NUCLEAR GEOMETRY: FROM NITROGEN TO NEON

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Abstract. The nuclear geometry was developed by analogy with the fullerene geometry. On the basis of this geometric approach, it was possible to design the structure of nitrogen, oxygen, fluorine and neon isomers and their isotopes, which can be obtained by means of nuclear synthesis. The most stable 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 latter ensure their mechanical stability with respect to shear stresses, sending their electron to the external coat of mail created by the basic nuclei.

Keywords: fluorine, carbon, graph representation, isomer, isotope, neon, nitrogen, nuclear electron, nuclear geometry, nuclear reaction, nuclear synthesis, oxygen

1. Introduction

Earlier, by analogy with fullerenes, the nuclear geometry was designed. For hydrogen, deuterium, tritium and helium 3, we obtained a point, a linear and a plane structure respectively. Helium 4 has a tetrahedral symmetry. Three-fold symmetry prisms refer to lithium 6 and 7; four-fold ones are in correspondence with beryllium 8, 9, and 10; and five-fold symmetry prisms with boron 10 and 11. Carbon is an unusual element. It has four isomers of different symmetry: three-fold, six-fold and tetrahedral ones. The two stable and one half-stable isotopes of carbon inherit the structure of these isomers.

The geometric models of nuclei, developed by analogy with the fullerene geometry, allow explain why the nuclei have a definite number of stable isotopes and isotopes having a large half-decay period. Contrary to the usual "arithmetic approach", when the nuclear reactions are written down simply as, e.g. $^{12}\text{C} + ^4\text{He} \to ^{16}\text{O}$ or $^{16}\text{O} + ^4\text{He} \to ^{20}\text{Ne}$ [1], we have used the geometric approach, when the reactions are considered if the reacting nuclei are compatible from the geometric standpoint.

In this contribution I submit the geometric approach which explains not only the generation of nitrogen, oxygen, fluorine and neon but also that of their isotopes and isomers in the framework of one and the same unified modeling. It should be emphasized that we use, instead of this vague notion "nuclear isomerism" [1], the clear notion accepted for molecules, i.e. we accept that 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 space.

2. Isotopes of nitrogen and their isomers

There are two stable isotopes of nitrogen: $^1\text{N}^{14}$ (99.63 %) and $^1\text{N}^{15}$ (0.37%) [2]. This brings up the question: how to obtain them and their space isomers? It has stated above that the reacting nuclei should be compatible from the geometric standpoint. Using the previous experience, write down the nuclear reactions which are geometrically compatible:

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\[ ^4\text{He} + ^6\text{Li} \rightarrow ( ^4\text{He}^6\text{Li} ) + ^4\text{He} \rightarrow ^{14}\text{N}, \quad ^4\text{He} + ^7\text{Li} \rightarrow ( ^4\text{He}^7\text{Li} ) + ^4\text{He} \rightarrow ^{15}\text{N}, \]

They formally describe the formation of nitrogen isotopes. The reactions are written in line with the postulate by Svante August Arrhenius (1889) according to which a chemical reaction is a two-stage process. At first, there forms an intermediate compound and afterwards a usual chemical reaction is going on. Now we investigate this question more closely.

2.1. Joining a tetrahedron with a triangular prism. From the geometric point of view, the headline is in conformity with reaction \[ ^4\text{He} + ^6\text{Li} \rightarrow ( ^4\text{He}^6\text{Li} ) \rightarrow ^{10}\text{B} \] which is illustrated in Fig. 1. From the figure it follows that helium is almost completely dissolved in the boron structure formed. As for lithium, only three protons (from six) take part actually in the reaction. The reacting particles are specially marked in the figure; the protons are light pink balls, the new proton-proton bonds are lilac, the old bonds, which have to be destroyed, are shown using red dot lines. The graph representation of the reaction is shown in Fig. 2.

![Fig. 1. Joining of a tetrahedron (α-particle) to a triangular-prism (6Li): a) separate tetrahedron and triangular prism; proton bonds (red lines), reacting protons (light pink spheres), neutral atoms (dark pink spheres), b) intermediate compound: old bonds to be destroyed (red dot lines), new bonds (lilac lines), c) semiregular heptahedron (10B)](image1)

![Fig. 2. Graph representation of the nuclear reaction 4He + 6Li → 10B. Embedding the graph of α- particle into the graph of lithium: a) separate graphs corresponding to a triangular prism (above) and to a tetrahedron (below), b) embedding, c) graph of tri-(tetra-penta)3 polyhedron shown in Figure 1c. All notations are the same as before)](image2)

To get a comprehensive idea of the fusion, one need to construct a tertion net and its graph. Since graph designing is simpler, we begin with it. There is no need to construct the graph of the tertion net \textit{ab ovo}. One can take as a base the graph of the proton cell and put on its edges the tertions, and then to connect them (brown lines) (Fig. 3a). Removing the base, one receives the graph of the tertion net (Fig. 3b). Having this graph and the proton cell shown above (Fig. 1c), designing the tertion net becomes easier (Fig. 3c).
2.2. **Joining a tetrahedron with a semiregular heptahedron.** By analogy with the previous procedure one can design reaction $^{4}\text{He} + ^{10}\text{B} \rightarrow (^{4}\text{He}^{10}\text{B}) \rightarrow ^{14}\text{N}$ which is illustrated in Fig. 4. One can see that helium is again completely dissolved in the nitrogen structure formed. As for boron, only three protons (from ten) take part in the reaction. The reacting particles are specially marked in the figure as before: the protons are light pink balls, the new proton-proton bonds are lilac, the old bonds, which have to be destroyed, are shown using red dot lines. The graph representation of the nuclear reaction is shown in Fig. 5. The tertion net and its graph are presented in Fig. 6.

![Fig. 4. Joining of a tetrahedron to a heptahedron: a) separate tetrahedron ($\alpha$-particle) and heptahedron ($^{10}\text{B}$), b) intermediate compound, c) regular nonahedron ($^{14}\text{N}$)](image)

![Fig. 5. Graph representation of the nuclear reaction $^{4}\text{He} + ^{10}\text{B} \rightarrow ^{14}\text{N}$. Embedding the graph of boron into the graph of $\alpha$-particle: a) inversion graph of $\alpha$-particle above and boron graph below, b) embedding, c) graph of tetra$_{6}$-hexa$_{3}$ nonahedron shown in Fig. 4c. All notations are the same as before)](image)
2.3. **Embedding isotopy.** The reactions considered above $^4\text{He} + ^6\text{Li} \rightarrow (^4\text{He}^6\text{Li}) \rightarrow ^{10}\text{B}$ and $^4\text{He} + ^{10}\text{B} \rightarrow (^4\text{He}^{10}\text{B}) \rightarrow ^{14}\text{N}$ show the mechanism of obtaining the nucleus of nitrogen 14. If to replace in these reactions lithium 6 by lithium 7, i.e. to consider reactions $^4\text{He} + ^7\text{Li} \rightarrow (^4\text{He}^7\text{Li}) \rightarrow ^{11}\text{B}$, $^4\text{He} + ^{11}\text{B} \rightarrow (^4\text{He}^{11}\text{B}) \rightarrow ^{15}\text{N}$, one can construct the nucleus of nitrogen 15. The structure of the reaction components is presented in Fig. 7. From the figure it follows that the proton cells become the body-centered ones. The most drastic changes are connected with the terton nets and their graphs.
2.4. Another isomer. Modeling the growth of fullerenes [3], we obtained two isomers of C\(_{14}\), one having the shape similar to that of presented in Fig. 4c; the other is shown in Fig. 8 and corresponds to reaction C\(_4\)C\(_{10}\) → (C\(_4\)C\(_{10}\)) → C\(_{14}\). It should be emphasized that the second fullerene isomer was designed by the mechanisms which are typical for the fullerenes, but not for the nuclei. The question arises how to obtain the same shape for the nucleus of nitrogen 14 through the use of possible nuclear reactions only.

Fig. 8. C\(_{14}\) as joining cluster C\(_4\) with cupola C\(_{10}\); Dark–red and light-blue balls are reacting and neutral atoms, respectively; solid and dot red lines are new covalent bonds

One has to approach the problem in stages. 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 cluster C\(_4\) can be associated with α-particle and cupola C\(_{10}\) with an intermediate nucleus \(^{10}\text{B}\). Therefore the general problem is reduced to the problem how to obtain the intermediate nucleus \(^{10}\text{B}\) having the shape similar to cupola C\(_{10}\).

One is inclined to think that there is the following chain of nuclear reactions (Fig. 9). At first, two alpha-particles combine forming a dimer (a). Then the dimer combines with another alpha-particle forming a linear trimer having one proton, which is slightly connected with the trimer through the use of only one bond (b). Similar to the interactions of electronic and atomic degrees of freedom [4], the interaction of tertions (they are not shown in the figure) and protons leads to internal rotation [5] of the slightly connected proton (c). This structure can fold up in three dimensions (d). During the process some inter-proton bonds are destroyed and there appear two split protons (e). Relaxation of the structure obtained creates the boron nucleus having three-fold symmetry (f). The reactions can be written as

\[ ^4\text{He} + ^4\text{He} \rightarrow (^4\text{He}^4\text{He}) + ^4\text{He} \rightarrow (^4\text{He}^4\text{He}^4\text{He}) \rightarrow ^{10}\text{B} + d. \]

Fig. 9. Generation of boron-10 isomer: a) dimer formation, b) trimer formation with one slightly connected proton, c) internal rotation of the proton, d) folding and appearance of two new slightly connected protons, e) folding and splitting two new protons, f) heptahedron structure obtained after relaxation
2.5. **Joining a tetrahedron with another heptahedron.** Now it is possible to design another reaction \( ^4\text{He} + ^{10}\text{B} \rightarrow (^4\text{He}^{10}\text{B}) \rightarrow ^{14}\text{N} \) which is illustrated in Fig. 10. One can see that helium is again completely dissolved in the nitrogen structure formed. As for boron, now six protons (from ten) take part in the reaction. The reacting particles are specially marked in the figure as before: the reacting protons are light pink balls, the new proton-proton bonds are lilac, the old bonds, which have to be destroyed, are shown using red dot lines. The graph representation of the nuclear reaction is given in Fig. 11. The tertion net and its graph are presented in Fig. 12.

![Fig. 10. Joining of a tetrahedron to a heptahedron: a) separate tetrahedron (α-particle) and heptahedron (\(^{10}\text{B}\)), b) intermediate compound, c) base-truncated triangular bipyramid (\(^{14}\text{N}\))](image)

![Fig. 11. Graph representation of the nuclear reaction \(^4\text{He} + ^{10}\text{B} \rightarrow ^{14}\text{N}\). Embedding the graph of boron into the graph of α-particle: a) inversion graph of α-particle above and boron graph below, b) embedding, c) graph of tetra₃-penta₆ base-truncated triangular bipyramid shown in Fig. 10c. All notations are the same as before](image)
2.6. **Embedding isotopy.** The reaction considered above $^4\text{He} + ^{10}\text{B} \rightarrow (^4\text{He} {^{10}}\text{B}) \rightarrow ^{14}\text{N}$ shows the mechanism of obtaining the nucleus of nitrogen 14 If to replace in that reaction boron 10 by boron 11, i.e. to consider reaction $^4\text{He} + ^{11}\text{B} \rightarrow (^4\text{He} {^{11}}\text{B}) \rightarrow ^{15}\text{N}$, one can construct the nucleus of another isotope of nitrogen 15 (Fig. 13).

3. **Isotopes of oxygen and their isomers**

There are three stable isotopes of oxygen: $^{16}\text{O}$ (99.76 %), $^{17}\text{O}$ (0.04 %) and $^{18}\text{O}$ (0.20 %) [2]. As stated above, the reacting nuclei should be compatible from the geometric standpoint. Using our previous experience, write down the nuclear reactions which are geometrically compatible:

- $^{12}\text{C} + ^4\text{He} \rightarrow ^{16}\text{O}$,
- $^{13}\text{C} + ^4\text{He} \rightarrow ^{17}\text{O}$,
- $^8\text{Be} + ^8\text{Be} \rightarrow ^{16}\text{O}$,
- $^8\text{Be} + ^9\text{Be} \rightarrow ^{17}\text{O}$,
- $^9\text{Be} + ^9\text{Be} \rightarrow ^{18}\text{O}$

They formally describe the formation of oxygen isomers and isotopes. Now we investigate the reactions more closely.

3.1. **Joining of a tetrahedron to a heptahedron.** Reaction $^4\text{He} + ^{12}\text{C} \rightarrow (^4\text{He} {^{12}}\text{C}) \rightarrow ^{12}\text{O}$ is illustrated in Fig. 14. From the figure it follows that helium is almost completely dissolved in the carbon structure formed. As for carbon, only three protons (from six) take part actually in the reaction. The graph representation of the nuclear reaction is shown in Fig. 15. The tertion net and its graph are presented in Fig. 16.
Fig. 14. Joining of a tetrahedron to a heptahedron: a) separate tetrahedron ($\alpha$-particle) and truncated tetrahedron ($^{12}\text{C}$), b) intermediate compound, c) another truncated tetrahedron ($^{16}\text{O}$).

Fig. 15. Graph representation of the nuclear reaction $^4\text{He} + ^{12}\text{C} \rightarrow ^{16}\text{O}$: a) inversion graph of $\alpha$-particle above and carbon graph below, b) embedding, c and c') graphs of tria-hexa-$\alpha$-truncated tetrahedron shown in Fig. 14c. All notations are the same as before.

Fig. 16. Electronic structure of oxygen isomer $^{16}\text{O}$: a) graph of terton net constructed on the base of the proton-cell graph (dot red lines); b) graph of terton net; c) terton net.

3.2. Embedding isotopy. The reaction considered above shows the mechanism of obtaining the nucleus of oxygen 16. If to replace in that reaction carbon 12 by carbon 13, i.e. to consider reaction $^4\text{He} + ^{13}\text{C} \rightarrow (^4\text{He}^{13}\text{C}) \rightarrow ^{17}\text{O}$, one may obtain an isotope of oxygen 17 (Fig. 17).

Fig. 17. Structure of isotope $^{17}\text{O}$: a) Proton cell; b) Graph of the terton net; c) Terton net.
3.3. Fusion of two cubes. Now we can design reaction $^8\text{Be} + ^8\text{Be} \rightarrow ^{16}\text{O}$ which is illustrated in Figs. 18, 19 and 20.

![Fig. 18. Joining of two cubes: a) separate cubes (beryllium) b) intermediate compound, c) square barrel-shape decahedron ($^{16}\text{O}$)](image)

3.4. Embedding isotopy. The reaction considered above shows the mechanism of obtaining the nucleus of another isomer of oxygen 16. Replace again in that reaction one
beryllium 8 by beryllium 9; then we obtain another isotope of oxygen 17 (Fig. 21). Replacing both beryllium 8 by beryllium 9, we have an isotope of oxygen 18 (Fig. 22).

Fig. 21. Structure of isotope ¹⁷O: a) Proton cell; b) Graph of the tertion net; c) Tertion net

Fig. 22. Structure of isotope ¹⁸O: a) proton cell; b) graph of the tertion net; c) tertion net

4. Isotopes and isomers of fluorine
There is only one stable isotope of fluorine, ¹⁹F (100 %), and an unstable isotope having a comparatively large half-decay period being equal to 109.8 min., ¹⁸F [2]. As we stated above, the reacting nuclei should be compatible from the geometric standpoint. Using the previous experience, write down the geometrically compatible nuclear reaction \( ^{12}\text{C} + ^{6}\text{Li} \rightarrow ^{18}\text{F} \). Consider the reaction more closely.

4.1. Joining of a triangular prism to a triangular barrel. The reaction is illustrated in Fig. 23. From the figure it follows that only three protons of lithium (from six) and three protons of carbon (from twelve) take part actually in the reaction. The graph representation of the nuclear reaction is shown in Fig. 24. The tertion net and its graph are presented in Fig. 16.
4.2. **Embedding isotopy.** If to replace in that reaction lithium 6 by lithium 7 or carbon 12 by carbon 13, i.e. to consider reactions $^7\text{Li} + ^{12}\text{C} \rightarrow ^{19}\text{F}$ or $^6\text{Li} + ^{13}\text{C} \rightarrow ^{19}\text{F}$, one has only one and the same isotope of fluorine 19 (Fig. 26). It should be emphasized that, on the basis of previous results, the first reaction is more probable.
4.3. Joining of a triangular prism to a truncated tetrahedron. The reaction illustrates an example of nuclear special isomerism (Fig. 27). Here the number of reacting protons is increased from six to nine. The figure obtained has the shape of a truncated triangular bipyramid. The graph representation of the nuclear reaction is shown in Fig. 28. The terton net and its graph are presented in Fig. 29.

Fig. 26. Structure of isotope $^{19}$F: a) Proton cell; b) Graph of the terton net; c) Terton net

Fig. 27. Joining of a triangular prism to a truncated tetrahedron: a) separate prism (lithium) and separate truncated tetrahedron (carbon) b) intermediate compound, c) truncated triangular bipyramid ($^{18}$F)

Fig. 28. Embedding the graph of carbon into the graph of lithium: a) separate graphs, b) embedding, c) graph of truncated triangular bipyramid (fluorine)
4.4. Embedding isotopy. If to replace in reaction $^{12}\text{C} + ^{4}\text{Li} \rightarrow ^{18}\text{F}$ lithium 6 by lithium 7 or carbon 12 by carbon 13 one obtains one and the same isotope of fluorine 19 (Fig. 30). It should be emphasized that, on the basis of previous results, the first reaction is more probable.

5. Isotopes of neon and their isomers

There are three stable isotopes of neon: $^{10}\text{Ne}^{20}$ (90.51 %), $^{10}\text{Ne}^{21}$ (0.27 %) and $^{10}\text{Ne}^{22}$ (9.22 %) [2]. The crucial question is how to obtain them and their space isomers in the framework of one and the same assumptions. Consider the nuclear reactions which are geometrically compatible.

5.1. Fusion of two pentagonal pyramids. The reaction is written as $^{10}\text{B} + ^{10}\text{Be} \rightarrow ^{20}\text{Ne}$. It is illustrated in Figs. 31, 32 and 33.
5.2. Two-stage reactions. The reactions can be written as $^{12}C + ^4He \rightarrow ^{16}O, \quad ^{16}O + ^4He \rightarrow ^{20}Ne$.

As it was shown, carbon 12 has several space isomers. Therefore there appear several space isomers of neon.

5.2.1. Joining two tetrahedrons with a hexagonal prism. Those two-stage reactions are illustrated in Figs. 34-35. The graph representation of the nuclear reactions is shown in Fig. 36. The tertion net and its graph are presented in Fig. 37.

Fig. 32. Fusion of two prisms as connection of their graphs: a) separate graphs (boron) $^{12}C$; b) intermediate compound, $c$) dodecahedron ($^{20}Ne$).

Fig. 33. Electronic structure of neon isomer $^{20}Ne$: a) graph of tertion net constructed on the base of the proton-cell graph (dot red lines); b) graph of tertion net; c) tertion net.

Fig. 34. Joining of a tetrahedron ($\alpha$-particle) to a hexagonal prism ($^{12}C$): a) separate tetrahedron and hexagonal prism; proton bonds (red lines), reacting protons (light pink spheres), neutral atoms (dark pink spheres), b) intermediate compound: old bonds to be destroyed (lilac dotted lines), new bonds (lilac lines), c) cupola of three-fold symmetry ($^{16}O$).
Fig. 35. Joining of a tetrahedron to a cupola: a) separate tetrahedron (α-particle) and cupola (\(16O\)), b) intermediate compound, c) tetra3-penta6-hexa3 dodecahedron (\(20Ne\))

Fig. 36. Embedding the graph of α-particle into the graph of carbon (a, b, c); embedding the graph of cupola into the graph of α-particle (d, e, f)

Fig. 37. Electronic structure of neon isomer \(20Ne\): a) graph of tertion net constructed on the base of the proton-cell graph (dot red lines); b) graph of tertion net; c) tertion net

5.2.2. Joining two tetrahedrons with a triangular barrel. Those two- stage reactions are presented in Figures 37-38. The graph representation of the nuclear reactions is shown in Fig. 39. The tertion net and its graph are illustrated in Fig. 40.
Fig. 37. Joining of a tetrahedron (α-particle) to a triangular barrel ($^{12}$C): a) separate tetrahedron and triangular barrel, b) intermediate compound, c) tri-(tetra-penta-hexa)$_3$ decahedron ($^{16}$O)

Fig. 38. Joining of a tetrahedron to a decahedron: a) separate tetrahedron (α-particle) and decahedron ($^{16}$O), b) intermediate compound, c) (tetra-hexa)$_6$ dodecahedron ($^{20}$Ne)

Fig. 39. Embedding the graph of α-particle into the graph of carbon (a, b, c); embedding the graph of oxygen into the graph of α-particle (d, e, f)
5.3. Embedding isotopy. If to replace in the previous reactions carbon 12 (hexagonal prism) by carbon 13 (body centered hexagonal prism), one obtains the isotope of neon 21 shown in Fig. 41. Replacing carbon 12 (triangular barrel) by carbon 14 (dimer embedded triangular barrel) leads to appearance of the isotope neon 22 (Fig. 42). It should be emphasized that here only the most probable reactions of the isotopes are considered.

6. Discussion
As stated above, there are two stable isotopes of nitrogen, \( \gamma N^{14} \) (99.63%) and \( \gamma N^{15} \) (0.37%), three stable isotopes of oxygen, \( \delta O^{16} \) (99.76%), \( \delta O^{17} \) (0.04%) and \( \delta O^{18} \) (0.20%), only one
stable isotope of fluorine, $^{19}\text{F}$ (100 %), and three stable isotopes of neon, $^{20}\text{Ne}$ (90.51 %), $^{21}\text{Ne}$ (0.27 %) and $^{22}\text{Ne}$ (9.22 %) [2]. Consider the most stable isotopes: nitrogen $^{14}\text{N}$ (99.63 %), oxygen $^{16}\text{O}$ (99.76 %), fluorine $^{19}\text{F}$ (100 %), neon: $^{20}\text{Ne}$ (90.51 %) and neon $^{22}\text{Ne}$ (9.22 %). They can be classed into two groups: basic nuclei having equal number of protons and neutrons (Fig. 43) and isotopes having one or two more neutrons (Fig. 44).

It should be noted that the nuclei of the first group have several space isomers. By analogy with fullerenes, only such isomers were chosen which have the most probability of generation. What all the nuclei have in common is that their proton structure is stable with respect to mechanical shear stresses. At the same time basic nuclei of the second group are unstable with respect both shear stresses and thermal vibrations. However they acquire stability incorporating one or two neutrons. It is believed that the stability is ensured also by the coat of mail (tertion net) which becomes denser after the nuclei embed the extra neutrons.

Fig. 43. Protonic and electronic structure of basic nuclei: a) nitrogen, b) oxygen c) neon

7. Summary
By analogy with fullerenes, the nuclear geometry has been designed. For nitrogen, oxygen, fluorine and neon the protonic and electronic structures both for basic isomers and their
isotopes were obtained. The most stable 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 latter ensure their mechanical stability with respect to shear stresses, sending their electron to the coat of mail created by the basic nuclei.

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