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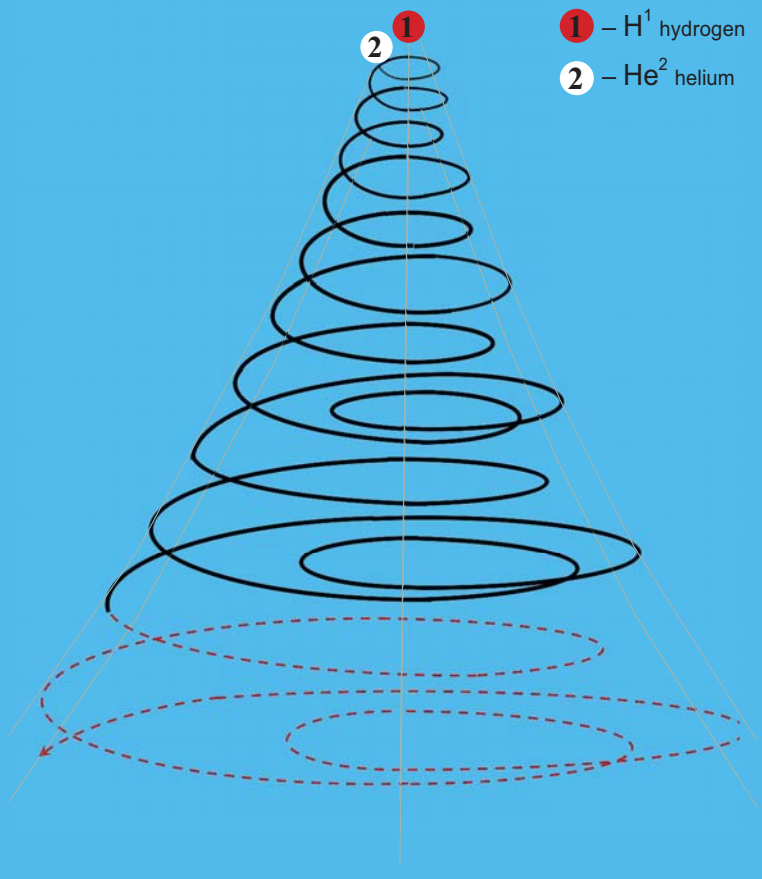
NEW MODEL TO ARRANGE CHEMICAL ELEMENTS



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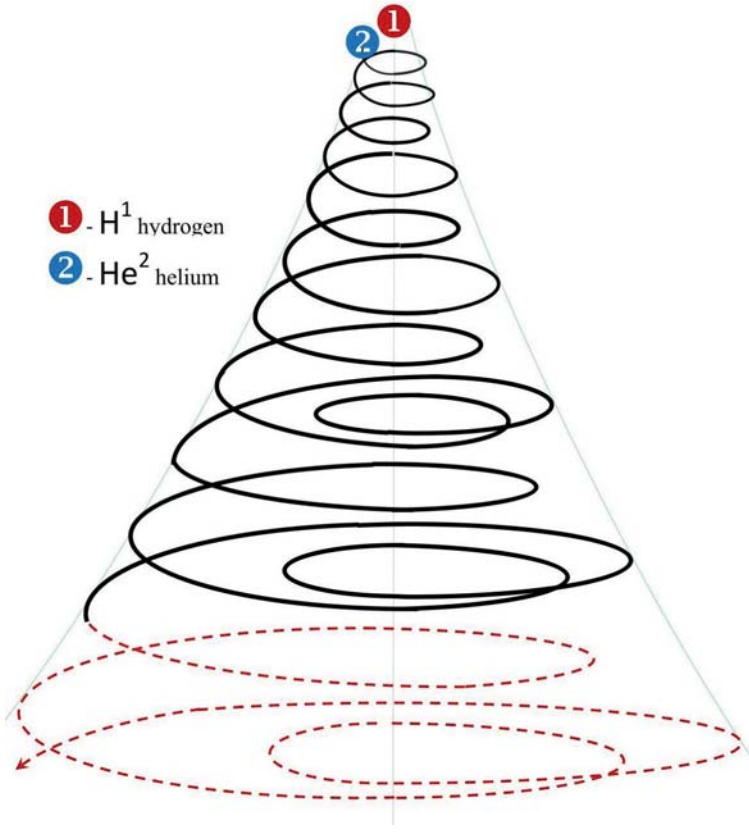

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The Periodic Law and its tabular representation by D. I. Mendeleyev and by IUPAC are one of the outstanding discoveries of humankind. At the end of 2019, the world scientific community under the UN auspices celebrated the 150th anniversary of this discovery. The authors of the brochure took into account Nobel Prize Winner N.N. Semenov's remarks to bring the tables by D.I. Mendeleev and IUPAC up to date and proposed a new model to arrange chemical elements.

It has been proved in cosmology that chemical elements and their origin have to do with the development and Big Bang of the Universe as well as the processes that took place and keep going on in stellar systems with extreme conditions of ultra-high temperatures and pressure within these giants. The authors used the physical model of the Big Bang and expanding Universe as a basis, and set the task to describe the elements of the periodic system in the form of a three-dimensional expanding matrix of chemical elements. At the top of the matrix is hydrogen, being the basis for creating subsequent elements. The new model made it possible to present the chemical elements more clearly and consolidate new generalizations. The brochure presents the number of elements wider than the already known 118 elements and considers possible electronic structures for 100 new elements.

The book may be useful for studying the current state of the Periodic Table of Chemical Elements. It may also be of interest to scientists, chemical workers, teachers and students of chemical and associated specialties.

ISBN: 978-5-907292-46-8

"Imagination is more important than knowledge.
For knowledge is limited, whereas imagination embraces the entire world"
Albert Einstein

PREFACE

The Periodic Law and its tabular display of the chemical elements is an outstanding discovery of humankind. At the end of 2019, the world scientific community under the auspices of the UN celebrated the 150th anniversary of this discovery. In terms of advancing knowledge on periodicity, there has been published a huge number of works, which emphasizes the importance of the discovery. Currently, the Table contains 118 elements, but not all of them are found in nature, since some have been obtained artificially. In addition, according to Nobel Prize winner **N. N. Semyonov**, the Table is, far from being perfect.

Considering the concept of the Universe, the authors took the **physical model of the Big Bang and expanding Universe** as a basis and set the task to describe the elements of the Periodic Table in the form of a three-dimensional expanding matrix of chemical elements. Hydrogen (**H**) and helium (**He**) are at the top of the matrix being the basis for the creation of subsequent elements and occupying zero and first periods. The other elements serving as facets of this structure are arranged along the expanding spiral.

Another important consideration is the idea of the **origin** and evolution of the Universe as well as the development of **all living** and **non-living** in it in a **spiral order**. It is obvious for the living nature; as to non-living nature, it was assumed that chemical elements might serve as the "building blocks" for this spiral. These elements will interact with each other, and, thus, form molecules. The entire material inorganic world is being generated from molecules giving rise to further natural processes of creating living nature: plants, animals and people. Thus, the entire development of the mineral and living world proceeds in spirals.

The presented generalizations show that the concept of **cyclicity and block structure of elements** is preferable for **arranging the system of chemical elements**. It becomes obvious in the process of analysing and generalizing nuclear masses in block periods, where neutrons and protons ratios are averagely equalized within the block

Such physical confirmation of cyclicity makes up the concept of block structure and harmonizes the arrangement of elements in the **Three-Dimensional Matrix of Chemical Elements (TDMCE)**. It is important not only for chemistry, but might be useful for other sciences, including cosmology.

The following concepts and definitions have been proposed in the book:

Physical model is a universal term widely used in science and technology when developing a system to assess complex properties or processes in mathematical and other types of describing (modelling) a phenomenon. For instance, when describing the structure for a set of chemical elements, the authors took the concept of an expanding conical matrix during the origin and evolution of the Universe after the Big Bang and its further expansion.

Periodicity is a sequential change of one or more indicators related to properties of chemical elements. In existing tables, all 118 elements consistently change in nuclear charge, mass and other characteristics.

Cyclicity is completion of changing key properties or recurring of these properties at a new level. In the book, along with the word "cyclicity", the concept of "block structure" for structurally identical paired periods is used, where similar properties begin to appear at a new level.

Grouping is a set (group) of chemical elements with similar properties, located, as a rule in the same valence group. An example of grouping is lanthanides and actinides forming one of the orbitals s^2, p^6, d^{10}, f^{14}, etc.

1. D. I. Mendeleev and IUPAC systems of chemical elements and their analysis

Studies on properties of chemical elements as well as their interaction when obtaining new substances and materials lie at the very core of chemistry. In materials science, the main task of which is to obtain a substance with high performance characteristics, one inevitably has to turn to the scientific basis of natural science i.e. the Periodic Law of Chemical Elements. Various literary sources emphasize the contribution to the development of the periodic system of chemical elements by *D. I. Mendeleev, J. L. T Mayer, A. Shankurtua, J. Newlands, W. Odling*. Without limiting the preceding, it is noted that after D. I. Mendeleev the most important contribution to the study of the Periodic Law was made by H. Moseley, who established the relationship between frequencies in X-ray spectra and atomic numbers of elements and predicted the existence of previously unknown elements with atomic numbers 43, 61 and 72 [12]. As D. Mendeleev foresaw, this fundamental scientific discovery affects all areas of modern theoretical natural science: "*Keeping this track, we will inevitably come to a completely new insight into many processes and phenomena, and we might even change our ideas about the Universe*" [1].

As science develops, the law is being improved and modified, new elements are being discovered, new substances and areas of their application are being

created. In other words, the periodic table of chemical elements promoted scientific progress in all areas where chemical elements are the basis of natural or artificial processes.

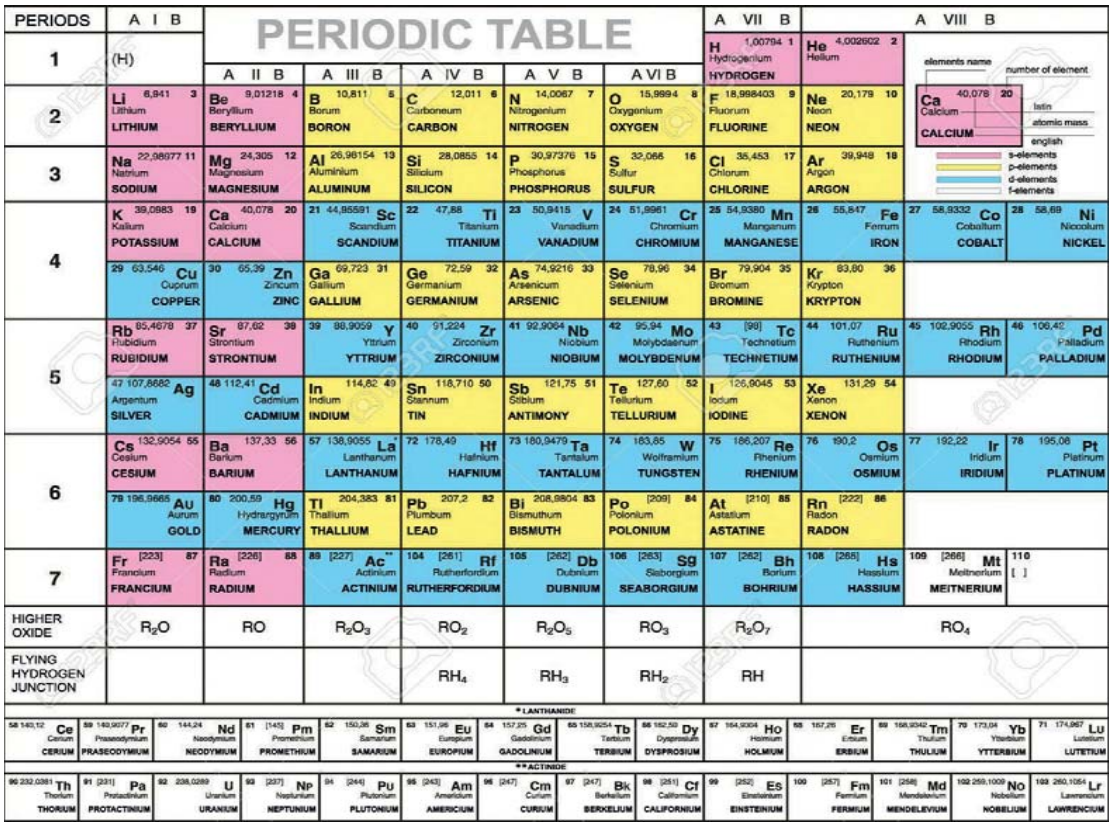
At the beginning of the twentieth century, the science of matter made a big leap in connection with the development of the nuclear theory of the atom structure, the experimental determination of the charges of atomic nuclei and electron shells (*Moseley, Van der Bruck, Thompson, Rutherford, Bohr and others*, 1907–1914) [10]. Since it became clear that it is the nuclear charge that determines the individuality of chemical elements, and the atomic weight (atomic mass) of an element is a quantity that depends on the nuclear charge, the formulation of the Periodic Law has also changed. The modern formulation of the Periodic Law is the following: ***the properties of simple substances as well as the forms and properties of element compounds are periodically dependent on the nuclear charge of elements' atoms, expressed in the periodic recurrence in the structure of the outer valence electron shell***. [2, 5]. Table 1 shows a short-period table of chemical elements by D. I. Mendeleev.

Currently, there are plenty of ways to present the Periodic Law. Oftentimes, the original authors' ways are not reasoned enough and do not reflect the patterns of changes in the properties of elements and their compounds. Naturally, the first table was not perfect either. The very version of the Periodic Table, according to which many of us studied, turned out to be very confusing, is due to the presence of main and side groups and the unrestricted designation of these subgroups with letters **"A"** and **"B"** (Table 1). In other words, the subgroups in which of us ***s***- and ***p***-elements are located are called principal ones, and the subgroups with ***d***-elements are called secondary subgroups. The electronic structure and chemical properties of the elements in the main and secondary subgroups may not have anything in common. The coincidences are rather random. For the elements of secondary subgroups, the valence electrons are not only external, but also second to the last (second outside) levels, which is the main difference in the properties of the elements in the main and secondary subgroups. Elements of side subgroups (***d***-elements) are called transition elements or transition metals (all ***d***-elements are metals). The term "transition metals" was coined due to the fact that all ***d***-elements in periods serve as a kind of "transition bridge" from metallic ***s***-elements to ***p***-elements, among which there are already many non-metals. Sometimes the term "transition metals" is applied to ***f***-elements.

All known elements occupy their definite places in the Periodic Table in accordance with the nuclear charge of their atoms and the structure of the electron shells. However, the issue of hydrogen's position (**H**), which is placed

*Table 1**

Short-period table of chemical elements by D.I. Mendeleev



* Internet resource used https://en.wikipedia.org/wiki/Periodic_table

in the **1st** or **7th** groups remains unsolved. **Hydrogen** in chemical reactions exhibits two opposite oxidation states: ± 1. All modern knowledge on hydrogen chemistry objectively indicates that it is the only element that **cannot be assuredly assigned to any specific group in the system** and **should be presented as an independent element over periods**.

In addition, it is necessary to make a sensible decision about the position of helium (**He**) in the Periodic Table. Being ***s***-element and one of the first elements of the Periodic Table, it should be placed above lithium (**Li**) and beryllium (**Be**).

A special feature is that group **III** contains a set of 14 chemically very similar ***f***-elements, ***lanthanides***, from **Ce** to **Lu** and 14 elements having similar properties with actinium **Ac** (thorium **Th** – **Lr** lowrencium) i.e. ***actinides.*** Lanthanides and actinides are plotted in a separate line at the bottom of the Table. This technique is somewhat inconvenient, since 28 elements appear to be outside the table and, in fact, two tables are used.

The **VIII** group of elements occupies a special position, and its structure is extremely contradictory. It includes subgroup **VIII*b*** with the triad of the "iron group" (**Fe**, **Co**, **Ni)** and the "group of platinum metals" (**Ru**, **Rh**, **Pd**, **Os**, **Ir**, **Pt**), which should include elements 108-110 (that had never been platinum ones) in the form of three vertical rows. This group also includes, contrary to common sense, subgroup **VIII*a***, which includes the noble gases **He, Ne** and others. We can confidently assert that historically these triad-groups were "squeezed" into the last **VIII** group out of necessity, contrary to logic, since this group according to the electronic structure of atoms is naturally meant only for the indicated gaseous elements [7].

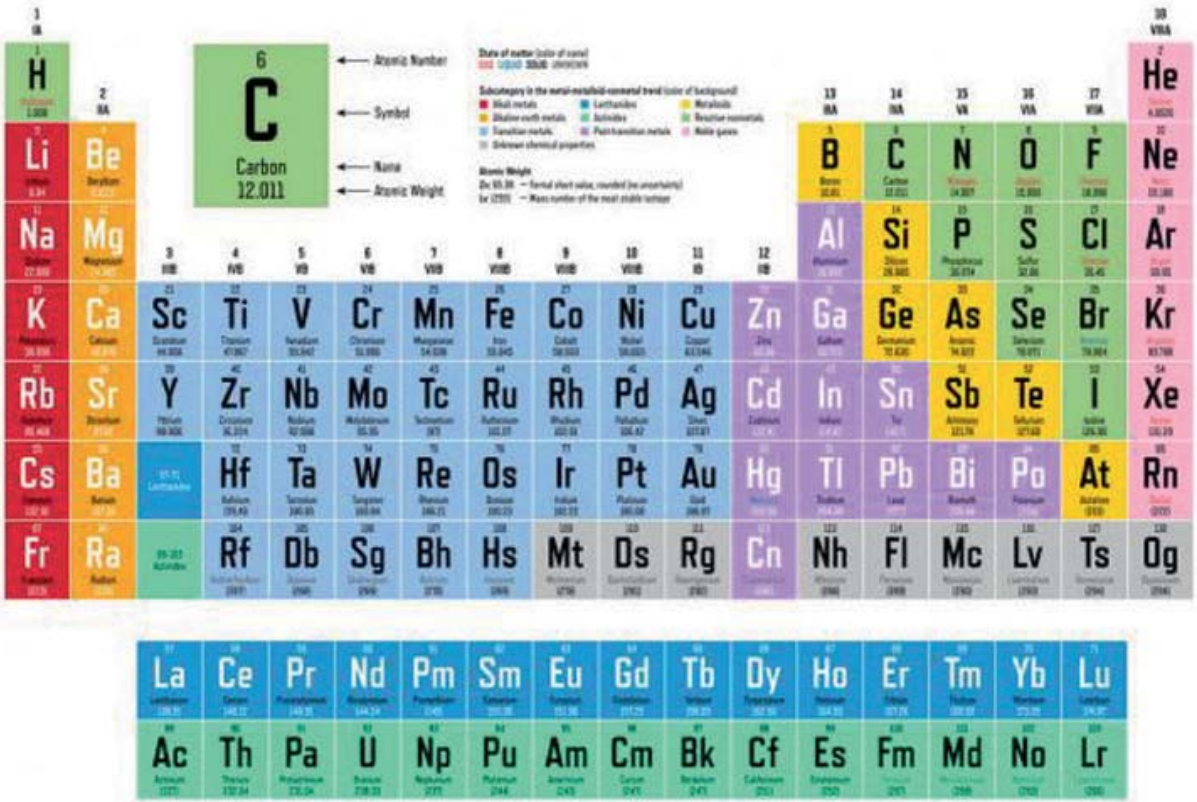
The short form of the Table (7 periods, 8 groups, lanthanides and actinides are separately taken out) needs to be refined in accordance with the modern achievements in chemistry and physics, although it is convenient for teaching chemistry due to its seemingly rational compactness. In 1989, it was officially replaced by the International Union of Pure and Applied Chemistry, **IUPAC**. The recommended form of the periodic system includes 18 groups formed from the elements of ***s***-, ***d***- and ***p***- orbitals (Table 2).

The order of forming long periods is as follows. Here the elements are arranged in 18 groups and 7 periods (see Table 2). The seventh period ends with element 118, and the next eighth period must begin with element 119. The groups are assigned numbers from 1 to 18 from left to right i.e. from alkali metals to noble gases. Elements of the **1st** and **2nd** groups constitute ***s***-elements; groups **3** to **12** refer to ***d***-elements, and from **13** to **18** to ***p***-elements, which reflects the order of completing the energy levels and sublevels in the atom.

The long-period form of the Periodic Table, recommended for use at the present time, eliminated some difficulties. This form of the Periodic Table

*Table 2**

Long-period Periodic Table of Chemical Elements IUPAC



* Internet resource used https://en.wikipedia.org/wiki/Periodic_table

appeared only after the electronic structure of atoms was clarified and the differences between ***s***-, ***p***- and ***d***-elements became clear. The idea is explicitly presented in Table 3.

There are no subgroups here, but only 18 groups (according to the **IUPAC** rules, they are numbered not in Roman, but in Arabic numerals). Ten ***d***-elements are arranged in 10 independent groups. Together with two groups for ***s***-elements and six groups of ***p***-elements, the total number of groups is 18. In the long form, each period occupies only one line, and there are seven of them in total.

In the long form of the Table, all sublevels go strictly one after the other from top to bottom: under 1***s*** there are 2***s***, 3***s***, and so on; under 2***p*** there go 3***p***, 4***p***, etc.; under 3***d*** there go 4***d***, 5***d*** and so on. Following this, the sequence of completing all electronic levels of any element becomes clear. It is only necessary to remember that after ***6s***-sublevel 4***f***-sublevel is completed, and after 7***s***-sublevel 5***f***-sublevel is completed; ***f***-elements are arranged in separate rows at the bottom of the Table so as not to make it "extra-long". The long version of the Periodic Table did not solve the problem of arranging ***f***-elements in the Table, but removed the inconvenience when using main groups and subgroups [11].

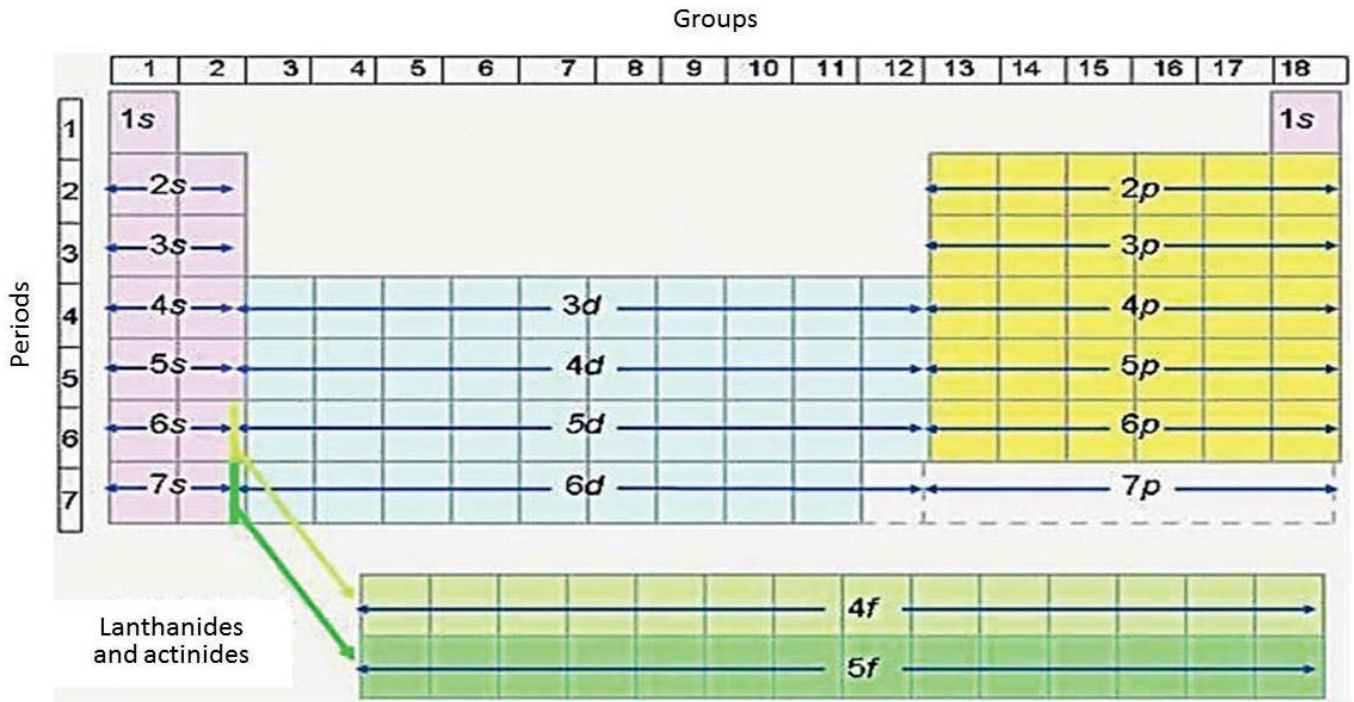
Currently, various authors have proposed many forms, which are mainly aimed at didactic presentation of the material, since not all correlations between chemical elements are visible from the standard Periodic System [8, 9, 11]. However, all these proposals do not allow us to get an answer to the question of where the boundaries of the periodic system are and what the reasons for the rhythmically repetitive disturbance in the arrangement of elements in the Table are, when a large number of elements are arranged into separate groups, for example, actinides and lanthanides [13].

Numerous unsuccessful attempts to improve the Periodic Table of chemical elements by D.I. Mendeleev demonstrate the extreme complexity of the task set in 1951 by the Nobel Prize winner Academician *N.N. Semyonov* to eliminate at least five shortcomings that gave rise to its unsystematic and asymmetric nature:

1. Rows (the so-called half-periods in the newly designated periods) have different lengths, and in this case there appear 37 unfilled places i.e. free cells.
2. There are only two elements in the first row; moreover, hydrogen does not occupy a constant place, and these two elements of the same row make up the whole period (there can be no half-periods here).
3. Lanthanides and actinides were taken out of the table.
4. A group of inert gases was added later by the scientists who discovered them on behalf of Ramsay.
5. The long-period Table introduced later does not save the situation as a whole and remains too asymmetric.

*Table 3**

Arrangement of *s*-, *p*-, *d*- and *f*-elements in the long-period Periodic Table



* Internet resource used https://en.wikipedia.org/wiki/Periodic_table

Despite this, the system had been the foundation for scientific research, engineering solutions and chemical education for over 80 years. According to N. N. Semyonov, *"... after eliminating the shortcomings, new properties and interrelationships of elements will be discovered, which will allow most scientific research to be carried out at a new, higher level and to solve the engineering problems faced by not only physicists, but all scientists, engineers and practitioners*"[3].

2. General prerequisites to develop a new model of arranging chemical elements

The rapid development of the natural sciences at the beginning of the 19th century was marked by the active desire of scientists to understand the fundamental laws and regularities of the material basis of the world i.e. matter. The medieval empiricism of alchemical knowledge is being replaced by the era of the cyclical ordering of chemical elements in accordance with their natural properties. In 1817, the German chemist *Johann Debereiner* anticipated the predictive properties of chemical elements with common chemical properties. In Debereiner's triads, with an increase in atomic masses, the chemical properties of the middle element between similar ones turned out to be averaged relative to the sum of the properties of the two boundary elements of this triad [15]. This scientific fact is the first predictive method to determine properties of undiscovered chemical elements.

One of the first systemic ideas about the arrangement of elements in a spiral was made by the outstanding Russian mathematician *Nikolai Ivanovich Lobachevsky*, who did not stay indifferent to the natural systemic harmony of elements. He presented a sketch for the system of chemical elements in the form of a nonlinear expanding cylindrical spiral (Fig. 1).

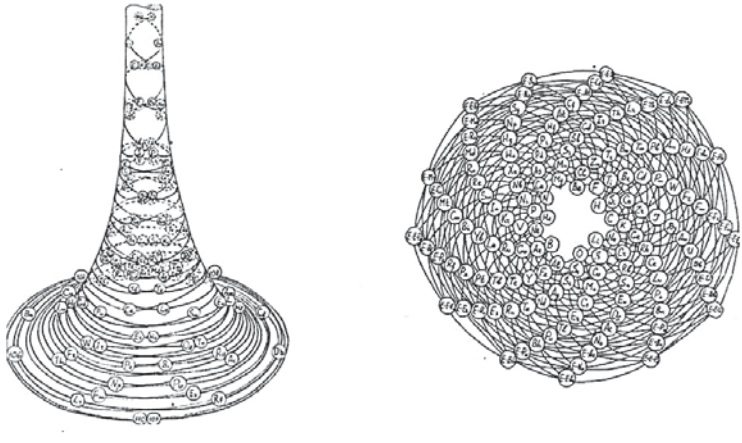


Fig. 1. **Sketch of the system of chemical elements by N.I. Lobachevsky**

In 1862, the French scientist *Alexandre Chancourtois* made the first attempt to systematize chemical elements as their atomic masses increased. The spiral representation of the periodically repeating properties of chemical elements, called the "earth spiral", is located on a cylindrical surface of 16 evenly distributed verticals, forming a straight line with an intersection at an angle of $\pi / 4$ to them, on which there are points proportionally located to the atomic masses of the elements. Elements which atomic weights differed by a multiple of 16 had similar properties and turned out to be located on the verticals of the cylinder. The explanation for the discovery was given more than half a century after the experimental determination of the nucleus structure.

In 1868, the Periodic Table of Chemical Elements by D. I. Mendeleev was published in a two-dimensional form. Later, he expressed the idea of a **spiral form** for the Table of chemical elements in the final article "Periodic Order of Chemical Elements": "*Practically speaking, the entire distribution of elements is continuity and corresponds to a certain extent to a spiral function ...*". Now it is obvious that all intuitive ideas of the author of the Periodic Law can be realized in the three-dimensional spiral form of the Periodic Law. The prophetic words belong to him: "*The future does not threaten the Periodic Law with destruction, but only promises superstructuring and development ...*". S. A. Shchukarev correctly noted that the system of elements is too complex in its content "for a single canonical representation in the form of a generally acknowledged Table" [7].

The formulated idea of the Three-dimensional matrix [14, 17] was based on fairly obvious propositions about the Universe [15, 16], and chemical elements were considered from the standpoint of their origin as "building blocks" of the Universe. The next assumption was that the formation of elements proceeded in the same way as the Universe developed and is developing. The imposition of a natural periodic sequence of chemical elements on the 3D matrix provides a more complete display of their properties, taking into account their valence. The matrix includes all known natural elements, and is a harmoniously organized three-dimensional model for studying the laws of matter, predicting new elements that are still unknown to science. The three-dimensional matrix of chemical elements is shown in Fig. 2.

In comparison with the tabular form the three-dimensional spiral provides a sequential continuous arrangement of elements with the possibility of including isotopes, lanthanides and actinides. This will make it possible to create a digital model to calculate the interaction processes of chemical elements with each other throughout the spiral as well as to forecast methods for obtaining new substances.

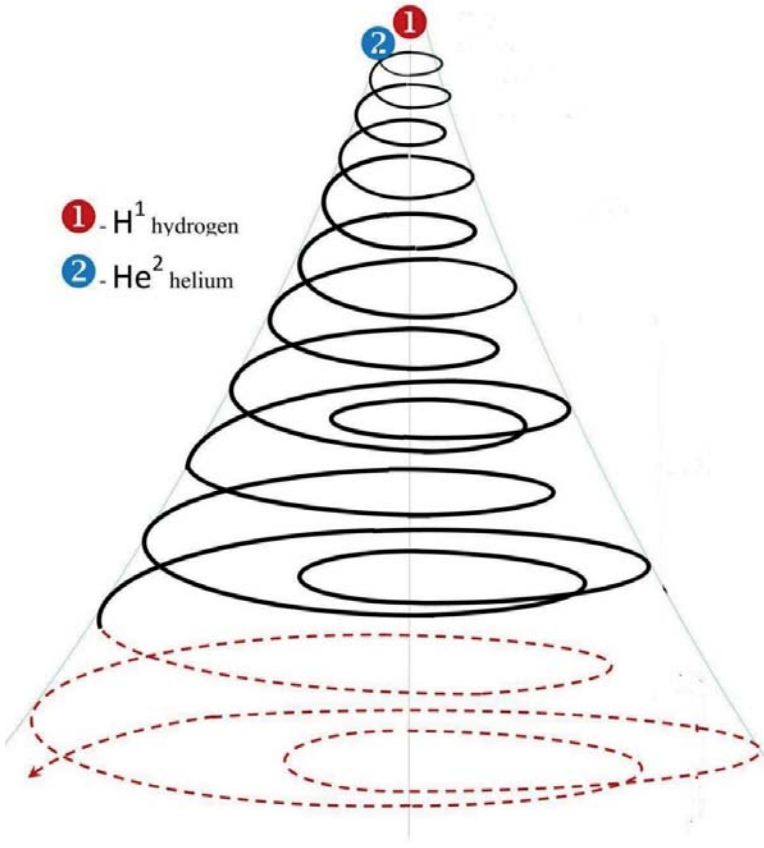


Fig. 2. **Scheme of the three-dimensional matrix of chemical elements (TDMCE)**

Thus, it becomes possible to identify the main prerequisites to create Three-dimensional periodic matrix of chemical elements:

— based on the laws of the Universe evolution, the authors propose to consider the arrangement of chemical elements in the form of an expanding conical spiral. Primary elements hydrogen and helium are placed at the top of the spiral;

— in comparison with the tabular form the three-dimensional spiral provides a sequential continuous arrangement of elements with the possibility of including lanthanides and actinides and all discovered and predicted groups. By means of the thorough study of the short and long-period tables by D. I. Mendeleev and **IUPAC,** taken as a basis in different countries, all known structures should find their reflection on the spiral.

3. Three-dimensional periodic matrix of chemical elements

Basing on the two-dimensional periodic table of chemical elements by D. I. Mendeleev the authors present by far informative three-dimensional form, achieving a more complete mapping of properties, taking into account the structures of the electron shells of chemical elements located in a natural continuous order of its expansion [18-20].

There has been proposed a three-dimensional coordinate system of a spatial expanding matrix with an attempt to eliminate the disadvantages formulated by academician *N. N. Semyonov*. Distinctive features of this classification system are the following: the central symmetry of the known elements with respect to hydrogen and helium, the linear symmetry of the main and secondary subgroups along the coordinate axes, as well as the compact placement of transition elements triads in the table, as well as lanthanides, actinides, which is due to the spiral arrangement of the elements by their serial numbers (Fig. 3). Long and short periods of the elements have a ring configuration, thereby simulating the structure of the electronic shells of atoms according to *N. Bohr*. Lanthanides, actinides and transactinides are placed in the sixth and seventh periods also according to the spiral principle up to element 118 (analogue of radon **Rn**), completing the seventh period.

Thus, the three-dimensional matrix is based on:

— arrangement of all known elements along cylindrical coordinates, which forms a planetary model of their structure. Atomic numbers ***n*** with the dimension of a continuous series of natural numbers from 1 to 118 (and more) are evenly arranged along the spiral from top to bottom.

— The ordinal number of the element coincides with the magnitude of the nuclear charge (Z) and with the same total number of energetically balancing electrons in the orbitals of the shells. The approach is universal both for the short-period table by D. I. Mendeleev as well as for the long-period **IUPAC** Table.

— An exponential increase in the number of elements in periods is shown, which forms a Three-dimensional spiral system of chemical elements [20].

The proposed representation of the three-dimensional periodic matrix of chemical elements in the form of an expanding conical spiral is a universal tool that makes it possible to study a wide variety of physical and chemical properties of already known and not yet discovered elements and their compounds. The versatility of the three-dimensional matrix also lies in the fact that, in addition to the mandatory serial number and strict coordinate binding of chemical elements to the groups, there appears a tremendous potential to structurally analyse physical and chemical properties of elements as well as the laws of their interaction.

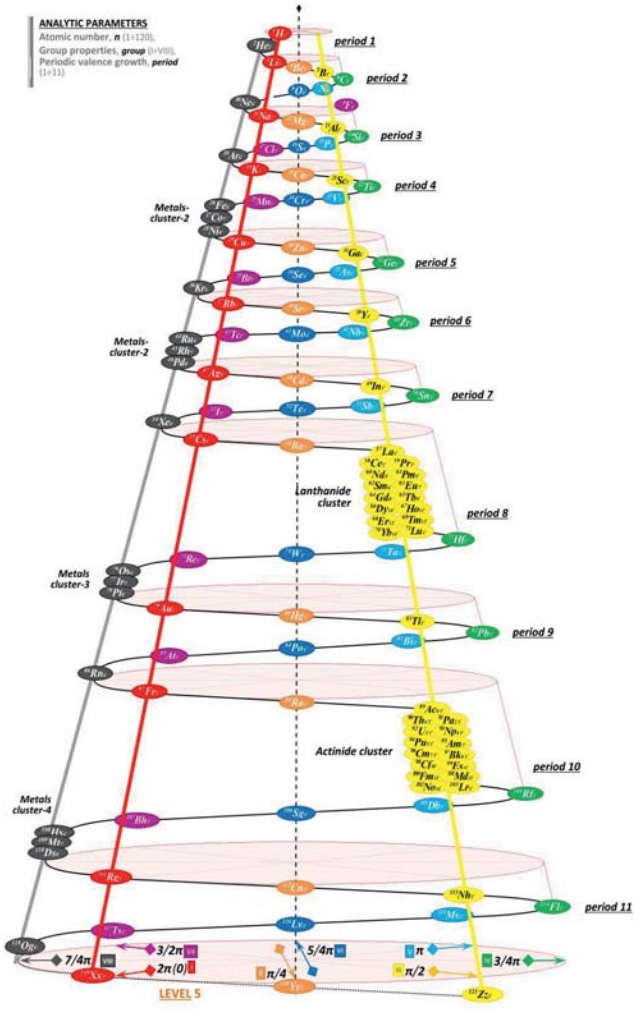


Fig. 3. **Three-dimensional matrix of chemical elements**

4. Cyclicity and block structure of chemical elements

The modern Periodic System is based on the nuclear charge (**Z**), which determines the place of an element in the system. Nuclear periodicity is expressed in a periodic change in the properties of atomic nuclei. The main parameter that determines this periodicity is the number of protons (**P**) and neutrons (**N**) in the nucleus. Figure 4 shows the dependence of nucleus mass of elements (protons and neutrons) and the mass of neutrons for the discovered 118 chemical elements.

The authors have calculated the ratio of neutrons and protons in the nuclei of chemical elements. In the short-period table 4a the averaged indicators of these ratios for the blocks are presented. It should be noted that these averaged values for blocks are equal, both in the short-period table and in the **IUPAC** Table (Table 4 b). Therefore, the block structure, in our opinion, corresponds to the concept of cyclicity i.e. the completeness of the periodicity for two periods, including the groups of lanthanides and actinides.

The study on the Three-dimensional periodic matrix of chemical elements based on a multiparameter coordinate system clearly demonstrates the stable formation of block patterns in the cyclic periodicity of the elements' properties in periods and blocks with an increase in their ordinal numbers and unites all the previously described periodicity options [4, 7]. It should be noted that the concepts of "period" in two types of tables are identical (there are 7 of them each), but an important circumstance that requires special attention is the obvious discrepancy between the "rows" and the group valence principle of periodicity in a long-period table.

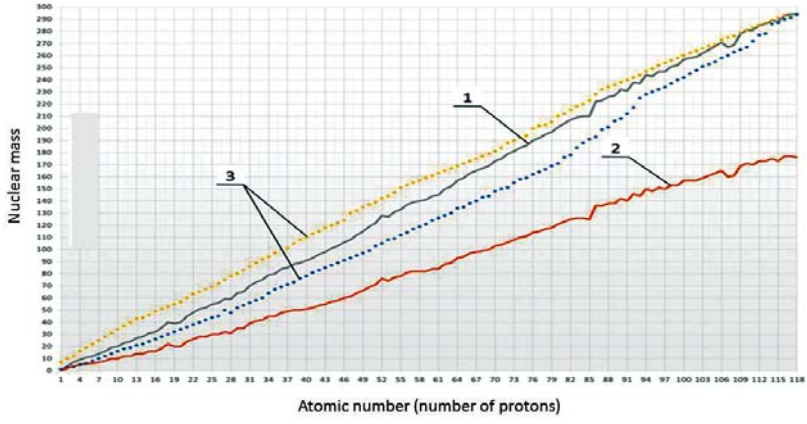


Fig. 4. **Dependences of nuclear masses (protons and neutrons) and mass neutrons (neutrons) for 118 chemical elements**

1 — the number of protons and neutrons; 2 — the number of neutrons; 3 — isotopes

In [18, 19], it was concluded that the three-dimensional spirally diverging system of the chemical elements matrix has **4** periodicity blocks and 7 periods. Structural analysis of period formation confirms that periods can be simple, in which one element is formed in each group (2 elements with an external signal orbital and 6 elements with an external valence orbital, 8 in total) and more complex ones containing grouped "family" elements within one group (**III** or **VIII**). Thus, in blocks, everything can be represented as follows (Table 4).

Table 4

The ratio of neutrons and protons in the nuclei of chemical elements
a) Mendeleev Table

Ratio of neutrons (n) to / protons (p)	Blocks, periods / rows	I	II	III	IV	V	VI	VII	VIII
	A 1	H 1 1,008 1							2 2 He 4 1,0
Less than 1,1	B 2	3 4 Li 7 1,33	4 5 Be 9 1,25	5 6 B 11 1,20	6 6 C 12 1,0	7 7 N 14 1,0	8 8 O 16 1,0	9 10 F 19 1,11	10 10 Ne 20 1,0
	B 3	11 12 Na 23 1,09	12 12 Mg 24 1,0	13 14 Al 27 1,08	14 14 Si 28 1,0	15 16 P 31 1,07	16 16 S 32 1,0	17 18 Cl 35 1,09	18 22 Ar 40 1,22
Less than 1,3	C 4/4-5	19 20 K 39 1,05	20 20 Ca 40 1,0	21 24 Sc 45 1,14	22 26 Ti 48 1,18	23 28 V 51 1,22	24 28 Cr 52 1,17	25 30 Mn 55 1,20	26 30 Fe 56 1,15 / 27 32 Co 59 1,19 / 28 31 Ni 59 1,11
		29 35 Cu 63 1,21	30 35 Zn 65 1,17	31 39 Ga 70 1,26	32 41 Ge 73 1,28	33 42 As 75 1,27	34 45 Se 79 1,32	35 45 Br 80 1,29	36 48 Kr 84 1,33
	C 5/6-7	37 49 Rb 85 1,32	38 50 Sr 88 1,32	39 50 Y 89 1,28	40 51 Zr 91 1,28	41 52 Nb 93 1,27	42 54 Mo 96 1,29	43 55 Tc 96 1,28	44 57 Ru 101 1,30 / 45 58 Rh 103 1,29 / 46 60 Pd 106 1,30
		47 61 Ag 108 1,30	48 64 Cd 112 1,33	49 66 In 115 1,35	50 69 Sn 119 1,38	51 71 Sb 122 1,39	52 76 Te 128 1,46	53 74 I 127 1,40	54 77 Xe 131 1,43
Less than 1,55	D 6/8-9	55 78 Cs 133 1,42	56 81 Ba 137 1,45	57 82 La 139 1,44	72 106 Hf 179 1,49	73 108 Ta 181 1,48	74 110 W 184 1,49	75 111 Re 186 1,48	76 114 Os 190 1,50 / 77 115 Ir 192 1,49 / 78 117 Pt 195 1,50
		79 118 Au 197 1,49	80 121 Hg 201 1,50	81 123 Tl 204 1,52	82 125 Pb 207 1,52	83 126 Bi 209 1,52	84 126 Po 210 1,50	85 125 At 210 1,47	86 136 Rn 222 158
	D 7/9-11	87 136 Fr 223 1,56	88 138 Ra 226 1,57	89 138 Ac 227 1,55	104 161 Rf 265 1, 55	105 163 Db 268 1,55	106 165 Sg 269 1,56	107 160 Bh 267 1,50	108 161 Xs 269 1,49 / 109 169 Mt 278 1,55 / 110 171 Ds 281 1,55
		111 170 Rg 281 1,53	112 173 Cn 285 1,54	113 173 Nh 286 1,53	114 175 Fl 289 1,54	115 173 Mc 288 1,50	116 177 Lv 293 1,53	117 177 Ts 294 1,51	118 176 Og 294 1,49

58 82 Ce 140 1,41	59 82 Pr 141 1, 39	60 84 Nd 144 1,40	61 84 Pm 145 1,38	62 88 Sm 150 1,42	63 89 Eu 152 1,41	64 93 Gd 157 1,45	65 94 Tb 159 1,45	66 97 Dy 163 1,47	67 98 Ho 165 1,46	68 99 Er 167 1,46	69 100 Tm 169 1,45	70 103 Yb 173 1,47	71 104 Lu 175 1,46
90 142 Th 232 1,58	91 140 Pa 231 1,53	92 146 U 238 1,59	93 144 Np 237 1,55	94 150 Pu 244 1,60	95 148 Am 243 1,56	96 151 Cm 247 1,57	97 150 Bk 247 1,55	98 153 Cf 251 1,56	99 153 Es 252 1,55	100 157 Fm 257 1,57	101 157 Md 258 1,55	102 157 No 259 1,54	103 159 Lr 262 1,54

The ratio of neutrons and protons in the nuclei of chemical elements
b) IUPAC Table

n/p ratio	Block, period	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII
1,0	A 1	H 1 1,008 1																	2 2 He 4 1,0
Less than 1,1	B 2	3 4 Li 7 1,33	4 5 Be 9 1,25											5 6 B 11 1,20	6 6 C 12 1,0	7 7 N 14 1,0	8 8 O 16 1,0	9 10 F 19 1,11	10 10 Ne 20 1,0
	B 3	11 12 Na 23 1,09	12 12 Mg 24 1,0											13 14 Al 27 1,08	14 14 Si 28 1,0	15 16 P 31 1,07	16 16 S 32 1,0	17 18 Cl 35 1,09	18 22 Ar 40 1,22
Less than 1,3	C 4	19 20 K 39 1,05	20 20 Ca 40 1,0	21 24 Sc 45 1,14	22 26 Ti 48 1,18	23 28 V 51 1,22	24 28 Cr 52 1,17	25 30 Mn 55 1,20	26 30 Fe 56 1,15	27 32 Co 59 1,19	28 31 Ni 59 1,11	29 35 Cu 64 1,21	30 35 Zn 65 1,17	31 39 Ga 70 1,26	32 41 Ge 73 1,28	33 42 As 75 1,27	34 45 Se 79 1,32	35 45 Br 80 1,29	36 48 Kr 84 1,33
	C 5	37 49 Rb 85 1,32	38 50 Sr 88 1,32	39 50 Y 89 1,28	40 51 Zr 91 1,28	41 52 Nb 93 1,27	42 54 Mo 96 1,29	43 55 Tc 98 1,23	44 57 Ru 101 1,30	45 58 Rh 103 1,29	46 60 Pd 106 1,30	47 61 Ag 108 1,30	48 64 Cd 112 1,33	49 66 In 115 1,35	50 69 Sn 119 1,38	51 71 Sb 122 1,39	52 76 Te 128 1,46	53 74 I 127 1,40	54 77 Xe 131 1,43
Less than 1,55	D 6	55 78 Cs 133 1,42	56 81 Ba 137 1,45	57 82 La 139 1,44	72 106 Hf 179 1,49	73 108 Ta 181 1,48	74 110 W 184 1,49	75 111 Re 186 1,48	76 114 Os 190 1,50	77 115 Ir 192 1,49	78 117 Pt 195 1,50	79 118 Au 197 1,49	80 121 Hg 201 1,50	81 123 Tl 204 1,52	82 125 Pb 207 1,52	83 126 Bi 209 1,52	84 126 Po 210 1,50	85 125 At 210 1,47	86 136 Rn 222 158
	D 7	87 136 Fr 223 1,56	88 138 Ra 226 1,57	89 138 Ac 227 1,55	104 161 Rf 265 1,51	105 163 Db 268 1,55	106 165 Sg 271 1,56	107 160 Bh 267 1,50	108 161 Xs 269 1,49	109 169 Mt 278 1,55	110 171 Ds 281 1,55	111 170 Rg 281 1,53	112 173 Cn 285 1,54	113 173 Nh 286 1,53	114 175 Fl 289 1,54	115 173 Mc 288 1,50	116 177 Lv 293 1,53	117 177 Ts 294 1,51	118 176 Og 294 1,49

— The first block **A** corresponds to short single-element periods (and rows **0-1**) of the matrix, where the first elements are hydrogen and helium (**H**^{1}-hydrogen and **He**^{2}-helium). For the first block, the neutrons (N) — protons (P) ratio can be taken equal to 1.

— The second block **B** structurally postures the completeness of the cyclic eight-element periodicity, which corresponds to simple periods (or rows) **2** (includes 8 elements from **Li**[3] to **Ne**[10]) and **3** matrices (includes 8 elements from **Na**[11] to **Ar**[18]). For the second block the N : P ratio is less than 1.1.
— The third block **C** structurally represents the completeness of the cyclic 10- and 8-element periodicity in the block, two additional "families" have appeared: from iron (**Fe)** to platinum (**Pt**), from ruthenium (**Ru**) to palladium (**Pd**). The third block C presents the first short pair of rows **4** (includes 10 elements from **K**[19] to **Ni**[28]) and 5 of the short-period table (includes 8 elements from **Cu**[29] to **Kr**[36]) and the second short pair of rows 6 (includes 10 elements from **Rb**[37] to **Pd**[46]) and 7 short-period tables (includes 8 elements from **Ag**[47] to **Xe**[54]). In the long-period table, a pair of rows **4** and **5** corresponds to period **4**, and a pair of rows **6** and **7** corresponds to period **5**. For the third block, the N : P ratio is less than 1 : 1,3.
— The fourth block **D** structurally represents the completeness of the cyclic 24 and 8-element periodicity as a block of chemical elements **D**, which additionally included the "families" of lanthanides (**La**) and actinides (**Ac**), as well as two "families": osmium (**Os**), iridium (**Ir**), platinum (**Pt**) and chassium (**Hs**), maitnerium (**Mt**), darmstadtium (**Ds**).

The fourth block corresponds to the first pair of the long row of lanthanides **8** (includes **24** elements from **Cs**[55] to **Pt**[78]) and the short row **9** of the short-period table (includes 8 elements from **Au**[79] to **Rn**[86]) and the second pair of the long row of actinides **10** (includes 24 elements from **Fr**[87] to **Ds**[110]) and short row **11** of the short-period table (includes 8 elements **from Rg**[111] to **Og**[118]). In the long-period table, a pair of rows **8** and **9** corresponds to period **6**, and a pair of rows **10** and **11** corresponds to period **7**. "Families" of lanthanides, actinides and some grouped metals require special study and attention of researchers. For the fourth block, the **N : P** ratio is less than 1.55.

Thus, in comparison with the short-period and long-period tables of chemical elements, the block structure of the Three-dimensional matrix of chemical elements using a three-dimensional coordinate system can significantly boost the informational value (multidimensionality).

5. Electronic characteristics of elements and analysis of their cyclicity in the structure of TDMCE

The spatial form of the three-dimensional periodic matrix made it possible to structure the anomalous groups of **III** (lanthanides and actinides) and **VIII** (metalloids) groups of the third **C** and fourth **D** levels of block

periodicity, and the level formulas of electron shells facilitate the study of systemic regularities of periodicity, including the mechanisms of saturation and transition electrons at different energy levels (orbital) of electron shells. The consistency of the periodicity is relevant when studying nuanced mechanisms of interlevel transitions and consistent interruption of synthesis of electron orbitals (Table 5).

The arrangement of electrons on energy levels (states) of shells ***K, L, M, N, O, P, Q, X*** (**EL**), consisting of sublevels (orbitals) ***s-, p-, d-, f-, g-, h***- at each level, satisfies the principle of minimum potential energy.

Table 5

The structure of energy levels and sublevels (orbitals) for blocks

Block A – 1	energy level ($K^s \equiv 1s^2$) ends with Helium (**He)**
Block B – 3	energy levels $K^sL^{s\text{-}p}M^{s\text{-}p\text{-}}$ ($M^{2\text{-}6\text{-}} \equiv 3s^2 3p^6$) ends with Argon (**Ar)**
Block C – 5	energy levels $K^sL^{s\text{-}p}M^{s\text{-}p\text{-}d}N^{s\text{-}p\text{-}d\text{-}}O^{s\text{-}p\text{-}}$ (*valence orbital* $O^{2\text{-}6\text{-}} \equiv 5s^2 5p^6$) ends with Xenon (**Xe)**
Block D – 7	energy levels $K^sL^{s\text{-}p}M^{s\text{-}p\text{-}d}N^{s\text{-}p\text{-}d\text{-}f\text{-}}O^{s\text{-}p\text{-}d\text{-}f\text{-}}P^{s\text{-}p\text{-}d\text{-}}Q^{s\text{-}p\text{-}}$ (*valence orbital* $Q^{2\text{-}6\text{-}} \equiv 7s^2 7p^6$) ends with Oganesson (**Og**)
	Predicted energy levels and electronic structure of the sublevels of Block E
Block E –	has to have **9** energy levels from element 119 to 218 $K^sL^{s\text{-}p}M^{s\text{-}p\text{-}d}N^{s\text{-}p\text{-}d\text{-}f}O^{s\text{-}p\text{-}d\text{-}f\text{-}g}P^{s\text{-}p\text{-}d\text{-}f\text{-}g\text{-}}Q^{s\text{-}p\text{-}d\text{-}f\text{-}}R^{s\text{-}p\text{-}d\text{-}}X^{s\text{-}p\text{-}}$ (*valence orbital* $X2\text{-}6\text{-} \equiv 9s^2 9p^6$) ends with element **№218**

The maximum number of electrons at the energy level is calculated by the formula $R = 2n^2$, where n is the level number or the principal quantum number (1, 2, 3, etc.). Each filled level corresponds to a certain set of sublevels (orbitals) (Table 6).

The sequence of filling the orbitals with electrons is determined by the Madelung rule [5, 7]. Periodicity, as a valence cycle in the system of chemical

elements, manifests itself during the formation of two successive orbitals — the initial ***s***-orbital and the valence ***p***-orbital with the number of valence electrons continuously increasing within the periods.

Table 6

Principal quantum number, types and number of orbitals, maximum number of electrons at sublevels and levels

Energy level (n)	Number of sublevels (n)	Orbital type	Number of orbitals		Maximum number of electrons	
			In sublevel	In level, equals to n^2	In sublevel	In level, equals to $2n^2$
K (n = 1)	1	1s	1	1	2	2
L (n = 2)	2	2s 2p	1 3	4	2 6	8
M (n = 3)	3	3s 3p 3d	1 3 5	9	2 6 10	18
N (n = 4)	4	4s 4p 4d 4f	1 3 5 7	16	2 6 10 14	32

Two groups of elements are initial. The first group of chemical elements with one electron at s^1 sublevel is **Li**[3] — **Fr**[87], and so on. The filling of s^1 — sublevel with the first electron indicates (signals) the completion of the valence shell of the previous period. The **II** group of chemical elements with two electrons at s^2 — sublevel is made up of **Be**[4] — **Ra**[88], etc. The filling of s^2-sublevel with two electrons shows its saturation and the forthcoming formation of the ***p***-valence shell sublevel, starting with the first electron of p^1-sublevel and the subsequent set of sublevels of the valence period. For clarity and convenience of analysis, electronic formulas of chemical elements were used.

Thus, grouping of elements into new periods starts with a systemically bound pair of chemical elements from groups **I** and **II**, which show the completion of the valence electron shells of elements' atoms in the previous period as well as the readiness to form the valence electron shell of a new period. In this case, in chemical elements of group **I**, there forms a new two-electron initial orbital of *the* sublevel ***ns*** of the corresponding energy level (from ***K, L, M, N, P, O, Q, X***) by filling the formed energy shell with the first electron (***ns***^{1}, electronic symbol

K, L1, M1, etc.), and in the subsequent chemical element of group **II,** the same atomic orbital is filled with a second saturating electron (***ns*²**, electronic symbol ***K2, L2, M2***, etc.), which forms a consistent pair of the external electrons atomic orbital. This initial pair completes the filling of ***1s*²** sublevel, after which the next layers of the corresponding energy level of the periodic sequence of chemical elements in the three-dimensional matrix are filled.

On the other hand, the filling of the outer atomic orbital with a consistent pair of electrons is always preceded by the formation of a new layer of the valence shell in the atom. The initial elements in all periods of the matrix form new periods on a new valence orbital (***np*¹**) by filling the corresponding energy level with the first electron and reflect the periodic patterns of the elements formation in material world. The mechanism of block periodicity to fill atomic orbitals is present at all levels of the three-dimensional periodic matrix of chemical elements.

Speaking from the perspective of the periodicity laws of the formation of chemical elements, there is a clear evidence for the special role of the initial atomic orbitals of the two successive elements. The first element of the pair demonstrates the completion of the stable state formation of the electronic layers structure in the previous, fully completed period, consisting of elements with maximum filling of energy level shells with electrons. All first elements are odd ones. Best practices confirm that electronic layers of elements shells of a fully completed period have a high degree of resistance to external energy influences and have a pronounced attraction to stationary interaction with the energy field of the atomic nucleus. Such consistent pattern implies the indifference of the electronic layers e of the maximum filled atomic shells to the valence (chemical interaction).

The second element is a formation significator of new electronic layers for the elements of the subsequent (forming) period, consisting of electrons of new shells of energy levels. All second elements are even. The electronic layers of the shells of the elements of the forming period do not have a high degree of resistance to external energy influences and have a lesser tendency to interact with the energy field of the atomic nucleus. Such consistent pattern implies the ability of the outer electronic layers of the unfilled atom shells to show polyvalence when combined into molecules.

The first elements of the valence ***p*-**orbitals of the new period in each energy level form elements with a ***p*¹**-orbital with one valence electron (**B**^{5} — **Nh**^{113}, etc.). All such elements are odd and belong to the **III** group of chemical elements. The second element is the element with two valence electrons of the ***p*²**-orbital in each energy level (**C**^{6} — **Fl**^{114}, etc.). All elements are even and

belong to the **IV** group of chemical elements. Subsequent elements with three valence electrons of the p^3-orbital and a different number of electrons of the valence orbital in each energy level are structured similarly, belonging to the **V, VI, VII** and **VIII** groups of chemical elements, respectively.

Consistent patterns to form electron atom shells using electronic-level formulas make it possible, on the basis of the block approach and structural analysis, to predict chemical elements outside the 118th element as well as to form the structure of new periods, starting with the chemical elements of the 11th period of D. I. Mendeleev Table or the 8th period of the **IUPAC** Table. Electron-orbital formulas is an extremely short description of the structure of chemical elements.

6. Detailed record on electronic structure and valence of Chemical elements

To characterize the ability of atoms to bind with each other there are used the following concepts: valence (covalence), ionization potential, etc. Valence as a number (bonds of atoms) is to some degree formalized in any of its electronic form [6]. The periodic dependence of the ionization potentials of atoms on the ordinal number of an element is well known and is presented in many publications and reference books [12].

Physical and chemical properties of elements have multiple variability when chemical elements interact with each other. Models of interelectronic interactions based on the **natural property of polyvalence** make it possible to consolidate all knowledge available for analysis and synthesis. Examination of chemical bonds of interacting elements at the electronic level convinces us that the decisive factor is the relative electron donation of the atoms involved in reactions. An element with a higher donor characteristic with more mobile electrons of the outer layers acts as a positive one. The mobility depends on the type of the outer layer of the sublevels ***s-, p-, d-, f-, g-, h***-orbitals of the energy levels ***K, L, M, N, O, P, Q, X*** , the electron shell, which manifests itself in the cyclic periodicity inside the sublevels in the system of chemical elements [7]. At the same time, electronic interactions in chemical reactions do not change the atom nuclei, the study of the internal structure of which is engaged in physics.

In general, the commonly accepted structure of the electron shell of an atom gives an idea of the physical meaning of valence, which changes with the development of the electronic theory of chemical bonds and the atom structure. Valence, as a very important characteristic of elements' chemical activity

and the formation of stable molecules is not a definitive characteristic, but is of great applied importance for high-quality analysis and effective synthesis of chemical elements and their compounds [6]. This implies the exceptional role of energy models of chemical reactions for the reasoned control of the "affinity energy" to the atom of external electrons, alongside with an understanding of the theory of chemical bonds, mechanisms and the physics of the obtained result.

The block structure of the polyvalent matrix is presented on the basis of the IUPAC long-period Periodic Table. Both in the short-period table and in the long-period table of the international community of **IUPAC** chemists, the group principle (introduced by D. I. Mendeleev) to differentiate the properties of chemical elements of the main (*a*) and secondary (*b*) subgroups is used. Analysis of periodicity on the basis of polyvalence for all known chemical elements is fairly informative in the matrix coordinate system (Fig. 5). The structuring of the energy levels of the polyvalence matrix is as follows:

— period **0-1** corresponds to block **A**;
— periods **2** and **3** correspond to block **B**;
— periods **4** and **5** correspond to block **C**;
— periods **6** and **7** correspond to block **D**.

In this case the cyclic periodicity is clearly in evidence in the electronic structure of the atom shells of chemical elements as well as in its maximum and minimum valences for each block. Thus, for block **A** there is one maximum valence, for block **B** there are two maximum valences, for block **C** there are four, and for block **D** there are six maximum valences. There are also negative valences from -4 and -3.

Consistent patterns of filling the electronic levels and orbitals of the electron shell become more sophisticated with the distance from the atomic nucleus, which leads to disruptions in filling the levels and sublevels. The reason may be the alignment of the energy levels of neighbouring sublevels, at which the electrons begin to jump between the sublevels and even to the neighbouring level without changing their total number in the atom. The results of polyvalences presented on the graph (Fig. 5) summarize the available knowledge about the energetic activity (valence) of elements in each period as well as show the cyclic nature of the build-up of the electron cloud.

The shortened periods 0 and 1 are formed by the pair of elements $\mathbf{H^1}$ — $\mathbf{He^2}$ of the lower energy level ***K1***, the maximum filling of the ***s***-orbital of which indicates the readiness for the beginning of the formation of chemical elements of the second energy level ***L2*** of the next period **2.** The filling of the small period is carried out in relation to the electron-orbital formulas (***EOF***) of the

elements that form periods and blocks. The first s-element with one electron in the outer orbital exhibits the maximum valence **+1**, and is included in the main subgroup **Ia** and indicates the completed formation cycle of the previous energy level period. The second ***s*-**element with two electrons in the outer maximum filled orbital exhibits a maximum valence of **+2**, which indicates the beginning of the formation cycle of the next energy level. The maximum filled ***s*-**orbital (***s*-**pair of elements), formed by the elements of groups **I** and **II** is the start of the forthcoming cycle of periodicity of the outer valence orbitals at all energy levels.

In each of the subsequent energy levels ***M, N, O, P, Q, X,*** after the initial signal ***s***-pair of period elements, there is a build-up of electrons of the outer "valence" ***p*-**orbitals, after which there continues the filling of ***d-, f-, g-*** orbitals in reverse order. Similar initial ***s*-**pairs of elements are formed in each period: **Li**^{3} — **Be**^{4} (period 2), **Na**^{11} — **Mg**^{12} (period 3), **K**^{19} — **Ca**^{20} (period 4), **Rb**^{37} — **Sr**^{38} (period **5**), **Cs**^{55} — **Ba**^{56} (period **6**), **Fr**^{87} — **Ra**^{88} (period **7**) in short period table numbering.

Despite the continuous increase in the number of electrons in the electron shells of chemical elements, an **identical structure of periodicity** is observed in periods **2** and **3**:

s-pair → 5 valence **p**-elements → inert gas.

For elements of period **2**, the structure is described by the following sequence:

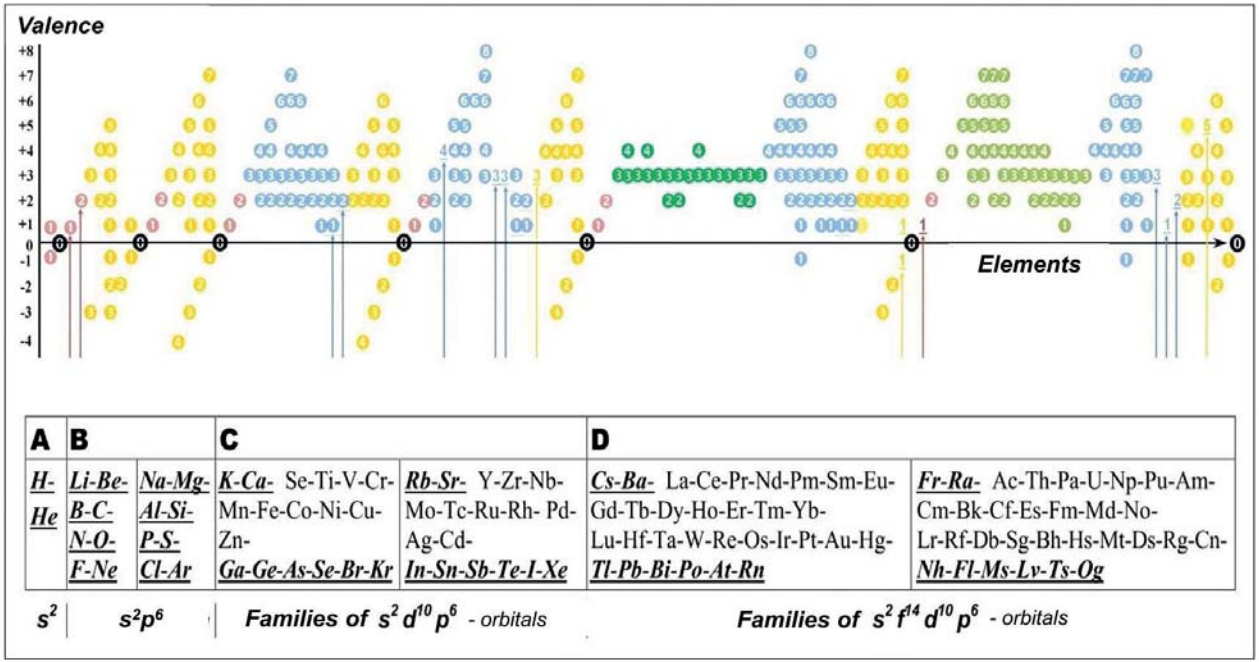
$$Li^{3} — Be^{4} \rightarrow B^{5} — F^{9} \rightarrow Ne^{10}.$$

For elements of period **3**, the structure is described by the following sequence:

$$Na^{11} — Mg^{12} \rightarrow Al^{13} — Cl^{17} \rightarrow Ar^{18}.$$

Period **4** begins with ***s***-pair **K**^{19}– **Ca**^{20} with the further build-up of electrons of the outer valence ***d***-orbitals **Sc**^{21} — **Ni**^{28} of the energy level *M3*. The subsequent structural transition of the formed elements of ***d*-**sublevel in the specified period in the sequence of the outer valence elements of ***p***-sublevel **Ga**^{31} — **Br**^{35} and inert **Kr**^{36} corresponds to the new energy level *N*4.

In the structure of the fourth period of chemical elements of ***p***-sublevel, one pair **Cu**^{29} — **Zn**^{30} precedes, which indicates the completion of the formation of ***d*-**sublevel of the energy level ***M*** and the beginning of the formation of a sequence of external valence elements of ***p*-**sublevel of the new energy level ***N***. Formally belonging to the to the ***d***-sub-level, they are initial with respect to the subsequent ***p***-sub-level of the new energy level ***N***. This is the development of a different structure of cyclic periodicity in relation to periods **2** and **3**.



A	B		C		D	
H-	*Li-Be-*	*Na-Mg-*	*K-Ca-* Se-Ti-V-Cr-	*Rb-Sr-* Y-Zr-Nb-	*Cs-Ba-* La-Ce-Pr-Nd-Pm-Sm-Eu-	*Fr-Ra-* Ac-Th-Pa-U-Np-Pu-Am-
He	*B-C-*	*Al-Si-*	Mn-Fe-Co-Ni-Cu-	Mo-Tc-Ru-Rh- Pd-	Gd-Tb-Dy-Ho-Er-Tm-Yb-	Cm-Bk-Cf-Es-Fm-Md-No-
	N-O-	*P-S-*	Zn-	Ag-Cd-	Lu-Hf-Ta-W-Re-Os-Ir-Pt-Au-Hg-	Lr-Rf-Db-Sg-Bh-Hs-Mt-Ds-Rg-Cn-
	F-Ne	*Cl-Ar*	*Ga-Ge-As-Se-Br-Kr*	*In-Sn-Sb-Te-I-Xe*	*Tl-Pb-Bi-Po-At-Rn*	*Nh-Fl-Ms-Lv-Ts-Og*
s^2	s^2p^6		Families of $s^2 d^{10} p^6$ - orbitals		Families of $s^2 f^{14} d^{10} p^6$ - orbitals	

Fig 5. **Polyvalences and orbitals of chemical elements**

For elements of period **4**, the structure is described by the following sequence:

$$K^{19} — Ca^{20} \rightarrow Sc^{21} — Ni^{28} \rightarrow Cu^{29} — Zn^{30} \rightarrow Ga^{31} — Br^{35} \rightarrow Kr^{36}.$$

Period **5** begins with ***s***-pair **Rb**^{37} — **Sr**^{38} with the further build-up of electrons of the outer valence ***d***-orbitals **Y**^{39}– **Pd**^{46} of the energy level ***N***.

The subsequent structural transition of the formed elements of the ***d***-sublevel in the sequence of external valence elements of the ***p***-sublevel **In**^{49} — **I**^{53} and inert **Xe**^{54} corresponds to a new energy level ***O***.

In the structure of the fifth period of chemical elements of ***p***-sublevel, the pair **Ag**^{47} –**Cd**^{48} from the subgroup of metals precedes the formation of ***d***-sublevel of the energy level ***N*** and the formation of external valence elements of ***p***-sublevel of the new energy level ***O*** begins. Officially belonging to ***d***-sublevel, they perform a signal function with respect to the next ***p***-sublevel of the new energy level ***O***. For period **5**, in the nomenclature of chemical elements, the structure is described by the following sequence:

$$Rb^{37} –Sr^{38} \rightarrow Y^{39} — Pd^{46} \rightarrow Ag^{47} — Cd^{48} \rightarrow In^{49} — I^{53} \rightarrow Xe^{54}.$$

Period **6** begins with ***s***-pair **Cs**^{55} — **Ba**^{56}of the main subgroups **I***a* and **II***a* of the energy level ***P*** with the further build-up of electrons of the outer valence ***f***-orbitals **La**^{57} –**Yb**^{70} of the energy level ***N***. The formed elements of f-sublevel as a part of the specified period are structurally transferred to the external valence chemical elements of d-sublevel **Lu**^{71} — **Pt**^{78} of the energy level ***O*** and ***p***-sublevel **Tl**^{81} — **At**^{85} together with inert **Rn**^{86}, corresponding to the new energy level ***P***. For period **6**, in the nomenclature of chemical elements, the structure is described by the following sequence:

$$Cs^{55} — Ba^{56} \rightarrow La^{57} –Yb^{70} \rightarrow Lu^{71} –Pt^{78} \rightarrow Au^{79}– Hg^{80} \rightarrow Tl^{81} — At^{85} \rightarrow Rn^{86}.$$

Period **7** begins with ***s***-pair **Fr**^{87} — **Ra**^{88} of the energy level ***Q*** with the further build-up of electrons of the outer valence ***f***-orbitals **Ac** ^{89}– **Lr**^{103} of the energy level ***O***. The specified period shows the subsequent structural transition from the formed elements of ***f***-sublevel to the external valence elements of ***d***-sublevel **Rf**^{104}–**Ds**^{110} of the energy level ***P*** and ***p***-sublevel **Nh**^{113} — **Ts**^{117} in the element **Og**^{118} of the energy level ***Q***.

In the structure of the seventh period, elements of the ***p***-sublevel are preceded by elements **Rg**^{111} — **Cn**^{112} of metal subgroups, which indicate the completion of the formation of ***d***-sublevel of the energy level ***O*** and the beginning of the formation of external valence elements of ***p***-sublevel of the new energy level ***P***. They perform a signalling function in relation to the next ***p***-sublevel of the new energy level ***Q***. For period **7**, in the nomenclature of chemical elements, the structure is described by the following sequence:

$$Fr^{87} — Ra^{88} \rightarrow Ac^{89} — Lr^{103} \rightarrow Rf^{104}– {}^{110}Ds \rightarrow Rg^{111}–Cn^{112} \rightarrow Nh^{113} –Ts^{117} \rightarrow Og^{118}.$$

There can be laid an emphasis on some consistent patterns related to the valence of chemical elements [13]:

— elements of a group (subgroup) have a similar configuration of external electronic shells and the same valence in compounds;
— ***s***-elements have the same valence as the group number;
— ***p***-elements have the highest valence equal to the group number, and can also have a valence equal to the difference between number 8 and the number of their group;
— ***d***-elements have different valences that do not coincide with the group numbers.

The cyclic nature of the electronic saturation of elements is also manifested in the fact that after a certain number of elements in the periodic table, ***s-, p-, d-*** and other orbitals with the same configurations of electronic sublevels are repeated. This entails a periodic change in chemical and physical properties of the elements. It means that any chemical element consisting of a nucleus and the corresponding configuration of the electron shell of an atom can be structurally represented in the form of four systemically related parts of chemical elements, individual for each element:

a) *nuclear structure of the atom* is its proton-neutron structure, which has a charge, an energetically balanced field of the electron shell and mass characteristic depends on the structure of the nucleus and does not directly affect the chemical interactions of the atom;

b) *lower energy levels of the shell* which are maximum filled with electrons do not directly affect the chemical interactions of the atom;

c) non-valence orbitals of *middle energy levels* cyclically built up by electrons which are formed in the elements of group **III** do not directly affect the chemical interactions of the atom;

d) valence orbitals of *external energy levels* which are periodically built up by electrons and formed in all chemical elements form the basis of the mechanism of chemical interactions; the structure is variable up to the maximum filling of the external energy level with electrons, after which it moves to a new (higher) energy level.

The existing practice of using the formula for the energy level of the shell and the electron-orbital structure (**EOS**) can be used as a systematic tool to describe and predict the structures of the electron distribution over orbitals-sublevels ***(s-, p-, d-, f-, g-, h- ...)*** in energy levels ***(K, L, M, N, O, P, Q ...)*** of chemical elements (Table 7). However, as the charge of the atomic nucleus increases, the orbital representation becomes cumbersome [3, 5].

It is advisable to write down the formulas for the energy level of the shell in abbreviated form by replacing the EOS orbitals filled with electrons only by the symbols of the corresponding energy levels without indicating the orbital structures. Such nomenclature can be valid only to analyse shell structures for periods in which there are no families of elements of the third group.

Table 7

Electronic structure of the last elements in blocks, including external (valence) orbitals

Block	Closing element	Energy levels			
		Filled / completed	incomplete	Number	External
A	He^{2}	K^{s}	–	1	$1s^2$
B	Ar^{18}	$K^{s}L^{s\text{-}p}$	$M^{s\text{-}p\text{-}}$	3 (2+1)	$3s^23p^6$
C	Xe^{54}	$K^{s}L^{s\text{-}p}M^{s\text{-}p\text{-}d}$	$N^{s\text{-}p\text{-}d\text{-}}O^{s\text{-}p}$	5 (3+2)	$5s^25p^6$
D	Og^{118}	$K^{s}L^{s\text{-}p}M^{s\text{-}p\text{-}d}N^{s\text{-}p\text{-}d\text{-}f}$	$O^{s\text{-}p\text{-}d\text{-}f\text{-}}P^{s\text{-}p\text{-}d\text{-}}Q^{s\text{-}p}$	7 (4+3)	$7s^27p^6$
E	218	$K^{s}L^{s\text{-}p}M^{s\text{-}p\text{-}d}N^{s\text{-}p\text{-}d\text{-}f}O^{s\text{-}p\text{-}d\text{-}f\text{-}g}$	$P^{s\text{-}p\text{-}d\text{-}f\text{-}g\text{-}}Q^{s\text{-}p\text{-}d\text{-}f}R^{s\text{-}pd}X^{s\text{-}p}$	9 (5+4)	$9s^29p^6$

The relationship between the electronic structure of an element or material and its functional properties is an issue of the utmost importance. It opens up the possibility to predict these properties by its electronic structure. Due to the scarcity of the available knowledge, for more than a century and a half it was impossible to explain and apply the periodicity of the system from the standpoint of predicting new and unknown chemical elements. The ratio of block structures, periods and energy levels in the three-dimensional matrix of chemical elements with boundary elements completing the energy levels is shown in Fig. 6.

The concept of **cyclicity,** introduced by the authors, as a property of the regular build-up of electrons of the inner shells ***d-, f-, g-, h-…*** in relation to valence orbitals, is repeated for families of chemical elements of the third group. The minimum valence of chemical elements, which is observed at the boundary of orbital cycles is analogous to the zero valence of neutral gases at the boundaries of the periods. Formulation of the consistent pattern of cyclic filling of non-valence internal orbitals in the periodicity structure makes it possible to predict new chemical elements and create a digital platform in materials science [20].

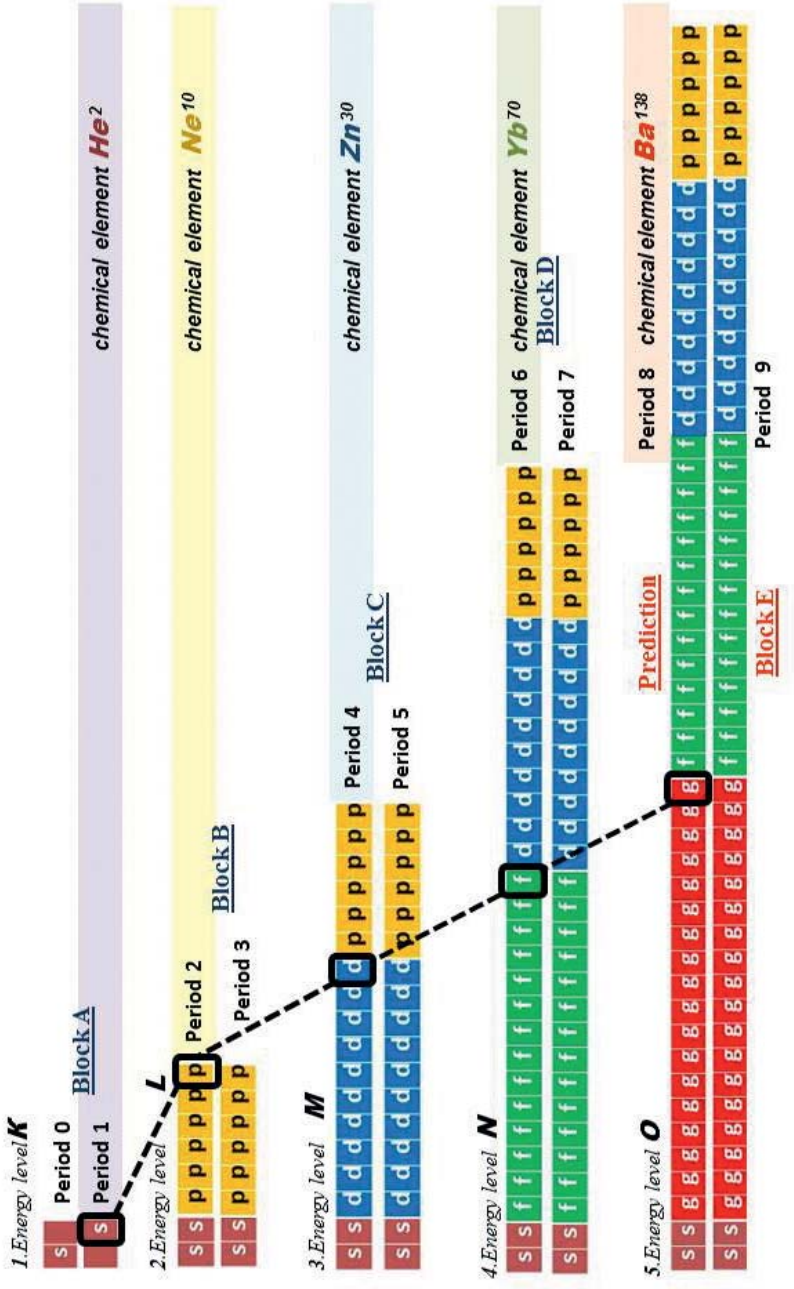


Fig. 6. **Cyclicity of orbitals of energy levels and boundary elements of the matrix**

7. Structural analysis of cyclicity in the Three-dimensional periodic matrix of chemical elements

To analyse the structure of the table of chemical elements, the authors proposed the method of **Structural Analysis** (**SA**). This method allows not only to eliminate the drawbacks noted by academician *N. N. Semenov*, but also to create a universal model of the structure of energy levels ***(K, L, M, N, O, P, Q ...)*** and orbital electronic sublevels ***(s-, p-, d-, f-, g-, h-, q -...),*** chemical elements when filling the electron shells of the nuclei of chemical elements. The analysis of block structures, periods and energy levels with their boundary elements and cyclicity in the three-dimensional matrix of chemical elements is shown in Fig. 7. Structural analysis of the discovered 118 chemical elements makes it possible to formulate a consistent pattern of block structure for the *pairing of orbital structures of odd and even periods in a block*. Block structure confirms all generally accepted laws, patterns and rules in chemistry, including Madelung's rule. The pattern of block structure is valid for all tabular forms of the Periodic Law and is most notably manifested, starting with the family cycles of ***f***-elements of block **D** and all subsequent ***g-, h***-elements of block **E** in group **III**. Pairing in block periods does not contradict the regular increase in the number of elements in periods. An important circumstance is the natural order i.e. the pattern of the cyclic build-up of electrons from the lower orbital sublevel to the next. The maximum filling of the lower orbital sublevels with electrons brings them to the area of chemically passive electron shells of these energy levels.

It is necessary to distinguish between non-periodic and periodic properties of chemical elements. Non-periodic properties of chemical elements are characteristic of the atom nuclei i.e. they are the nuclear charge, the number of electrons, the mass of atoms, the stability or radioactivity of chemical elements. The periodic properties of chemical elements are interrelated with the **cyclic** structure of filling nuclear shells with electrons. There take place changes in physical and chemical properties of elements due to the periodicity of the structure of the electron shells of atoms. The physics of the chemical periodicity is driven by the repetition of the configuration of the valence electrons of the external energy level of atoms with an increase in nuclear charge. In this regard, the following definition was formulated [25]: "*in* ***s-, p-, (s + p)-, d-*** *and* ***f****-elements there is a clear periodic dependence of the properties of elements and compounds on the number of their corresponding* ***s-****, or* ***p-****, or* ***(s + p)****-, or* ***d-****,or* ***f****-electrons in atoms.* " [19, 23].

The observed features of changes in the properties of the known chemical elements at the end of the periodic system and the prediction of the prop-

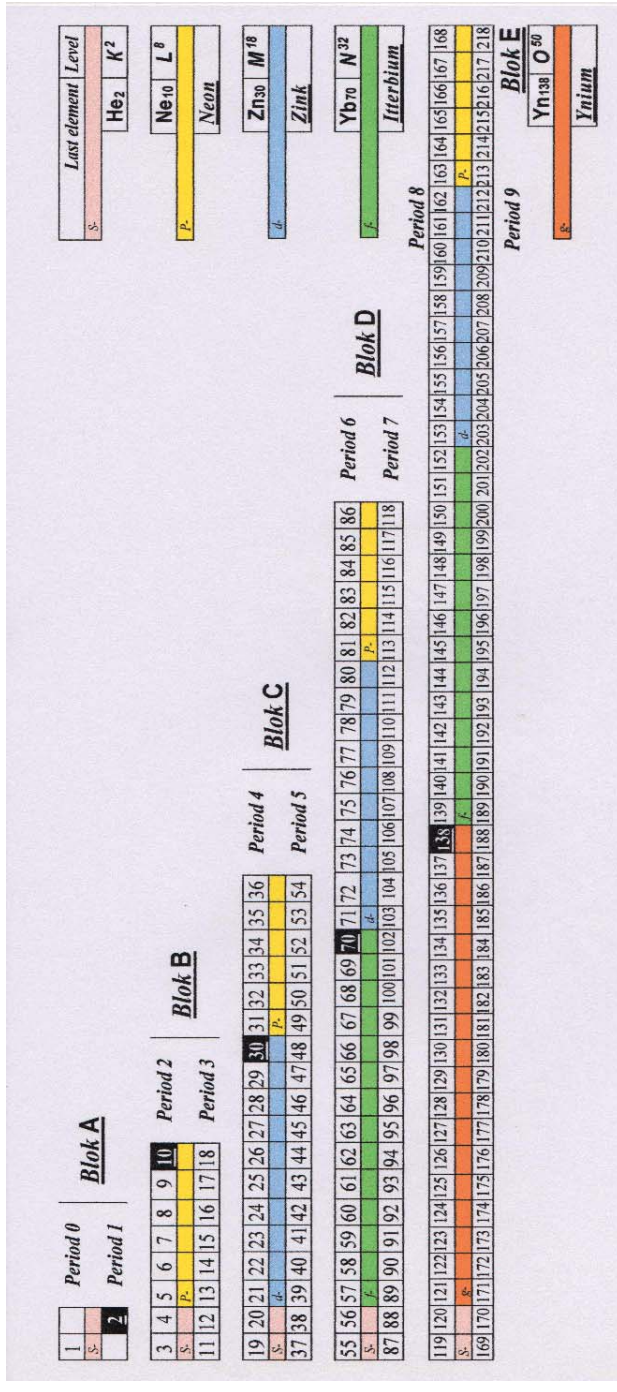


Fig. 7. **Cyclicity (block structure) of the three-dimensional matrix of chemical elements**

erties of elements with large ordinal numbers indicate that the phenomenon of periodicity turns out to be much more complex than it seemed on the basis of tabular knowledge of the chemistry of elements from the first to the seventh period inclusive.

The theory of the atom structure explained the reason for binding atoms into molecules as the tendency to form a stable two- or eight-electron outer shell. The formation of a stable electronic configuration can be achieved in various ways: by electron loss, attachment, or collectivization of electrons. Thus, by chemical binding we mean various types of interactions that determine the stable existence of bi- and polyatomic compounds: ions, molecules, and other structures.

The main parameters of the chemical binding between atoms and molecules are the following:

a) decrease in the total energy of a bi- or polyatomic system in comparison with the total energy of isolated particles from which this system is formed;

b) redistribution of the electron density of the chemical binding in comparison with a simple arrangement of unbound atoms when approaching at a binding distance.

The periodicity of the electronic structure is manifested in the fact that after a certain number of elements in the periodic table ***s-, p-, d-*** and other orbitals with stable configurations of electronic sublevels are repeated. This entails a periodic change in the chemical and physical properties of the elements. So, the functional difference in the property of periodicity of chemical elements reflects the pattern and mechanism of recurrence during the formation of the outer valence orbitals of the nuclear shells. As part of the development of chemical sciences, researchers are attracted by the ideas of searching for universal chemical constants, the influence of energy fields on the structure of periodicity and its relation to the structure of the Universe [24].

Some physical and chemical properties of atoms (ionization potential, atomic radius, etc.) of simple and complex substances can be not only qualitatively, but also quantitatively presented in the form of mathematical dependences on the ordinal number of an element with periodic maxima and minima.

The periodicity of the electronic structure of chemical elements from group **I** to **VIII** for ***s-*** and ***p***-sublevels and families of orbitals of ***d-, f-, g-, h-*** and ***q***-sublevels is presented in Table 8.

The properties of the group periodicity are the first in the periodic table to represent the 8-group even (shortened) period **2** of the block structure **B**. The period forms two orbitals of the initial energy sublevels s^2 **(**groups **I** and **II)** and six orbitals of the final energy sublevels p^6 (groups **III** to **VIII**). In this

case, the "range" of polyvalences is 8, from +5 to -3, depending on the chemical elements involved in the reactions, with subsequent zeroing of the valence by the end of the periods in inert gases. The order, consisting in a continuous increase in the number of electrons in the outer orbital of period **2**, extends to the next odd period **3** of the block structure **B.**

Table 8

Electronic structure and features of group III in TDMCE

No. of periods	No. of elements	Groups	Orbitals
0	1	I	*s*-
1	1	VIII	
2	**8**	I - II, - - III - IV - V - VI - VII - VIII	*s, p*
3	8	I - II, - - III - IV - V - VI - VII - VIII	
4	**18**	I - II, - ***d***-III - IV - V - VI - VII - VIII	*s, p,* ***d***
5	18	I - II, - ***d***-III - IV - V - VI - VII - VIII	
6	**32**	I - II, - ***f****, d*-III - IV - V - VI - VII - VIII	*s, p, d,* ***f***
7	32	I - II, - ***f****, d*-III - IV - V - VI - VII - VIII	
8	**50**	I - II, - ***g****, f, d*-III - IV - V - VI - VII - VIII	*s, p, d, f,* ***g***
9	50	I - II, - ***g****, f, d*-III - IV - V - VI - VII - VIII	
10	**72**	I - II, - ***h****, g, f, d*-III - IV - V - VI - VII - VIII	*s, p, d, f, g,* ***h***
11	72	I - II, - ***h****, g, f, d*-III - IV - V - VI - VII - VIII	
12	**98**	I - II, - ***q****, h, g, f, d*-III - IV - V - VI - VII - VIII	*s, p, d, f, g, h,* ***q***
13	98	I - II, - ***q****, h, g, f, d*-III - IV - V - VI - VII - VIII	

Starting from the fourth period **C** of the block structure, another pattern can be seen in the system of chemical elements i.e. the formation of an internal sequence of orbitals of sublevels ***d-, f-, g-, h-, q- ...,*** fundamentally changing the eight-group structure of periodicity (see Table 9).

From the standpoint of element "families", it is advisable to consider the families of three metals placed by D. I. Mendeleev in group **VIII**, which are artificially put in the group of inert gases, although they have their place in the table and the corresponding chemical properties, in the first of the inner orbitals of the lowest ***d***-sublevel. In addition, the average valence of chemical elements of ***d***-orbitals is +3 as well as the dominant valence of all elements of ***f***-orbital of lanthanides which is also +3 and this **confirms the authors' opinion** that **all families of internal non-valence orbitals**, starting with block **C**,

(families of ***d***-sublevel and subsequent internal block structures**), must belong to group III of the Table**.

Subsequent families of inner d^{10} — orbitals of the sublevel of higher energy levels and all subsequent orbitals of ***f-, g-, h-, q-*** higher sublevels, similar to f^{14}-lanthanides and f^{14}-actinides of block **D**, do not fit into tabular forms (including IUPAC). Moreover, structurally they should precede the s^1 orbitals of all levels, in group **III** with valency +3. The unjustified extension of family formations outside of any tabular forms is their disadvantage, fundamentally violating the conditions of continuity, including the **processes of energy interactions**.

Table 9

Polyvalence of TDMCE element families

Periods	Number of elements	Polyvalence	Polyvalence interval
0	1	**±1**	2
1	1	**0**	0
2	8	from +1 to+5 (-3); **0**	1-8 max
3	8	from +1 to +7 (-4); **0**	1-8 max
4	2 {10} — with the metals family	from +1 to +7	1-7, 6 max
	6	from +2 to +6 (-4); **0**	1-6, 8 max
5	2 {10} — with the metals family	from +1 to +8	1-8, 6 max
	6	from +2 to +7 (-3); **0**	1-7, 6 max
6	2 {14} — with lanthanides	from 1 to +4	1-4, 3 max
	{10} — with the metals family	from 1 to +8 (-1)	1-8, 8 max
	6	from 1 to +7 (-3); **0**	1-7, 8 max
7	2 {14} — actinides	from 1 to +7	1-7, 6 m***a***x
	{10} — with the metals family	from 1 to +8 (-1)	1-8, 8 max
	6	from 1 to +6 (-2); **0**	1-6, 8 m***ax***
8	50: 2 {18} {14} {10} 6	from 1 to +8	
9	50: 2 {18} {14} {10} 6	from 1 to +8; **0**	
10	72: 2 {22} {18} {14} {10} 6	from 1 to +8	*1-8, 8* max
11	72: 2 {22} {18} {14} {10} 6	from 1 to +8; **0**	*1-8, 8* max
12	98: 2 {26} {22} {18} {14} {10} 6	from 1 to +8	
13	98: 2 {26} {22} {18} {14} {10} 6	from 1 to +8; **0**	

The arrangement of the three-dimensional periodic matrix determines the place of family orbitals in group periodicity of the relationship of families of the discovered 118 chemical elements, which is presented in Table 9. The table shows the correspondence of periods, distribution of valence orbitals and {internal families}, practical manifestation of many possible valences (poly-

valence), their ranges and confirmed maximum. The elements of group **VIII** correspond to zero chemical activity.

From the eighth period of block **E**, the family structure and predicted valence limits for the new predicted elements are presented. An important feature of the block formation of families of chemical elements is noted, both in the short-period table and in the long-period IUPAC table. In the current understanding presented above, with the exception of the shortened periods **0** and **1** of block **A**, between the two outer valence orbitals of the ***s*-** and six orbitals of the ***p*-**sublevels in two periods **2** and **3** of block **B**, there are no elements with electronic orbitals of a higher sublevel of the group periodicity.

In the next two periods **4** and **5** of the **C** block, between the orbitals of the **s-** and **p-** "outer" valence energy sublevels, there are 10 chemical elements of the ***d*-**sublevel family of orbitals sequentially filled with electrons. And in two periods **6** and **7** of the **D** block, after two elements of the ***s*-** orbitals, the orbitals are sequentially filled with electrons of the ***f*-**sublevel family of orbitals (the lanthanide and actinide families), after which the filling with electrons of the orbitals of 10 chemical elements of the **I** sublevel family continues, preceding the six chemical elements of the outer valence closing orbitals of the ***p***-sublevel in each period.

In all subsequent paired periods, the block structures also lack the correspondence of the preferred mono valence to a particular group. There is a special pattern of further structural build-up of "internal" energy sublevels. The peculiarity consists in the regularity of the periodic formation of orbital electronic energy sublevels ***f-, g-, h-, q- …*** in sequence from the "senior" orbital of the higher sublevel to the "junior", lower sublevel. The consistent pattern of filling the nuclei shells: first the outer valence s^2-sublevel, and then ***(… q-, h-, g-, f-, d-)*** levels, ending with a sequence of p^6-orbitals.

The pattern to cyclically fill the electron shell orbitals of chemical elements' energy levels of the block pair periods for blocks **A, B, C** and **D** begins with a pair of chemical elements of the initial valence ***s*-**orbitals (group **I** with valence +1 and group **II** with valence +2) and ends with six valence ***p***-orbitals (groups **III** to **VIII** with corresponding valences). Boundary elements of periods are considered to be the first chemical elements with valence s^1-sublevels and the last chemical elements with energy sublevels of p^6-orbitals.

The structure of the cyclicity of the internal family orbitals of the three-dimensional periodic matrix is presented in Table 10. The block structures of the electron shells are brought in accordance with the number of chemical elements, the structure of the cyclicity of internal non-valence orbitals, the ordinal numbering of energy sublevels and the ordinal structure of cyclic elements in non-valence orbitals. Structural analysis of block correspondence of higher sublevels and boundary elements of energy levels is presented in Table 11.

Table 10

Groups and structure of chemical elements orbitals

P/№	Blocks	No. of elements in blocks	Groups in blocks	Orbital shells	Inner orbitals
1	**A**	2	none	(s^2)	none
2	**B**	8 x 2	none	s^2p^6	none
3	**C**	18 x 2	10 x 2	$s^2d^{10}p^6$	***d***-
4	**D**	32 x 2	(14+10) x 2	$s^2f^{14}d^{10}p^6$	***f***-*d*-
5	**E**	50 x 2	(18+14+10) x 2	$s^2g^{18}f^{14}d^{10}p^6$	***g***-*f*-*d*-
6	**F**	72 x 2	(22+18+14+10) x 2	$s^2h^{22}g^{18}f^{14}d^{10}p^6$	***h***-*g*-*f*-*d*-
7	**G**	98 x 2	(26+22+18+14+10) x 2	$s^2q^{26}h^{22}g^{18}f^{14}d^{10}p^6$	***j***-*h*-*g*-*f*-*d*-

This analysis showed a stable exponentially diverging nature of the ratio of underfilled cyclic and valence orbitals relative to passive energy sublevels filled with electrons in the structure of the block periodic sequence of 118 discovered and predicted chemical elements. If in the first four blocks **A, B, C** and **D** this divergence indicator of the three-dimensional periodic matrix relative to block **B** increases by 4 times, then in the next three predicted blocks **E, F** and **G** the divergence increases up to 8 times, which is due to the chemical elements of the third group.

Table 11

Energy levels and boundary elements

Blocks	Periods	Energy levels	Boundary shells	Boundary element	No. in period	Position in block
A	**0**	*1-st* ***K***	(s^2)	***He***^{2} Helium	(2)	(1 : 1)
B	**2**	*2- nd* ***L***	p^6	**Ne**^{10} Neon	8	***1 : 2***
C	**4**	*3-rd* ***M***	d^{10}	**Zn**^{30} Zinc	12	***1 : 3***
D	**6**	*4-th* ***N***	f^{14}	**Yb**^{70} Ytterbium	16	***1 : 4***
E	**8**	*5-th* ***O***	g^{18}	**Yn** ^{138}Yinium	20	***1 :5***
F	**10**	*6-th* ***P***	h^{22}	**Gu**^{242}	24	***1 : 6***
G	**12**	*7-th* ***Q***	q^{26}	**An**^{390}	28	***1*** : *7*

Block structures of even periods are brought in line with the boundary orbitals of energy levels. In these orbitals, a special role belongs to the final, extremely saturated with electrons, boundary chemical elements, the serial numbers of which make it possible to distinguish between the physical and chemical characteristics of the preceding and subsequent elements in the corresponding periods.

For the maximum filled first energy level ***K***, such element is helium **He²** of an energy level ***K2***. For the maximum filled second energy level ***L***, such element is neon **Ne¹⁰** with an energy level ***L6***. For the maximum filled third energy level ***M***, such element is zinc **Zn³⁰** with an energy level ***M10***. For the maximum filled fourth energy level ***N***, such element is ytterbium **Yb⁷⁰** with an energy level ***N***14. The stable pattern of the location of the maximum filled orbitals of chemical elements gives grounds to predict the cyclic filling of energy levels. The boundary elements of the maximum filled energy levels, with the exception of helium **He²**, the first energy level, are the last elements of the maximum filled with electrons higher orbital of the completed energy level of the first even period in each block. Their ordinal place within the indicated periods is determined by the formula:

$$\{2 \cdot (№_{of\ period}) + 4\}.$$

The developed formula is confirmed in all other periods **2–3** of block **B**, in periods **4–5** of block **C** of the third level, in periods **6–7** of block **D** of the fourth level for the discovered 118 chemical elements. The structural analysis makes it possible to forecast the predicted chemical elements for new periods **8–9** of block **E**, periods **10 –11** of block **F**, periods **12–13** of block **G**, and so on. The result of applying the formula for both 118 chemical elements and predicted blocks is presented in Table 12. The above structural analysis indicates that the cyclic sequence exponentially increases in paired periods **D, E, F, G**.

The structural analysis method allows to determine the position of the boundary chemical element of the eighth period in the fifth block **E**, completing the fifth energy level at number 138. The boundary chemical element of the tenth period of the sixth block **F** will complete the sixth energy level at number 242, and the boundary chemical element of the future paired periods **12** and **13** of the block **G** will complete the seventh energy level under the number of 390, etc.

For the first time there has been presented a structural internal block analysis of chemical elements of maximum filled orbitals in a completed energy level to the total number of chemical elements of incomplete cyclic and valence orbitals.

Within the discovered 118 chemical elements in the short-period tabular version, eight paired periods for four blocks (**A, B, C** and **D**) correspond to four maximum filled energy levels (***K, L, M*** and ***N)***. In this case, the boundaries of the periods do not coincide with the boundaries of the energy levels. The cyclicity manifests itself starting from period **4** of block **C** and in period **5** in groups of 10 elements of the energy ***d***-sublevel, which back in the day led

to the introduction of the concept of "half-periods" in long periods, starting with paired periods **4** and 5 of block **C**. As further structural analysis shows, for the sake of preserving the "harmony" of the table, D. I. Mendeleev decided to include two additional metals of the energy ***d***-sublevel in group **VIII** of the first "half-period" and replaced the chemical elements of two ***s***-sublevels of groups **I** and **II** with two metals of the energy d-sublevel before six chemical elements of ***p***-sublevels of the second "half-period". The structure of "families" of group **III** is clearly shown in Table 12.

If the "harmony" of the short-period table had not been preserved, then two families of chemical elements of ***d***-sublevels of two "half-periods" in paired periods **4** and **5** of block **C** would have fallen outside of it. The cyclicity was more clearly exhibited in even period **6** and in period **7** of block **D** in groups of 14 chemical elements of the energy ***f***-sublevel of the previous fourth energy level ***N*** and in groups of 10 elements of ***d***-sublevels of the subsequent fifth energy level ***O***, which caused the groups of "lanthanides" and "actinides" to be removed from the tabular forms of ***f***-sublevel.

The above analysis allows us to assert that the long-period **IUPAC** table pushed the above problem of "harmony" to one block **E**, in which the discovery of new chemical elements confirms the need to withdraw 64 elements in the existing 18-group structure outside the table, and in block **F** outside the table there will be 108 chemical elements and so on in an increasing progression.

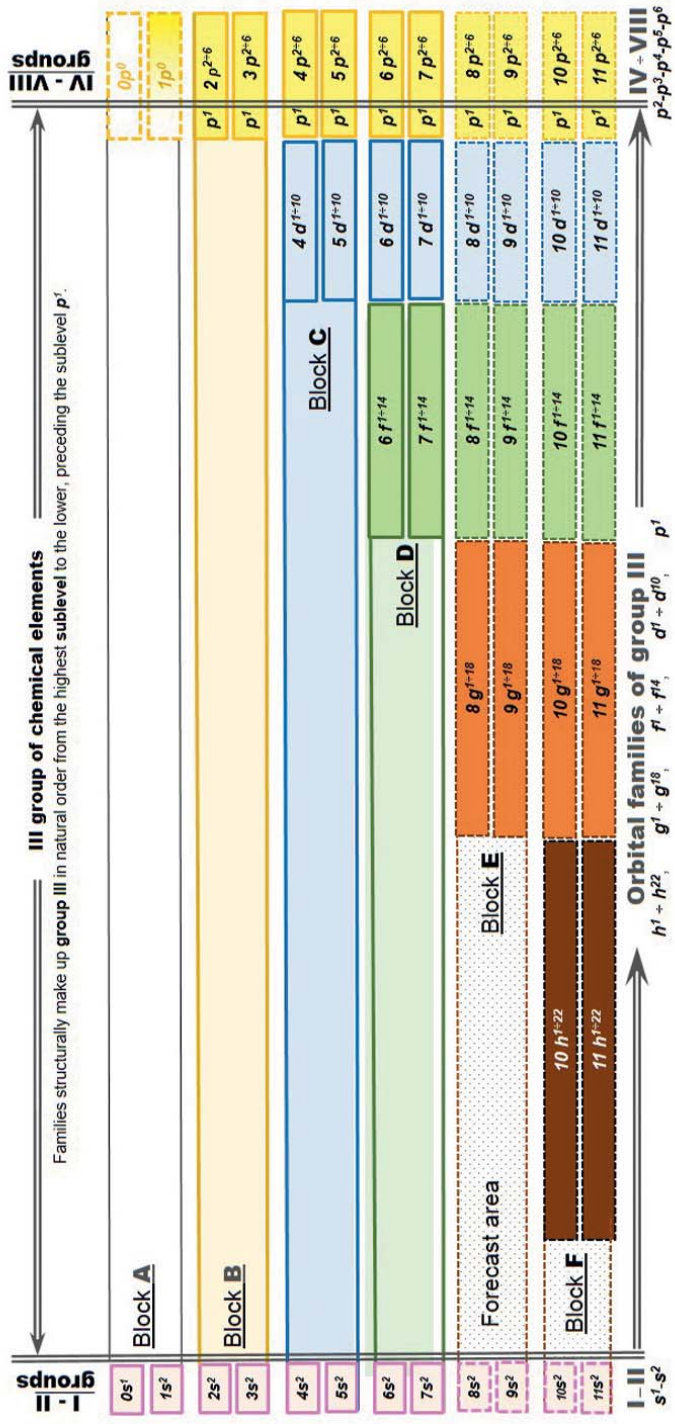
Thus, the authors have systematized the formation of new chemical elements due to the structural mechanism of the electronic build-up of the elements energy sublevels, which do not directly affect the processes of chemical interaction.

However, being internal in relation to external valence, they should affect the physical properties of the substance, which for the discovered chemical elements is confirmed by the knowledge on "lanthanides" and "actinides" taken out from the Table. Structural analysis, in accordance with the above formula, makes it possible not only to formalize the position of boundary elements completing energy levels, but also to predict the structures of periods and energy levels of undiscovered chemical elements for new paired periods **8** and **9** of block **E**, paired periods **10** and **11** block **F**, and so on.

The method of Structural Analysis applied by the authors made it possible to formulate new patterns indicated in the Three-dimensional matrix of chemical elements and which allowed to eliminate the shortcomings of the existing tabular forms.

Table 12

The structure and orbital structure of the families of the III group of chemical elements



The generalized concept of cyclicity in the structure of the Three-dimensional periodic matrix is given in Table 13. The Table analysis suggests that the three-dimensional matrix has practically eliminated the shortcomings in all five points, formulated by *N. N. Semyonov.* The mechanisms of energy interactions between the shells of chemical elements in the process of molecules formation from homogeneous and heterogeneous atoms are fundamental in materials science.

Table 13

General structural analysis of cyclicity and periodicity

STRUCTURE	Mendeleev Table	IUPAC Table	Three dimensional Matrix / GYS
Blocks	**A-B-C-D-**	**A-B-C-D-**	**A-B-C-D-(E-F-G-)**
Periods	0-1, 2-3, 4-5, 6-7	1, 2, 3, 4	0-1, 2-3, 4-5, 6-7, (8-9, 10-11, 12-13)
Groups	**I ÷ VIII**	**I ÷ XVIII**	**I ÷ VIII**
Element families	{metals **VIII**gr}, {**La**}, {**Ac**}	{**La**}, {**Ac**}	**in group III**
Energy levels	***K-L-M-N-***	***K-L-M-N-***	***K-L-M-N-*** (***O-P-Q-***)
Valent orbitals	s^2, p^6	s^2, p^6	s^2, p^6
Boundary elements	He^2, Ne^{10}, Zn^{30}, Yb^{70}	He^2, Ne^{10}, Zn^{30}, Yb^{70}	He^2, Ne^{10}, Zn^{30}, Yb^{70}, (Yn^{138})
External families	{d^{10}}, {**La**}, {**Ac**}	{**La**}, {**Ac**}	–
Forecasting of elements	Unavailable	Unavailable	Available

It should be noted that most of the elements, stable and unstable ones, can consistently exist under special physical conditions, including high pressures and temperatures, strong and weak fields of various energetic nature, significantly different from the "normal" living conditions on the Earth, and they also show new still unknown to science properties and energy states of elementary particles, chemical elements and materials.

Table 14 provides comparisons, and points out the novelty of the three-dimensional periodic matrix of chemical elements in comparison with the tables by D. I. Mendeleev and **IUPAC**. Figure 8 shows the Three-dimensional periodic matrix of chemical elements with analytical parameters, and Fig. 9 illustrates a full view of the three-dimensional matrix.

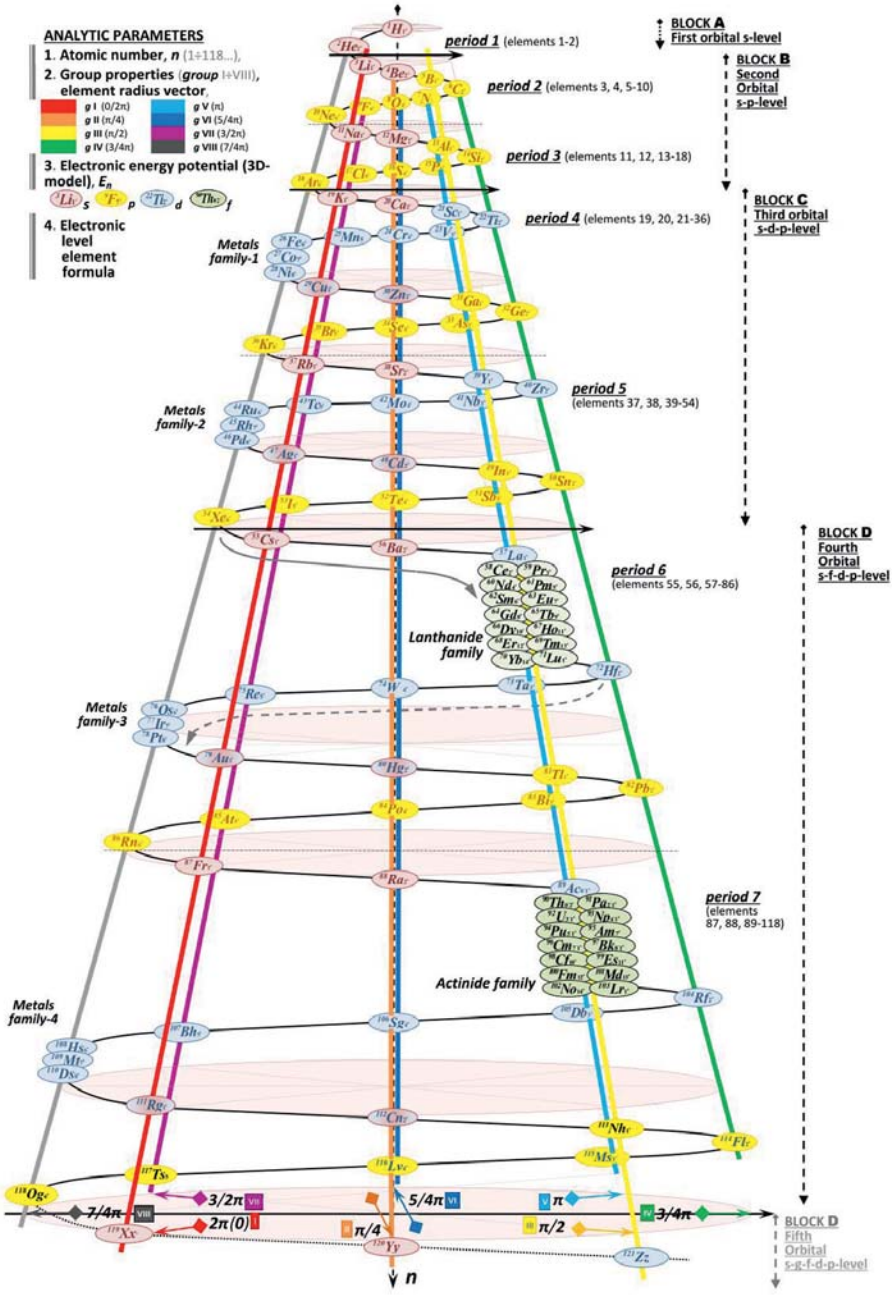


Fig. 8. **Three-dimensional matrix of chemical elements with analytical parameters**

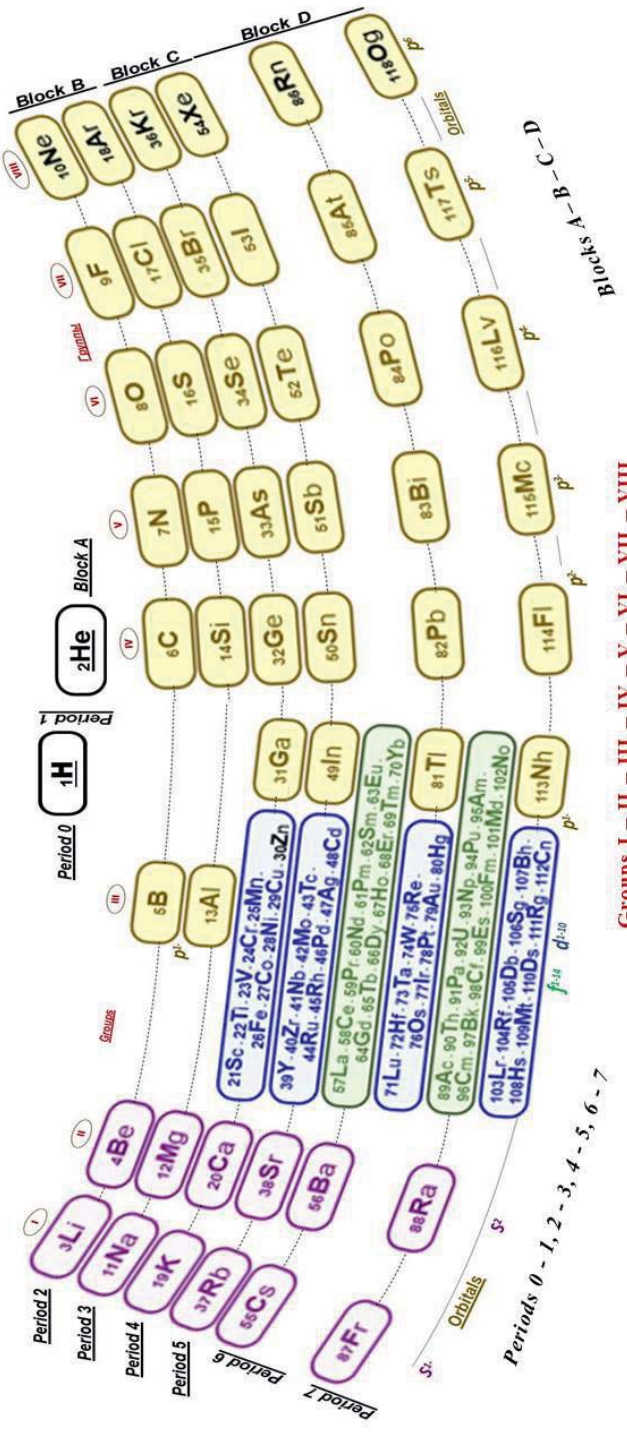


Fig. 9. **Flat drawing of the three-dimensional system of chemical elements**

Table 14

Comparison of the tables by D. I. Mendeleev, IUPAC and TDMCE

Mendeleev Table	**IUPAC Table**	**TDMCE/ GYS**	**Novelty**
no cell continuity		complete continuity (no empty cells)	Three-dimensional Matrix model - continuously expanding eight-sector spiral
I - II - III ÷ VIII	**I ÷ XVIII**	**I - II - III - - IV ÷ VIII**	is based on 8 valence groups of elements
lanthanides and actinides are taken out of the tables		families of group **III** are part of matrices and are presented in table 2	all families of chemical elements are included in group **III**
{**La**}, {**Ac**}	{**La**},{**Ac**}		
Mendeleev Table	**IUPAC Table**	**TDMCE/ GYS**	**Novelty**
K-L-M-N-	***K-L-M-N-***	***K-L-M-N-*** and new levels (***O-P-Q-***)	energy levels of chemical elements
He^2, Ne^{10}, Zn^{30}, Yb^{70}	**He^2, Ne^{10}, Zn^{30}, Yb^{70}**	**He^2, Ne^{10}, Zn^{30}, Yb^{70}, (Yn^{138})**	boundary elements with complete electronic structure
no forecast of new elements		structural ordinal analysis is not limited	forecasting of new chemical elements

8. Prediction of new chemical elements

Of the known chemical elements of the short-period system, only 83 are found on Earth, the lightest of which is hydrogen (its atomic number is Z = 1), and the heaviest is uranium (Z = 92). In fact, only those elements survived in the solar system and on the planet Earth, the lifetime of which is longer than the age of the Earth (4.5 billion years). Others broke up and did not survive to this day. Uranus, which has a half-life of about 4.5 billion years, is still decaying. It is a radioactive element [21]. In nature, stable formations (elements nuclei, consisting of different number of protons and neutrons) exist only up to lead and bismuth, followed by a small area that includes thorium and uranium found on Earth. But as soon as the ordinal number of an element exceeds the number of uranium, its lifetime decreases sharply. For example, the nucleus of element 100 is by 20 times less stable than the nucleus of uranium, and this instability only intensifies further due to the spontaneous nuclear fission. With further attempts to obtain new elements, scientists around the

world face the increasing difficulty of synthesis. And only a tiny part of nuclear research ends with the successful synthesis of a new element. No laboratory can be compared with a neutron star, which can create other forms of matter. During the life of stars, there take place nuclear reactions which are beyond the human's power. Scientists are trying to find new types of elements, but experiments in search of "natural" superheavy elements still continue [22]. There arises a question: What is the practical use of such a pricey event to create new unstable elements? Despite this, the development of experimental methods to obtain elements led to the expansion of the periodic tables due to transuranic elements, and the problem of the table boundary remains one of the most fundamental in modern theoretical chemistry [24].

The representation of the nuclear-shell (orbital) structures (**NOS**) formulated by the authors makes it possible to predict the block pattern for the emergence of new elements, with the formation of families of ***d-, f-, g-, h***-orbitals in the reverse order between ***s-*** and ***p***-orbitals in the third group. There is a special prospect to predict chemical elements of the families of group **III** outside block **D**. The reason is that if the cyclic families of lanthanides and actinides of the **III** group in the paired block **D** consist of 14 ***f***-elements in each period, then the families of elements in the paired block **E** will consist of 32 ***g-f***-elements in each period, and the families of elements in the paired block **F** will consist of 54 ***g-f-***elements in each period, and so on. The issues that determine the possibility of the existence of predicted elements in special physical conditions have not been considered yet. However, taking into account the "theory of stability areas" supported by the discoverer of the element **Og^{118}**, Academician of the Russian Academy of Sciences *Yu. Ts. Oganesyan*, such existence of potential chemical elements is possible [21, 22], and the question of predicting new elements arises again. The structural analysis NOS makes it possible to predict the structure of so far unknown elements in the periodic system within 119–168 elements of the 8th period and within 169–218 elements of the 9th period of the block structure **E**, as well as within 219–290 elements of the **10th** period and within 291-362 elements of the **11th** period of the block structure **F** and subsequent blocks.

For the first time, a preliminary structural analysis of the short-period table is presented based on the forecast of four new periods of predicted chemical elements (Tables 15, 16). Thus, the idea of block structure made it possible to substantiate electronic-level formulas, including the alleged new chemical elements of the **5th** block **E** with numbers 119 to 218.

In the future, the use of digital models for chemical research will be considered, which can significantly increase the effectiveness of computer mod-

Extrapolation of the Periodic Table by D. I. Mendeleev (proton charge and nuclear mass *N+ MP*) for block E

(proton charge and nuclear mass *MP+N*)

Block	Period	Groups of chemical elements I	II	III	IV	V	VI	VII	VIII	IX	X
D	6	Cs55 135	Ba56 137	175 71Lu	179 72Hf	181 73Ta	184 74W	186 75Re	190 76Os	192 77Ir	195 78Pt
		197 79Au	200 80Hg	Tl81 204	Pb82 207	Bi83 209	Po84 210	At85 210	Rn86 222		
	7	Fr87 217	Ra88 220	262 103Lr	265 104Rf	268 105Db	271 106Sg	268 107Bh	269 108Xs	278 109Mt	280 110Ds
		281 111Rg	285 112Cn	Nh113 286	Fl114 290	Mc115 288	Lv116 293	Ts117 294	Og118 294		
E 1,75	8	119 / 336	120 / 338	153 / 435	154 / 437	155 / 440	156 / 442	157 / 445	158 / 449	159 / 452	160 /454
		161 / 457	162 / 460	163 / 463	164 / 465	165 / 468	166 / 473	167 / 475	168 / 478		
	9	169 / 483	170 / 487	203 / 582	204 / 585	205 / 586	206 / 590	207 / 593	208 / 600	209 / 578	210 / 581
		211 / 605	212 / 608	213 / 609	214 / 614	215 / 616	216 / 619	217 / 622	218 / 625		

Legend:

Element field color							
Orbital	*s-*	*p-*	*d-*	*f-*	*g-*	*h-*	
Number of electrons	1÷2 max	1÷6 max	0÷10 max	0÷14 max	1÷18 max	1÷22 max	1÷26 max

For block E
$n \equiv m_{P^+}$
$m_{P^+} / m_{P+N} = 1{,}75$

Element families in group III *(g=18, f=14)*, **block E** *(2x32 elements)*

121 346	122 349	123 352	124 355	125 358	126 361	127 364	128 367	129 370	130 373	131 376	132 378	133 381	134 384	135 387	136 390	137 393	138 396
g1	*g2*	*g3*	*g4*	*g5*	*g6*	*g7*	*g8*	*g9*	*g10*	*g11*	*g12*	*g13*	*g14*	*g15*	*g16*	*g17*	*g18*
139 399	140 402	141 404	142 407	143 410	144 413	145 415	146 418	147 421	148 424	149 427	150 430	151 433	152 436				
f1	*f2*	*f3*	*f4*	*f5*	*f6*	*f7*	*f8*	*f9*	*f10*	*f11*	*f12*	*f13*	*f14*				

period 8 — *Σ=32*

+

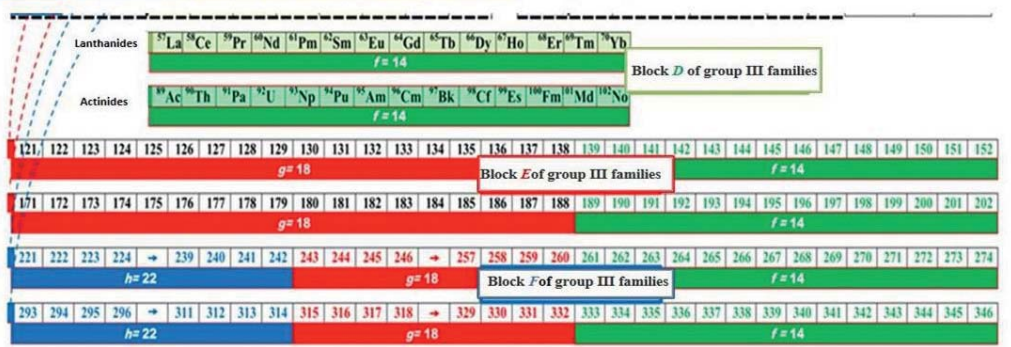
171 490	172 493	173 496	174 499	175 502	176 505	177 508	178 510	179 513	180 516	181 519	182 522	183 525	184 528	185 531	186 533	187 536	188 539
g1	*g2*	*g3*	*g4*	*g5*	*g6*	*g7*	*g8*	*g9*	*g10*	*g11*	*g12*	*g13*	*g14*	*g15*	*g16*	*g17*	*g18*
189 542	190 545	191 548	192 551	193 554	194 557	195 560	196 563	197 565	198 568	199 571	200 574	201 577	202 579				
f1	*f2*	*f3*	*f4*	*f5*	*f6*	*f7*	*f8*	*f9*	*f10*	*f11*	*f12*	*f13*	*f14*				

period 9 — *Σ=32*

Table 16

Block structural analysis in the table of D.I. Mendeleev for blocks E and F

Block	Groups of chemical elements								IX	X
	I	II	III	IV	V	VI	VII	VIII		
A	H^{1}							He^{2}		
B	Li^{3}	Be^{4}	B^{5}	C^{6}	N^{7}	O^{8}	F^{9}	Ne^{10}		
	Na^{11}	Mg^{12}	Al^{13}	Si^{14}	P^{15}	S^{16}	Cl^{17}	Ar^{18}		
C	K^{19}	Ca^{20}	^{21}Sc	^{22}Ti	^{23}V	^{24}Cr	^{25}Mn	^{26}Fe	^{27}Co	^{28}Ni
	^{29}Cu	^{30}Zn	Ga^{31}	Ge^{32}	As^{33}	Se^{34}	Br^{35}	Kr^{36}		
	Rb^{37}	Sr^{38}	^{39}Y	^{40}Zr	^{41}Nb	^{42}Mo	^{43}Tc	^{44}Ru	^{45}Rh	^{46}Pd
	^{47}Ag	^{48}Cd	In^{49}	Sn^{50}	Sb^{51}	Te^{52}	I^{53}	Xe^{54}		
D	Cs^{55}	Ba^{56}	^{71}Lu	^{72}Hf	^{73}Ta	^{74}W	^{75}Re	^{76}Os	^{77}Ir	^{78}Pt
	^{79}Au	^{80}Hg	Tl^{81}	Pb^{82}	Bi^{83}	Po^{84}	At^{85}	Rn^{86}		
	Fr^{87}	Ra^{88}	^{103}Lr	^{104}Rf	^{105}Db	^{106}Sg	^{107}Bh	^{108}Xs	^{109}Mt	^{110}Ds
	^{111}Rg	^{112}Cn	Nh^{113}	Fl^{114}	Mc^{115}	Lv^{116}	Ts^{117}	Og^{118}		
E	119	120	153	154	155	156	157	158	159	160
	161	162	163	164	165	166	167	168		
	169	170	203	204	205	206	207	208	209	210
	211	212	213	214	215	216	217	218		
F	219	220	275	276	277	278	279	280	281	282
	283	284	285	286	287	288	289	290		
	291	292	347	348	349	350	351	352	353	354
	355	356	357	358	359	360	361	362		



elling methods. Taking into account the crucial role of materials science, it is appropriate to conclude: "*whoever masters digital information tools earlier than others can become a leader in technological paradigm in many spheres of human life*" [13,20].

Key conclusions on the new arrangement of chemical elements

1. The periodic law and its tabular presentation of chemical elements is the **greatest discovery in chemistry**. Mendeleev's two-dimensional tables of chemical elements as well as IUPAC tables played a pivotal role in the development of chemistry. However, the fact that there are currently more than **500 options** for their modernization, including the statements by N. N. Semyonov, indicate the **need to continue work** in this direction at a **new level** of comprehension.

2. First of all, it is **the development of a physical model** for the likely processes of the **origin of chemical elements**. The concept of the Universe as an expanding system presented in Stephen Hawking's and Martin Rees's papers is a compelling evidence. In our opinion, the physical interpretation (model) of the origin and development of the Universe makes it possible to formulate a more general concept of the process the chemical elements are structured by and its representation in the form of an expanding conical spiral as well as to draw a number of new conclusions.

3. Like the Universe, the proposed Three-dimensional periodic Matrix is an expanding system (spiral) and a continuous sequence in the arrangement of elements from Hydrogen (1) and Helium (2) to Oganesson (118) with the inclusion of lanthanides and actinides and possible inclusion of other information preserving the periodicity for the groups of elements and the valence framework of the matrix, proposed by D. I. Mendeleev.

Hydrogen and helium are obviously structure-forming elements: all other elements originated on their basis.

4. The authors formulated the concept of **cyclicity** in the arrangement of the horizontal levels of chemical elements in the blocks of the three-dimensional matrix of chemical elements. Each of the blocks provides an approximate equality of the neutrons — protons mass ratio in the chemical elements nuclei. **There has been formulated the pattern of 4 levels of block cyclic structure in the existing system of chemical elements**. The blocks additionally include all cluster formations, as well as the families of lanthanides and actinides. New patterns of periodicity in the block matrix structure of chemical elements from

block **A** to block **D** were obtained, combining the periods presented in the tables of chemical elements by D. I. Mendeleev and IUPAC.

5. Based on the concept of **cyclicity, the structures of electron shells are presented** for the known 118 elements in four blocks **A, B, C, D**, which also allows obtaining electron-orbital formulas, including the formulas for new elements (119-218) of block **E** of the periodic system and the subsequent block **F**. There have been presented serial numbers and nuclear masses **for 100 new elements** in block **E**. Elements 119 and 218 ought to have been named after N. N. Semyonov Sm^1 and Sm^2.

6. It should be noted that a **progressive amount of new elements** is arranged in group **III** of the three-dimensional matrix and focus should be made on the presence of chemical elements in this group for blocks **C, D** and subsequent ones, the number of which is progressively increasing, especially for new blocks **E** *and* **F.** *100 years ago* this *circumstance made it necessary* to move the groups of lanthanides and actinides outside the D. I. Mendeleev and IUPAC tables.

7. Thus, the three-dimensional matrix of chemical elements is a more **general structure to continue generalizing main features of chemical elements** (their valence, polyvalence and valence orbitals in the tables by D. I. Mendeleev and IUPAC). Its three-dimensional nature and the concept of cyclicity made it possible to make a broader generalization, and the **tabular forms by D. I. Mendeleev and IUPAC** are included in its composition and shown in Fig. 8 and Fig. 9 as a layout.

8. The use of the three-dimensional matrix of chemical elements makes it possible to apply mathematical methods and create digital models for the interaction of chemical elements with each other enabling to obtain new types of molecules for new materials.

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Table of contents

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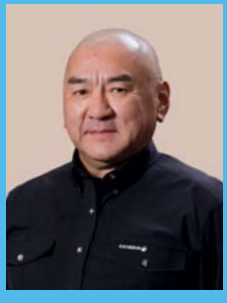

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