioned that the 3-fold S-symmetry perfect fullerene was obtained previously through the use of the two-stage reaction (sulfur 3). Now one must design the ways of producing the structure of the sulfur basic nucleus having four-fold symmetry. Here the analogy with fullerenes helps again. With the knowledge of the analogous process for fullerenes, one is able to solve this problem for nuclei.

One has to approach the problem in stages. When modeling the growth of fullerenes [28], we have obtained two isomers of fullerene C_{32} . They are shown in Fig. 35.

First of all it is necessary to set up a topological correspondence between the reacting constituents of the fullerene and those of the nucleus designed. Clear that cupola C_{16} can be associated with an intermediate nucleus ^{16}O , having the similar shape. Therefore the general problem is reduced to the problem how to obtain the intermediate nucleus ^{16}O .

By analogy with biosynthesis [29] one inclines to think that there is the following chain of nuclear reactions which are represented in Fig. 36. At first, two alpha-particles combine forming a dimer (a). Then the dimer adds another alpha-particle forming a linear trimer. The trimer has one proton, which is slightly connected with the trimer through the use of only one bond (b). Then the trimer attaches one more alpha-particle creating a

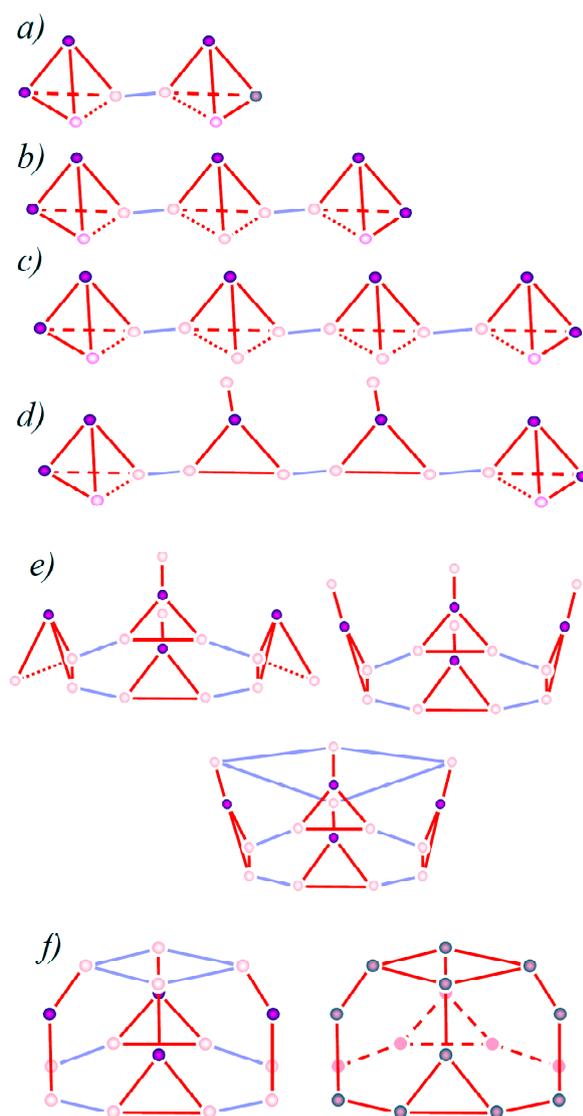
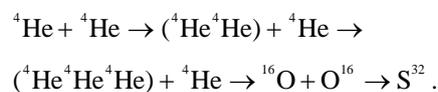


Fig. 36. Generation of cupola-oxygen-16 isomer: a) dimer formation, b) trimer formation with one slightly connected proton, c) four-link chain with two slightly connected protons, d) internal rotation of two protons, e) folding of the four-link chain, f) four-fold symmetry cupola.

four-link chain with two slightly connected protons (d). Similar to the interactions of electronic and atomic degrees of freedom in molecules [30], the interaction of tertions (they are not shown in the figure) and protons leads to internal rotation [31] of the slightly connected protons. This structure can fold up (e) and create cupola oxygen nucleus of four-fold symmetry (f). Therefore sulfur isomers of four-fold symmetry can be obtained by means of the following reactions



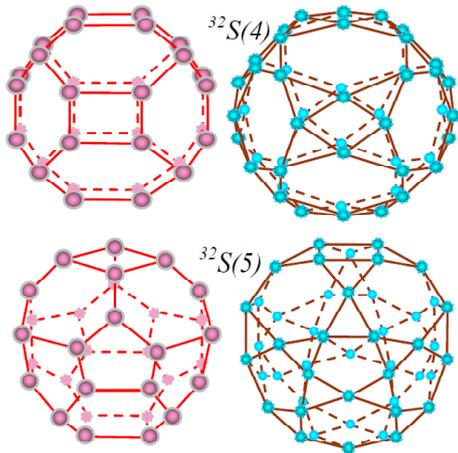


Fig. 37. Protonic and electronic structure of the isomers of sulfur ${}_{16}S^{32}$.

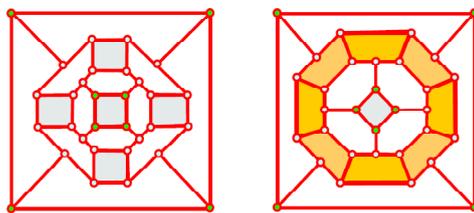
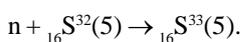
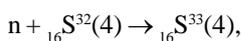
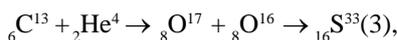
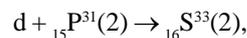
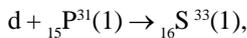


Fig. 38. Graph of the tetra₆-hexa₁₂ polyhedron at the left and that of the tetra₂-(penta-hexa)₈ polyhedron at the right.

The protons cells and tertion nets of the isomers are shown in Fig. 37. The nuclei obtained consist of six tetragons and twelve hexagons or two tetragons and eight pentagons and hexagons. It should be emphasized that there two ways of the oxygen cupola fusion: mirror symmetry one and rotation-reflection. The graphs of the nuclei are presented in Fig. 38.

8.4. One-neutron-core isotopes

From the results obtained for the basic nuclei, it follows that the isotope ${}_{16}S^{33}$ is able to form five isomers. They can be got by the following reactions



The protons cells and tertion nets of the isomers are shown in Fig. 39. For the first three isomers the neutron's tertions have the charge $1/6 e$. For the fourth isomer the charge is $1/12 e$, for the fifth one it equals to

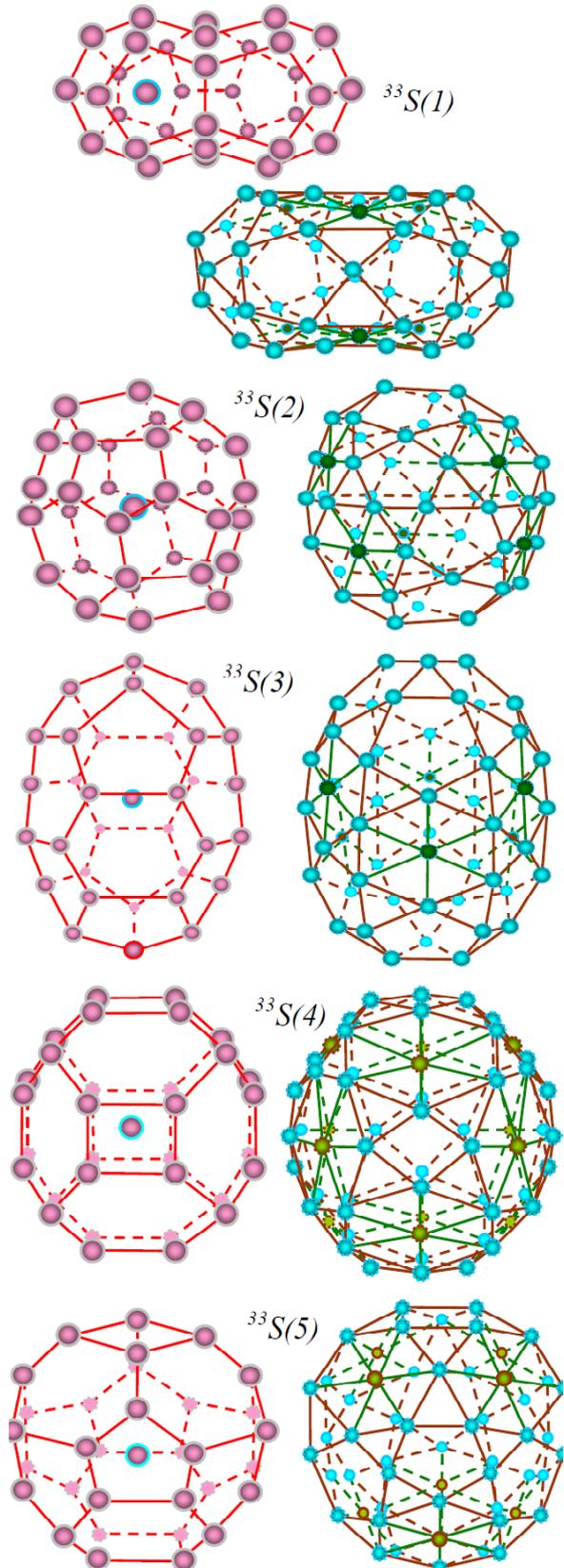


Fig. 39. Protonic and electronic structure of the five isomers of sulfur isotope ${}_{16}S^{33}$.

$1/8 e$. It should be remembered that the charge value is inversely proportional to the number of hexagons in the proton cell.

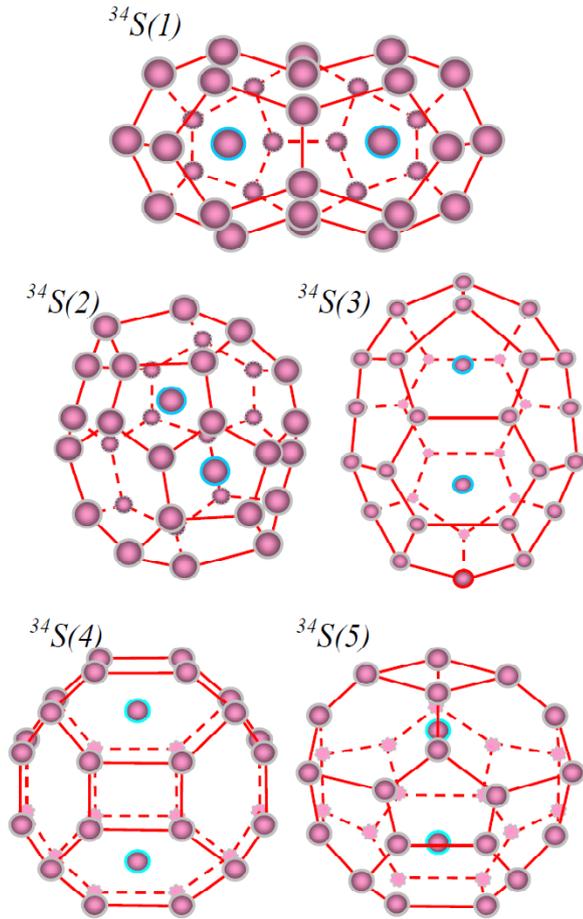
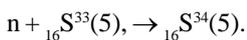
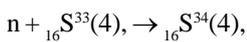
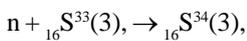
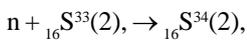
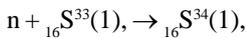


Fig. 40. Protonic cells of the isomers of sulfur isotope ${}_{16}\text{S}^{34}$.

8.5. Two-neutrons-core isotopes

On the basis of the results got above, one inclines to think that the isotope ${}_{16}\text{S}^{34}$ has also five isomers. They can be obtained by the following reactions



The protons cells of the isomers are shown in Fig. 40.

From the figure it follows that two neutrons are removed from one another at the distance larger than the parameter of proton cell. When there are two remote internal neutrons, the latter decompose into protons and tertions by the external surroundings, as before. The protons are localized in the minima of the double-well

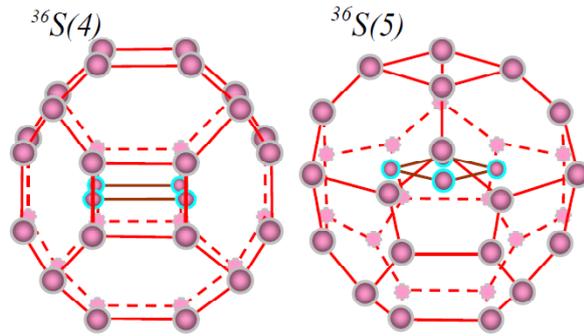


Fig. 41. Protonic cells of isotope ${}_{16}\text{S}^{36}$.

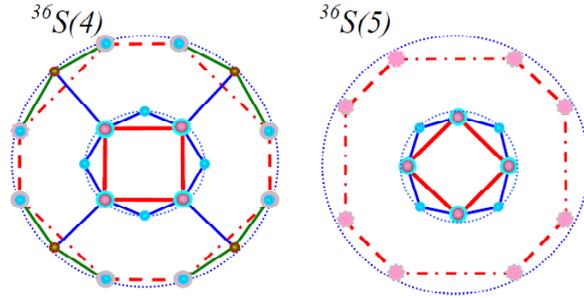


Fig. 42. Cross sections of isotope ${}_{16}\text{S}^{36}$.

potential directed along the main symmetry axis and only slightly connected with one another. It means that they behave themselves almost independently sending their tertions into the coat of mail. As a result, the shape of tertion net doesn't change but the neutron's tertions now have charge $1/3 e$, $1/6 e$ and $1/4 e$, respectively.

8.6. Four-neutrons-core isotopes

From the results obtained above for silicon ${}_{14}\text{Si}^{32}$, it follows that the isotopes, having more than two internal neutrons, can form cores inside the nucleus. However the core symmetry must be compatible with that of the external surrounding. It means that in our case only ${}^{34}\text{S}(4)$ and ${}^{34}\text{S}(5)$ are able to incorporate still more neutrons and to form isotopes ${}^{36}\text{S}(4)$ and ${}^{36}\text{S}(5)$ (Fig. 41). The cross sections of protons cells and tertion nets are presented in Fig. 42. The nearest cross sections are shown with the help of dot lines.

The internal protons create the cores having the shape of an equilateral quadrangle. Four internal neutrons had four electrons. After decomposition of the neutrons into protons and negatively charged particles, the latter must be allotted between the core, the external electronic coat of mail and the bonds connecting the core and the external proton cell. It is reasonable to assume that the core's four protons are similar to α -particles. They are tightly connected by the tertions of charge $1/3 e$.

In principle, the other negative charges must be allotted between the external electronic coat of mail and

the bonds connecting it with the core. However in our case, the distance between the core and any proton of the cell is larger than the cell parameter. So one inclines to suppose that there are no “covalent” bonds at all and the core is connected with the proton cell by means of totally electric field generated by the proton cell together with the tertion net and the core. There are twelve hexagonal faces of the proton cell (and accordingly of coat of mail) for $^{36}\text{S}(4)$ and eight for $^{36}\text{S}(5)$. Assume that the residual $8/3$ negative charges are incorporated into the coat of mail; therefore the corresponding tertions have the charge $2/9 e$ and $1/3 e$, respectively. The electronic structures of sulfur isotopes $^{33}\text{S}(4)$ and $^{33}\text{S}(5)$ are presented in Fig. 39. Here the incorporated tertions are marked in grass-green. For the four-neutron isotopes $^{16}\text{S}^{36}$, the shape of tertion net doesn't change but the neutron's tertions now have other charges.

Internal rotation. The isotope $^{36}\text{S}(4)$ has three axes of four-fold symmetry. It means that the core can occupy three different positions inside the nucleus. Similar to the molecules [1], one can consider such different space forms of one and the same nucleus as *nuclear conformers*. One can continue the analogy and come to conclusion that there exists internal rotation of cores inside some nuclei. In our case one has three conformers.

The isotope $^{36}\text{S}(5)$ has a rotation-reflection axis of four fold symmetry. Here the core can occupy two different positions; one in the upper part of the nucleus is shown in Fig. 41; another identical position in the lower part can be achieved through spiral motion of the core (Fig. 43).

8.7. Summary

The basic nucleus $^{16}\text{S}^{32}$ has five isomers of different symmetry. The one-neutron and two-neutron isotopes have

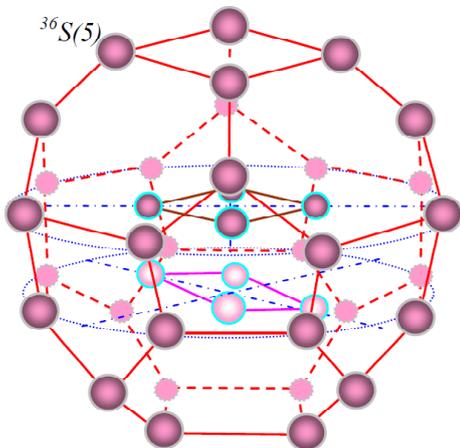


Fig. 43. Spiral-rotational nuclear isomers of sulfur isotope $^{16}\text{S}^{36}$: the core's protons in the lower part of nucleus are specially marked in the figure; they and their bonds are pale pink.

also five isomers of the same symmetry. The four-neutron isotope has two isomers, among them five rotational conformers.

9. CHLORINE: ISOMERS, ISOTOPES

The name derives from the Greek $\chi\lambda\omega\rho\omicron\varsigma$ for “pale green or greenish yellow color” of the element. It was discovered by the Swedish pharmacist and chemist Carl-Wilhelm Scheele in 1774. In 1810, the English chemist Humphry Davy proved that it was an element [9].

There are two stable isotopes of chlorine: $^{17}\text{Cl}^{35}$ (75.77%), $^{17}\text{Cl}^{37}$ (24.23%) and an isotope $^{17}\text{Cl}^{36}$, having the very large half-decay period being equal to $3.01 \cdot 10^5$ years [11]. As before, one may assume that all the isotopes have different isomers. Begin with the basic nuclei having equal number of protons and neutrons.

9.1. Joining deuteron to sulfur (1)

Consider reaction $d + {}^{16}\text{S}^{32}(1) \rightarrow {}^{17}\text{Cl}^{34}(1)$, which is illustrated in Fig. 44.

Here a deuteron is incorporated into a basic nucleus of sulfur having a disk shape. From the figure it follows that for sulfur only 4 protons from 32 take part in the reaction. They are pinked. The nucleus obtained contains twelve pentagons and seven hexagons. The graph representation of this reaction is shown in Fig. 45.

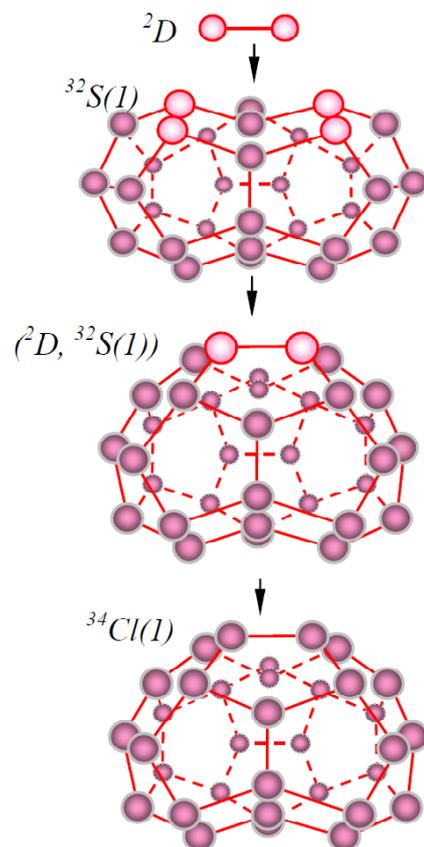


Fig. 44. Attachment of deuteron to sulfur (1) and formation of chlorine (1).

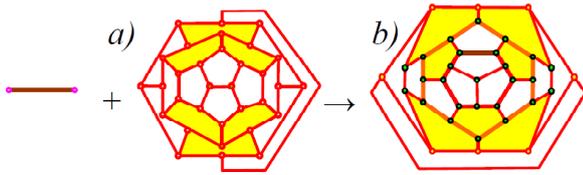


Fig. 45. Graph representation of the nuclear reaction $d + {}_{16}\text{S}^{32}(1) \rightarrow {}_{17}\text{Cl}^{34}(1)$: *a*) separate graphs of deuteron and sulfur; *b*) graph of chlorine.

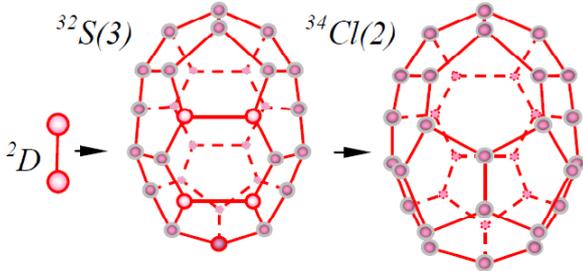


Fig. 46. Attachment of deuteron to sulfur (3) and formation of chlorine (2).

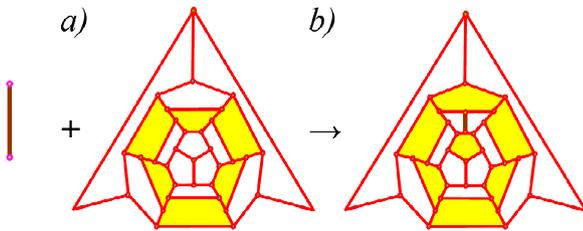


Fig. 47. Graph of the nuclear reaction shown above: *a*) separate graphs of deuteron and sulfur; *b*) graph of chlorine.

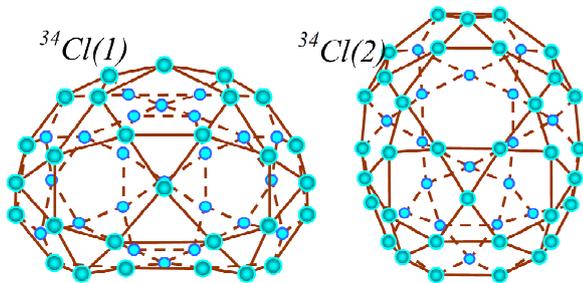


Fig. 48. Electronic structure of chlorine (1) and chlorine (2).

9.2. Joining deuteron to sulfur (3)

Consider reaction $d + {}_{16}\text{S}^{32}(3) \rightarrow {}_{17}\text{Cl}^{34}(2)$. The reaction shown in Fig. 46 in many respects is similar to the previous reaction. The nucleus obtained contains also twelve pentagons and seven hexagons. The graph of this reaction is presented in Fig. 47. To fully appreciate the nuclear reactions discussed, the electronic structure of the chlorine isomers are illustrated in Fig. 48.

9.3. Isomers of isotope ${}_{17}\text{Cl}^{35}$

From the results obtained for the basic nuclei it follows that isotope ${}_{17}\text{Cl}^{35}$ is able to form two isomers. They can be got by the following reactions

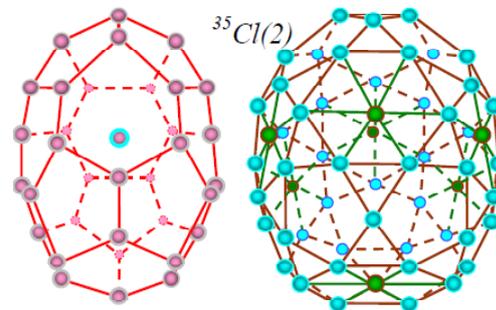
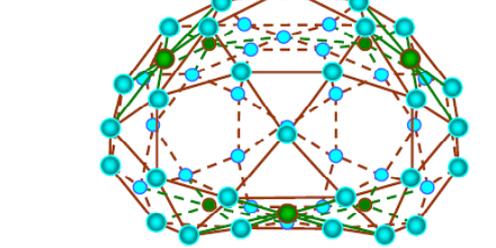
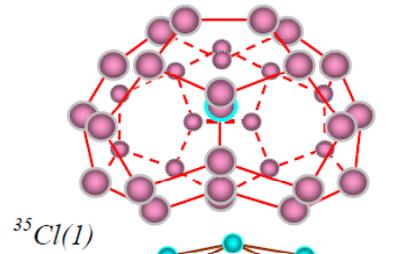
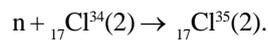
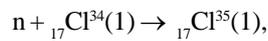


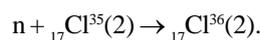
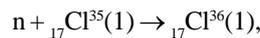
Fig. 49. Protonic and electronic structure of the isomers of chlorine isotope ${}_{17}\text{Cl}^{35}$.



The protons cells and tertion nets of the isomers are shown in Fig. 49, the neutron's tertions having the charge $1/7 e$ what is in agreement with the number of hexagons in the proton cell (and tertion net).

9.4. Isomers of isotope ${}_{17}\text{Cl}^{36}$

The isomers of isotope ${}_{17}\text{Cl}^{36}$ can be obtained by the following reactions



Their protons cells are shown in Fig. 50.

From the figures it follows that two protons are removed from one another at the distance larger than the parameter of proton cell. They are localized in the minima of the double-well potential directed along the main symmetry axis, the protons being only slightly connected with one another. It means that they behave themselves almost independently. As a result, the shape of tertion

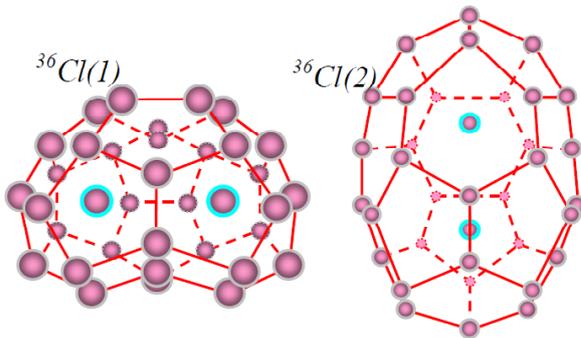


Fig. 50. Protonic structure of the isomers of chlorine isotope ${}_{17}\text{Cl}^{36}$.

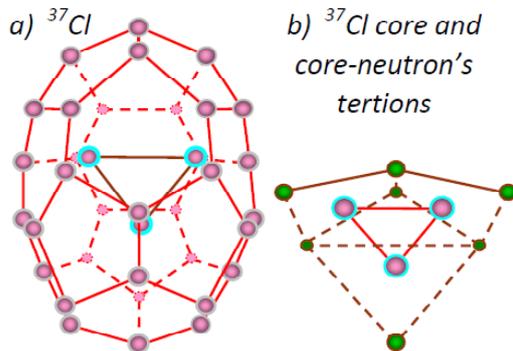
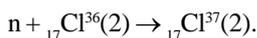


Fig. 51. Protonic structure of chlorine *a*) proton cell; *b*) nucleus core and its tertions.

net doesn't change (it is shown in Fig. 48) but the neutron's tertions now have double charge $2/7 e$.

9.5. Isotope ${}_{17}\text{Cl}^{37}$

The isotope can be obtained by the reaction



The structure of proton cell and core of the isotope is presented in Fig. 51.

Here only the three-fold symmetry chlorine is considered because other isomers have no room for incorporating three neutrons.

These results deserve further comment. Similar to the case of magnesium ${}_{12}\text{Mg}^{28}$, silicon ${}_{14}\text{Si}^{32}$ and sulfur ${}_{16}\text{S}^{36}$ the internal protons produce the core, where they are tightly connected one another. The core's shape resembles either that of α -particle or a square, now one has the core in the form of helium 3. Three internal neutrons gave three electrons. It is reasonable to assume that one of them is incorporated by the helium-3 core forming three tertions of the charge $1/3 e$. The other two electrons must be allotted between the external electronic coat of mail and the bonds connecting the core and the external electronic net. However in our case, the bond net contains more tertions than the core has protons. So one inclines to suppose that there are no "cova-

lent" bonds and the core is connected with the proton cell by means of totally electric field generated by the proton cell, the tertion net and the core. There are seven hexagonal faces of the coat of mail. Assume that the residual two electrons are incorporated into the coat of mail; so the corresponding tertions have the charge $2/7 e$. Therefore the external electronic structure of chlorine isotope ${}_{17}\text{Cl}^{37}$ is the same as that of isotope ${}_{17}\text{Cl}^{36}(2)$, in spite of the fact that their cores are different.

9.6 Summary

The basic nucleus ${}_{17}\text{Cl}^{34}$ (unstable) has two isomers of different symmetry. The one-neutron and two-neutron isotopes have also two isomers of the same symmetry. The three-neutron isotope has no isomers.

10. ARGON: ISOMERS AND ISOTOPES

The name derives from the Greek $\alpha\rho\gamma\omicron\varsigma$ for "lazy" or "inactive" because it does not combine with other elements. It was discovered in 1894 by the Scottish chemist William Ramsay and the English physicist Robert John Strutt (Lord Rayleigh) in liquefied air. Rayleigh's initial interest derived from a problem posed by the English physicist Henry Cavendish in 1785: when oxygen and nitrogen were removed from air, there was an unknown residual gas remaining [9].

There are three stable isotopes of argon: ${}_{18}\text{Ar}^{36}$ (0.337%), ${}_{18}\text{Ar}^{38}$ (0.063%), ${}_{18}\text{Ar}^{40}$ (99.600%) and two isotopes ${}_{18}\text{Ar}^{39}$ and ${}_{18}\text{Ar}^{42}$, having the rather large half-decay periods being equal to 269 and 32.9 years respectively, and one isotope ${}_{18}\text{Ar}^{37}$ of small half-decay period which equals to 34.8 diurnals [11]. The problem is how to explain these data in the framework of one and the same unified model.

Parallels between fullerenes and nuclei. In the Introduction it was stated that the nuclear models are approximate representations used for description of some properties of the nuclei. They are based on the identification of a nucleus with one of physical systems, which properties are well studied. As this takes place, any theoretical model should lead to predictions. A good model should predict more numerical values, parameters or functional relations than the number of input parameters. The first effort to make prediction for fullerenes was done in Ref. [23]. Succeeding modeling the fullerene growth allowed classifying the fullerenes, known and predicted, on the base of the periodic system of fullerenes formulated in Ref. [33].

Consider again the parallels between fullerenes and nuclei. From the periodic system it follows that there are the following fullerenes having the mass 36 and

different symmetry; namely, 3-fold S-symmetry imperfect fullerene having two extra dimers, 3-fold T-symmetry perfect fullerene, 4-fold symmetry semi-perfect fullerene having two extra dimers, 5-fold symmetry imperfect fullerene having three extra dimers and 6-fold perfect fullerene. It is reasonable to suggest that the basic nuclei of argon are highly symmetric. So from these possible structures one needs to choose the semi-perfect and perfect fullerenes. It should be mentioned that the 3-fold T-symmetry perfect fullerene must be excluded from consideration as having too high energy [32].

With knowledge of fullerene structure, it is possible to obtain nuclear structures. They can be designed through the use of the most probable geometrically compatible reactions. A better understanding can be gained if to begin with basic nuclei having equal number of protons and neutrons.

10.1. Joining two deuterons to sulfur

The reaction illustrated in Fig. 52 can be written as $d + \rightarrow {}_{16}S^{32}(4) + d \rightarrow {}_{18}Ar^{36}(1)$. The structure of sulfur 32 (4) was obtained previously. Now two deuterons are incorporated in series into one of the basic nucleus of sulfur having four-fold symmetry. From the figure it follows that for sulfur only 8 protons from 32 take part in the reaction. They are pinked. The nucleus obtained contains two tetragons, eight pentagons and ten hexagons. The graph representation of the reaction is shown in Fig. 53.

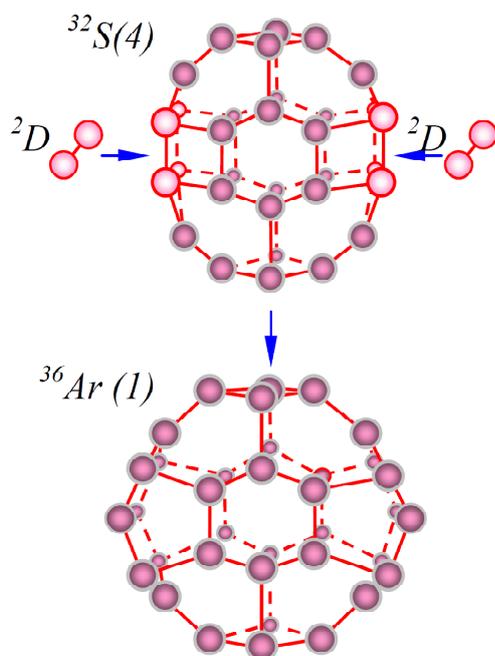


Fig. 52. Attachment of two deuterons to sulfur (4) and formation of argon (1).

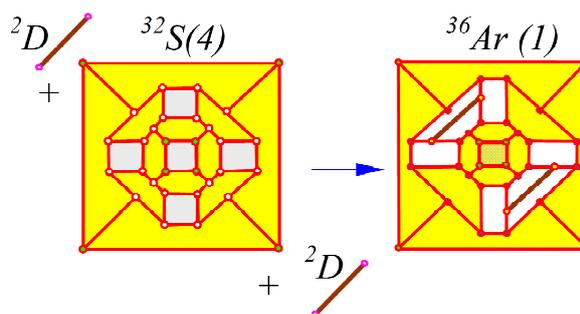


Fig. 53. Graph representation of nuclear reaction $d + {}_{16}S^{32}(4) + d \rightarrow {}_{18}Ar^{36}(1)$.

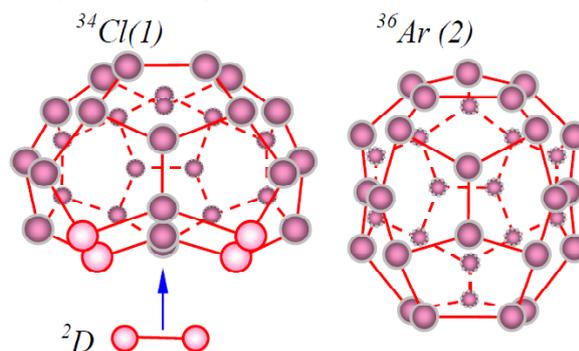


Fig. 54. Attachment of deuteron to chlorine (1) and formation of argon (2).

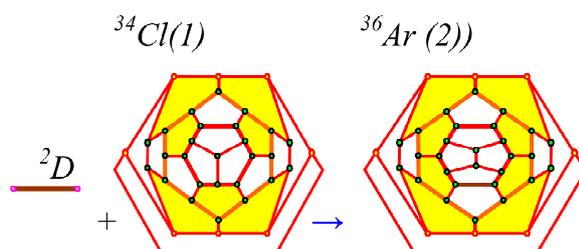


Fig. 55. Graph representation of the nuclear reaction $d + {}_{17}Cl^{34}(1) \rightarrow {}_{18}Ar^{36}(2)$.

10.2. Joining deuteron to chlorine

The reaction $d + {}_{17}Cl^{34}(1) \rightarrow {}_{18}Ar^{36}(1)$ is illustrated in Fig. 54. The structure of chlorine 34 (1) was obtained previously.

Now a deuteron is incorporated into a basic nucleus of chlorine resembling a disk. From the figure it follows that for chlorine only 4 protons from 34 take part in the reaction. They are pinked. The nucleus obtained contains twelve pentagons and eight hexagons. The graph representation of this reaction is given in Fig. 55.

10.3. Joining six-fold symmetry carbon to six-fold symmetry magnesium

The reaction is illustrated in Fig. 56. Its graph representation is given in Fig. 57. To fully appreciate the nuclear reactions discussed above, the electronic structures of the argon isomers are presented in Fig. 58.

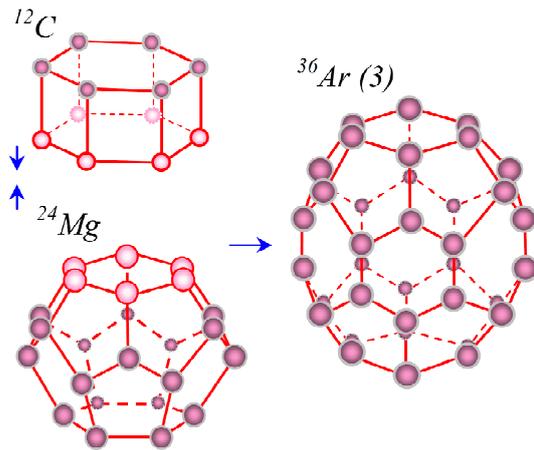


Fig. 56. Fusion of carbon with magnesium and formation of argon (3).

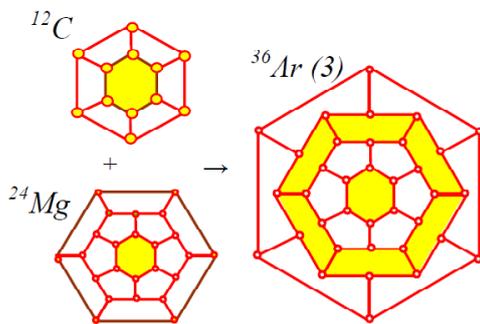


Fig. 57. Graph of the nuclear reaction.

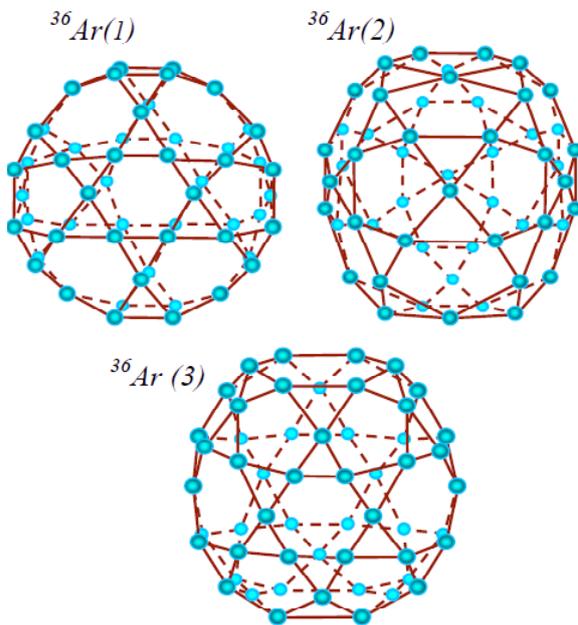


Fig. 58. Tertion net of argon isomers.

It is worth noting the following. Ar (2) and Ar (3) have the symmetry D_{2d} and D_{6h} , respectively. Among the fullerenes, only the fullerenes of such symmetry have the least energy [32].

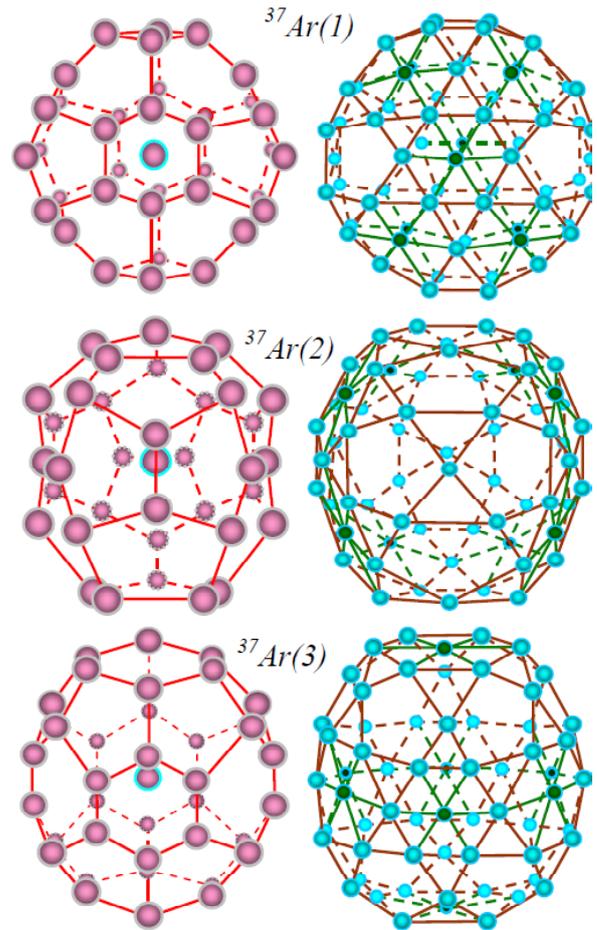


Fig. 59. Protonic and electronic structure of the isomers of argon isotope $_{18}\text{Ar}^{37}$.

10.4. Isomers of isotopes $_{18}\text{Ar}^{37}$ and $_{18}\text{Ar}^{38}$

From the results for the basic nuclei, it follows that the isotope of argon 37 is able to form three isomers. They can be got by incorporating a neutron, $n + _{18}\text{Ar}^{36} \rightarrow _{18}\text{Ar}^{37}$. It is possible to obtain also three isomers of the isotope of argon 38 through the use of reaction $n + _{18}\text{Ar}^{37} \rightarrow _{18}\text{Ar}^{38}$. The protons cells and tertion nets of the isomer $_{18}\text{Ar}^{37}$ are shown in Fig. 59.

The neutron's tertions have the charge $\frac{1}{10}e$ for argon 37 (1) and $\frac{1}{8}e$ for argon 37 (2) and argon 37 (3). It should be remembered that the value of additional tertion charge is defined by the number of hexagons in the external tertion net.

The protons cells of the isomers of isotope $_{18}\text{Ar}^{37}$ are shown in Fig. 60.

From Fig. 60 it follows that two internal protons are removed from one another at the distance larger than the parameter of proton cell. So they are localized in the minima of the double-well potential directed along the main symmetry axis. They are only slightly connected with one another and behave themselves almost

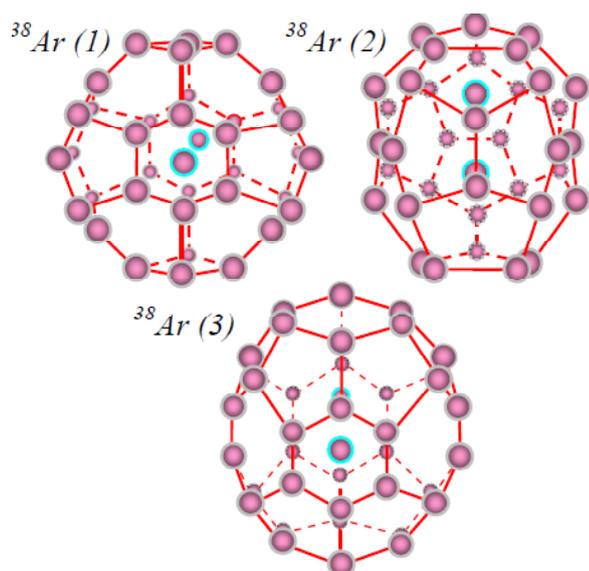


Fig. 60 Proton cells of the isomers of argon isotope ^{38}Ar .

independently. Their tertions are incorporated into the coat of mail. As a result, the shape of tertion net doesn't change but the neutron's tertions now have double charge $1/5$, $1/4$, and $1/4 e$ for ^{38}Ar (1), ^{38}Ar (2) and ^{38}Ar (3), respectively.

10.5. Internal compatibility of argon isotopes $^{18}\text{Ar}^{39}$, $^{18}\text{Ar}^{40}$ and $^{18}\text{Ar}^{42}$

The isotopes mentioned contain extra 3, 4 and 6 internal neutrons. From the results obtained previously it follows that they can form clusters (cores) inside the nucleus. It should be emphasized that the core symmetry must be compatible with that of the external surrounding. It means that argon 39 has a core having the shape of an equilateral triangle, argon 40 having that of tetrahedral symmetry, which is compatible with the six-fold symmetry of basic nucleus, and argon 42 is able to form the core of six protons having three-fold symmetry. For this reason, one needs to consider only argon (3). The possible structures of its isotopes are presented in Fig. 61.

These results deserve further comment. From the figure it follows that the nucleus cores are compact, and what is more interesting, the cores repeat the shape of the first elements of the periodic system; namely, helium

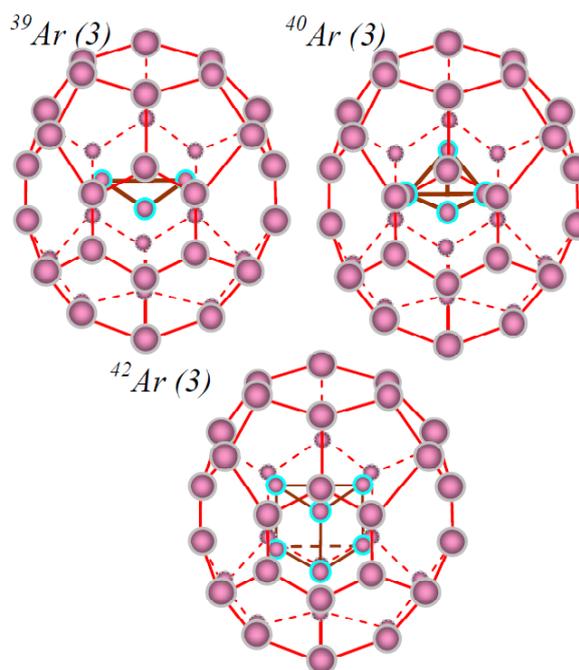


Fig. 61. Protonic cells of argon isotopes.

3, helium 4 and lithium 6. As for the electronic structure, it is the same one as for the isotopes with lesser number of internal neutrons. Really, although each next neutron above two ones gives an additional electron or three tertions, they are going for constructing the core; the external coat of mail remaining without changing.

10.6. Argon evolution

One fact is worthy of special attention. As was mentioned in the Introduction, William Crookes in 1886 suggested that elements had been developed by the effort of two forces, electricity and heat. Definite quantities of electricity were given to each element at its genesis; this electricity determined the element's valence. The atomic weight was only a measure of the cooling conditions that had prevailed at the moment of the element's birth. It is interesting to compare the isotopic composition of the planets Earth, Venus and Mars having different surface temperature. The data are given in Table 2 [1,34,35].

Argon has three stable isotopes (^{36}Ar , ^{38}Ar , and ^{40}Ar), each of which has radio- or nucleogenic components

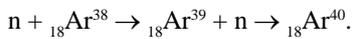
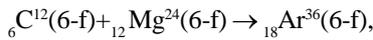
Table 2. Isotopic composition and temperature of the planets.

	Ar 36	Ar 38	Ar 40	40/38	T, K
Venus	44.2%	8.6%	47.2%	1.07	735
Earth	0.337%	0.063%	99.600%	295.5	240-310
Mars	36/38=4.2		40/36=1.9×10 ³	1900	200-270

that can be used in Earth sciences for dating and tracing rocks, gases, and water masses, i.e. for geochronology [36]. Whereas argon produced by stellar nucleosynthesis consists mainly of argon 36, the major isotope of argon on Earth is argon 40 [37]. “The fact that non-radiogenic atmospheric Ne, Ar, Kr, and Xe are all isotopically heavier than their solar counterparts is an important clue to the nature of the alteration process, and is central to evolutionary models in which the atmosphere was driven from solar progenitors to its present compositional state by energetic escape of a primordial atmosphere” [37].

Why have I cited the author [37] at great length? The reason is that the author, R.O. Pepin (School of Physics and Astronomy, University of Minnesota, Minneapolis, USA), in essence only partially rekindled Crookes’ hypothesis without mentioning the origin. (In Ref[37] there is no Crooke’s name). Apparently Crookes’ hypothesis is wrongly forgotten.

Let us return to the Founding Farther. Crookes had combined two forces: electricity and heat, which lead to the appearance of different isotopes. On the base of our results, one may write the following chain of nuclear reactions:



Besides, it is possible to visualize Crookes’ hypothesis in the manner illustrated in Fig. 62. Only the isotopes of six-fold symmetry are considered, since they cover all the mass range from 36 to 40.

11. DISCUSSION WITH REVIEWER

This paper was preliminary peer-reviewed and one of the Reviewers made very interesting remarks. To my mind, the answer to the Reviewer would be more worthwhile and instructive if it is written separately in the form of dialogue similar to the medieval discussions. Such form helps better understanding the new things which are introduced in the paper. For this reason the special section under the name mentioned above is added.

Reviewer 1. It is not clear what previously unknown stable isotopes were predicted with the model.

Author 1. I have shown that the *known stable* isotopes can create *unknown space isomers*. It means that instead of the previously known *one structureless isotope* there exist *several ones* having different space structures. They are just the new “previously unknown

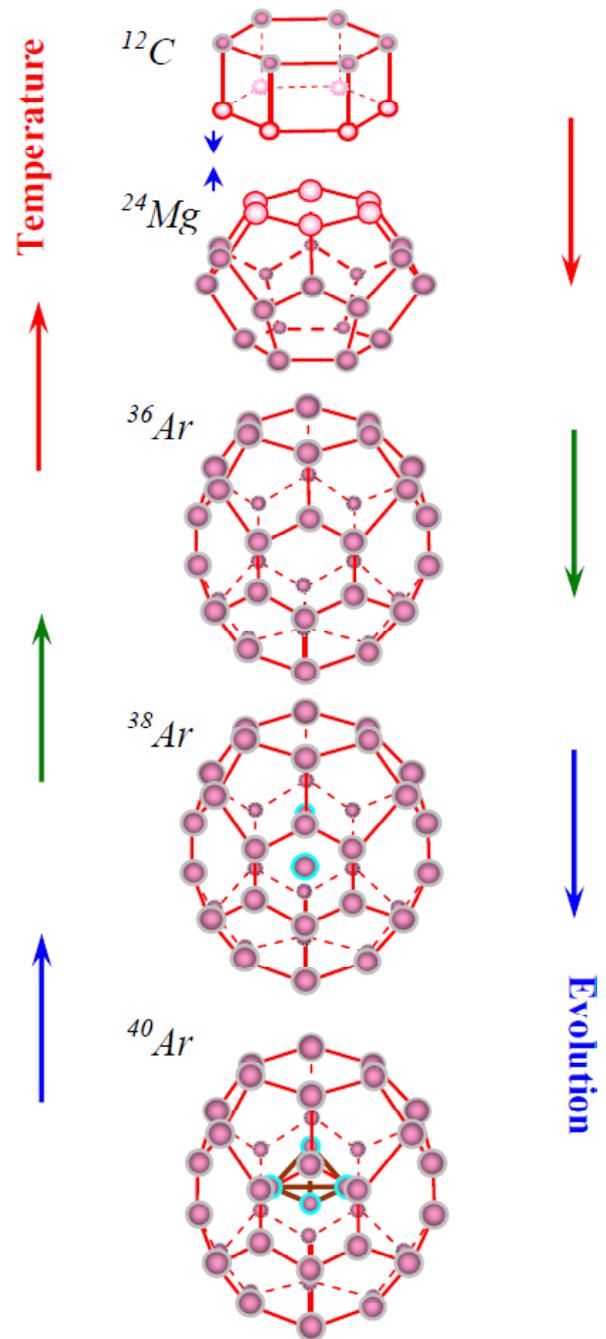


Fig. 62. Argon isotopes as a function of generation temperature. It is worth noting that carbon, magnesium, and argon refer to the most abundant elements [1].

stable isotopes”. However, the most important consequence of this discovery is that it allows give the *clear definition of nuclear isomerism* of the known isotopes, which is *in consent with the generally recognized definition* of space isomerism of molecules, crystals, etc. Before now it was accepted, that nuclear isomers are “*two states* of one and the same nucleus, having both different energies and half-life periods”, but *nothing* was said about their *geometric structure*.

R 2. The model predicts the quadratic dependence of the nuclear size on the number of nucleons. At the same time, it is known that this dependence is cubic.

A 2. It is not so. The quadratic dependence is valid only for basic nuclei with equal number of protons and neutrons. They have no a core and therefore *they have only a surface*; from this it follows the quadratic dependence. For the isotopes with one, two or more additional neutrons, which have a core and therefore a *volume structure*, the cubic dependence is realized.

It must be emphasized that in nuclear physics it is stated that the nuclei have no full-blown border and so the notion “*nuclear radius*” has conditional sense [38]. The empirical formula for the nuclear radius is $R = R_0 A^{1/3}$, where $R_0 = (1.3-1.7) \cdot 10^{-13}$ cm, $A = N + Z$ is the mass number. The formula is valid only for spheres, but the “nuclei having extra nucleons above the fulfilled nuclear shells are not spheres” [38].

R 3. It is not clear how the binding energy and other characteristics of the nuclear interaction can be predicted within the framework of the model.

A 3. Before calculating the binding energy and other characteristics, it is necessary *to have input data*, i.e. the structure. The purpose of the paper is to give the “input data”. Calculation is the following step.

R 4. The Author often uses the term “*tertium net*”, which is not used in modern scientific literature (a search for this term in Google scholar returns only the author’s previous articles, which do not explain the term).

A 5. It’s a pity, but the “modern scientific literature” became a little outdated after the appearance of my previous papers. The term “*tertium net*” was introduced in 2020 by me in Ref [5], where it is explained very carefully (see pp. 134-135).

R 5. The structure of fullerenes is determined by the electronic structure and valence of carbon atoms. The details of the interaction between the nucleons that provide similarity between the fullerenes and nuclei are not explained.

A 5. This is *very important comment*. (The previous comments were induced sometimes by *explanation shortage*). I will try to correct the slip in the following additional section.

12. ON THE PARALLELS BETWEEN FULLERENES AND NUCLEI AGAIN

The nuclear geometry has been designed by analogy with fullerenes. This statement leads to questions. The main question: Is the analogy is justified not only from the geometric point of view but also from physical one? Consider the problem in detail.

In Ref [39] I have analyzed the principles lying at the basis of different interatomic potentials which are used in molecular dynamics studies. In particular, there were considered *ab initio* quantum potentials, semi-empirical potentials, empirical potentials, including many-body ones, their origin and their connection with the elasticity theory. For fullerenes, the semi-empirical Morse pair potential is frequently used [30,15,40]. It can be written as follows

$$U(r) = U_0 \{ \exp[-2\alpha(r - r_0)] - 2 \exp[-\alpha(r - r_0)] \}$$

Here U_0 is the dissociation energy of a diatomic molecule, α is a constant, r is the distance between the molecule atoms. The function has the minimum $-U_0$ at the point $r=r_0$ and tends to zero when $r \rightarrow \infty$. Suggesting this potential in 1929 *Philip M. Morse* proceeded from the following condition. The potential being substituted into Schrödinger’s equation must describe exactly the allowed energy levels of a diatomic molecule. The only region where the Morse potential does not agree with numerical calculations is in the vicinity of $r=0$. Here the numerical solution tends to infinity whereas for all 21 molecules, studied by Morse, $U(0)$ falls in the range $10^2 - 10^4 U_0$. However these values are so large that they do not influence on the wave functions and energy levels.

In nuclear physics [41] “the sequence of energy levels of nucleons is defined by the explicit dependence of the potential energy from the nucleus center. This dependence can be written approximately as

$$V(r) = V_0 \{ 1 + \exp[(r - R) / a] \}^{-1}$$

Here $a = 0.5 \cdot 10^{-13}$ cm, $R = 1.33 \cdot A^{1/3} \cdot 10^{-13}$ cm (A is the mass number), $V_0 \sim 50-60$ MeV”. (I have conserved the words and designations by Davydov [41]). It is worth noting that both functions, Morse and Davydov, differ only by the analytical form but describe, in fact, one and the same dependence on the distance. Taking into consideration this fact, I assume that there is not only the geometric but also the physical similarity between the fullerenes and nuclei. The difference consists only in the scale and therefore in numerical values.

13. CONCLUSION

By analogy with fullerenes, the nuclear geometry has been designed. The nuclei can be classed into two groups: basic nuclei having equal number of protons and neutrons and isotopes having one, two or more additional neutrons. The latter ensure the mechanical stability of structure with respect to thermal vibrations and shear stresses.

If the number of additional neutrons exceeds two, the latter can form a core which symmetry is compatible with that of the basic nuclei. In some nuclei the core can perform internal rotation creating nucleonic conformers.

On the basis of the geometric approach, it is possible to design the structure of silicon, phosphorus, sulfur, chlorine and argon isomers together with their isotopes, within the framework of one and the same assumptions.

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