

On the Necessity of Using Element No.155 in the Chemical Physical Calculations: Again on the Upper Limit in the Periodic Table of Elements

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It is shown how the properties of different elements of the Periodic System of Elements can be obtained using the properties of the theoretically predicted heaviest element No.155 (it draws the upper principal limit of the Table, behind which stable elements cannot exist). It is suggested how the properties of element No.155 can be used in the synthesis of superheavy elements. An analysis of nuclear reactions is also produced on the same basis.

1 Introduction

At the present time, we know about 20 lists of chemical elements (representing their most important properties such as atomic mass and radius, density, temperatures of melting and boiling, energy of ionization, etc.), which were suggested by their authors as periodic tables of the elements. These data were however obtained for, mainly, stable isotopes and numerous other radioactive isotopes that makes further interpolation of these properties onto superheavy elements quite complicate.

This is most important for planning further experiments whose task is synthesis new superheavy elements which approach to the recently predicted heaviest element No.155, whose atomic mass is 411.66 (the upper limit of elements in Mendeleev's Table of Elements behind which stable elements cannot exist). Thus, using the parameters of element 155 in the analysis of other elements, we will see in this paper how the properties of the elements behave with increasing their number in the Table.

2 Some peculiarities of the dependency between atomic mass of the elements and their numbers in the Table of Elements

Consider the dependency between atomic mass of the elements and their number in the Table of Elements. This dependency is well known in science and industry and is presented as numerous lists and tables. As is seen in Fig. 1, this dependency is well described by the exponential equation of the line of the trend. However, if we take more attention to this figure, we find numerous areas which destroy the common picture. Approximately smooth line continues from the origin of coordinates to almost the end of Period 6 (No.83, 208.98, Bismuth). This is the last stable isotope, after whom all elements of the Table have an artificial (radioactive) origin, except of Thorium (No.90, 232.038), Protactinium (No.91, 231.036) and Uranium (No.92, 238.029). This is their order in the family of actinides. Period of half-decay of these natural elements consists many thousand years. It is easy to find in the figure that valuable deviations from the line of the trend are present in the region from Bismuth to element 104, then

to element 119 where the deviations from the line of the trend are high (especially — in the region of the already synthesized superheavy elements 104–118).

This is seen more obvious in Fig. 2, where the absolute deviations of the atomic masses are presented. These are deviations between the data of the Table of elements and the result obtained after the equation

$$y = 1.6143 x^{1.0981}, \quad R^2 = 0.9969, \quad (1)$$

where y is the atomic mass, while x is the number in the Table of Elements.

It should be noted that mass number is an integer equal to the common number of nucleons in the nucleus. Mass number of an isotope is equal to the numerical value of its mass, measured in atomic mass units (a.m.u.) and approximated to a near integer. A difference between the mass numbers of different isotopes of the same element is due to the different number of neutrons in their nuclei.

It is seen in the figure that this difference does not exceed 4 a.m.u. in the first five periods and in lanthanides. This tendency still remain upto Bismuth after whom the deviations of actinides experience a positive shift: this means that the numerical values of the atomic masses presented in the Periodic Table are overstated for the region.

Then, after actinides, a region of the atomic masses of the elements of Period 7 (elements 104–118) is located. These elements were obtained as a result of nuclear reactions. As is seen, all deviations in this region are negative: this can mean a large deficiency of the numerical values of the atomic masses obtained in the nuclear synthesis producing these elements, incorrect calculations, or a lack of neutrons in the nuclei. All these in common resulted large deviations of the atomic masses upto 10–12 a.m.u.

Look at Fig. 1 and Fig. 2 again. Section of the line of the trend in the interval No.119–155 is manifested in Fig. 1 as a very straight line without any deviation, while the same section in Fig. 2 manifests deviations from 0.63 to 1.28. Once we get a ratio of the difference between the table and calculated numerical values of the atomic masses to the respective a.m.u., we obtain Fig. 3 which shows the respective de-

viations in percents. As is seen in the figure, most valuable deviations are located in the left side (upto the first 20 numbers). This is because the respective elements of the Table of Elements bear small atomic masses under high difference of a.m.u., i.e. the larger numerator results the larger ratio. It is necessary to note that the results presented in this figure are within 3–5%. Most lower results are located in the scale from element 104 to element 118: according to our calculation, the deviations are only 0.2–0.3% there.

In order to exclude any influence of our calculations onto the creation of the line of the trend, we study the dependency “atomic mass — number in the Table” in the scale from element 1 to element 118 according to the equation

$$y = 1.6153 x^{1.0979}, \quad R^2 = 0.9966. \quad (2)$$

As a result we obtain that the general shape of the deviations and their numerical values are actually the same as the results obtained due to equation (1). So forth, the next particular equations were taken under analysis:

$$\text{elements 1–54: } y = 1.6255 x^{1.0948}, \quad R^2 = 0.9922, \quad (3)$$

$$\text{elements 55–118: } y = 1.8793 x^{1.0643}, \quad R^2 = 0.9954, \quad (4)$$

$$\text{elements 119–155: } y = 1.5962 x^{1.1009}, \quad R^2 = 1.0. \quad (5)$$

These sections gave no any substantial change to the previous: the ultimate high difference of the deviations taken in 3 points of 120 was 0.7% for element 111, 0.95% for element 118, and 1.5% for element 57.

3 Why one third of the elements of the Table of Elements is taken into square brackets?

94 chemical elements of 118 already known elements are natural substances (contents of several of them consists, however, of only traces). Rest 24 superheavy elements were obtained artificially as a result of nuclear reactions. Atomic mass of an element in Table of Elements is presented by the average atomic mass of all stable isotopes of the element with taking their content in the lithosphere. This average mass is presented in each cell of the Table, and is used in calculations.

If an elements has not stable isotopes, it is taken into square brackets that means the atomic mass of most long living isotope or the specific isotope contents. There are 35 such elements. Of those 35, elements from 93 to 118 are actinides and artificially synthesized superheavy elements. Hence, one third of 118 elements (known in science at the present time) bears undetermined atomic masses.

Fig. 4 shows common number of isotopes of all elements of the Table of Elements. Location of all elements can be described by the equation of parabola with a high coefficient of real approximation. As is seen, the descending branch of the parabola manifest that fact that the heavier element in the Table (the larger is its number) the lesser number of its isotopes. This tendency lads to decreasing the number of isotopes upto 1 at element 118.

4 Synthesis of superheavy elements and the upper limit of the Periodic Table

Because number of the isotopes reduces to 1 in the end of Period 7, the possibility of Period 8 and Period 9 (each consisting of 50 elements) in the Table of Elements suggested earlier by Seaborg and Goldanskii [1, 2] seems non-real. At the same time, Seaborg suggested a possibility of the synthesis of a “magic nucleus” consisting of 114 protons and 184 neutrons: according to his suggestion, this nucleus should be the centre of a large “island of stability” in the sea of spontaneous decay. Goldanskii told that the “isthmus of stability” may be a region where isotopes of the elements bearing nuclear charges 114, 126, and even 164 may be located. Flerov [3], when analysed studies on the synthesis of superheavy elements, claimed that the elements should give us a possibility for answering the question: are the elements bearing nuclear charges 100–110 located at the real end of the Table of Elements, or more heavy nuclei exist in the Nature? There are many studies of the conditions of nuclear reactions. For instance, in already 1966, Strutinski [4] theoretically predicted a valuable increase of stability of nuclei near the “magic numbers” $Z = 114$ and $N = 184$. His calculation was based on the shell model of nucleus (this model won Nobel Prize in physics in 1963 [5, 6, 7]).

In 1973, Oganessian in Dubna (Russia) and a group of German scientists in Darmstadt (Germany) first used cold synthesis, where the “magic nuclei” were used as both a target and bombing particles [8]. In 1973, Oganessian claimed that elements with atomic numbers 160 and, maybe, 170, are hypothetically possible. However only two years later, he claimed that the properties of an element with number 400 and bearing 900 neutrons in its nucleus were theoretically discussed [9].

In addition to the indeterminacy of atomic masses in the synthesis of superheavy elements, Oganessian also told, in his papers, that we do not know limits in the Table of Elements behind whom superheavy elements cannot exist. According to his own words, “the question about limits of the existence of the elements should be addressed to nuclear physics” [10]. A few years later, in 2005, Oganessian claimed “this question is still open: where is the limit of chemical elements?” [11]. In 2006, in his interview to *Moscow News*, he set up the questions again: “is a limit there?” and “how many elements can exist?”. So forth, he tells in the interview: “We use modelling instead a theory. Each models approaches this system in a form of those known to us in analogy to the macroscopic world. However we still do not understand what is nuclear substance. Thus the question asked about a limit of the Periodic System is still open for discussion” [12].

In January 20–21, 2009, in Dubna, the international symposium celebrating the 175th birthday of Dmitri Mendeleev set up the question about limits of the Table of Elements, and the complete number of elements in it again. Some-

one suggested even a possibility of the synthesis of elements with numbers 150–200 [13]. However a few weeks later, in February 09, at a press-conference in Moscow, the participants claimed that “at present the scientists discuss a theoretical possibility of extending Mendeleev’s Periodic Table upto **150 elements**” [14].

In April 07, 2010, the world press claimed about the end of an experiment in which element 117 was synthesized (this experiment continued from July 27, 2009, until February 28, 2010). During these seven months, the experimentalists registered six cases where nuclei of the new element were born. This experiment was also based on the supposition that there is an “island of stability” near an element bearing parameters $Z = 114$ and $N = 184$. Lifespan of this island should be a few million years. However this target was not reached in the experiment. The research group of experimentalists in Dubna prepares next experiments which target synthesis of element 119 and element 120 [15].

In this connexion it is interesting those words said by Sigurd Hofman (the GSI Helmholtz Centre for Heavy Ion Research, Darmstadt), where he claimed about filling the Table of Elements upto its end in the close time. According to his opinion, atomic nuclei heavier than No.126 cannot exist, because they should have not the shell effect [16].

5 Discussion of the results

1. The considered dependency of atomic masses of the elements on their numbers in the Table of Elements cannot answer the question “where is the upper limit of the Table”.

Despite the coefficient of the line of the trend is very close to unit, it is easy to see that there are large deviations of the data, especially starting from the numbers of actinides and then so forth. Because all actinides bear similar chemical properties, selecting a segregate element in this group is quite complicate task. Besides, the possibility of different isotopic content in samples of the elements leads to a large deviation of the calculated atomic masses from the atomic masses given by the Table of Elements. This is related to one third part of all elements of the Table.

2. Next elements to actinides, i.e. a group of elements 104–118, were synthesized as a result of nuclear reactions, in a very small portions (only segregate atoms were produced). The way how the elements were produced makes a problem in the identification of them, and the large deviations of the data of the Table of Elements from the line of the trend. Hence, atomic masses attributed to these numbers in the Table of Elements, are determined very approximate. The line of the trend, which includes element 155, gives a possibility to exclude the deviations of the atomic masses.

3. Section 4 gave a survey of opinions on the structure of the Table of Elements, its limits, superheavy elements (their synthesis and the products of the synthesis), the search for an “island of stability”, and the technical troubles with the

nuclear reactions.

Many questions could be removed from discussion, if my recommendations suggested in [17], where I suggested the last (heaviest) element of the Table of Elements as a reference point in the nuclear reactions, would be taken into account. This survey manifests that the quantum mechanical approach does not answer the most important question: **where is the limit of the Periodic Table of Elements?** Only our theory gives a clear answer to this question, commencing in the **pioneering paper of 2005**, where the **hyperbolic law** — a new fundamental law discovered in the Table of Elements — was first claimed. This theory was never set up under a substantially criticism.

It should be noted that the word “discovery” is regularly used in the press when telling on the synthesis of a new element. This is incorrect in the core, because “discovery” should mean finding new dependencies, phenomena, or properties, while the synthesis of a new element is something like an invention in the field of industry, where new materials are under development.

4. Taking all that has been said above, I suggest to IUPAC that they should produce a legal decision about the use of element 155, bearing atomic mass 411.66, as a reference point in the synthesis of new superheavy elements, and as an instrument correcting their atomic masses determined according to the Table of Elements.

My theory I used in the calculations differs, in principle, from the calculations produced by the quantum mechanical methods, which were regularly used for calculations of the stability of elements. The theory was already approved with the element Rhodium that verified all theoretical conclusions produced in the framework of the theory with high precision to within thousandth doles of percent. Therefore there is no a reason for omiting the theory from scientific consideration.

6 Conclusions

Having all that has been said above as a base, I suggest an open discussion of the study **Upper Limit in Mendeleev’s Periodic Table — Element No.155** at scientific forums with participation of the following scientific organizations:

- International Union of Pure and Applied Chemistry (IUPAC);
- International Council for Science (ICSU);
- American Physical Society (APS).

This step should allow to give a correct identification to the chemical elements and substances, and also to plan new reactions of nuclear reactions with a well predicted result. In this deal, financial spends on the experimental research in nuclear reactions could be substantially truncated, because the result would be well predicted by the theory. The experimental studies of nuclear reactions could be continued as a verification of the theory, and aiming the increase of the experimental techniques. Thus, according to the last data of the

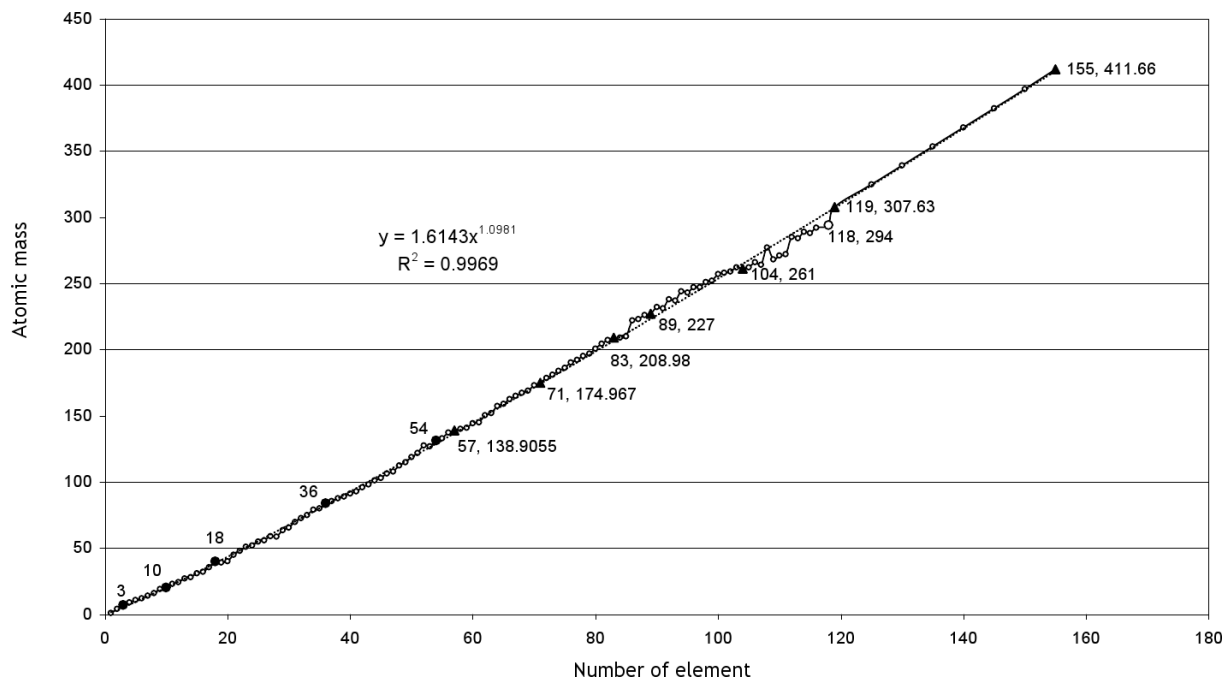


Fig. 1: Dependency between the atomic mass of the elements and their number in the Table of Elements (including element 155).

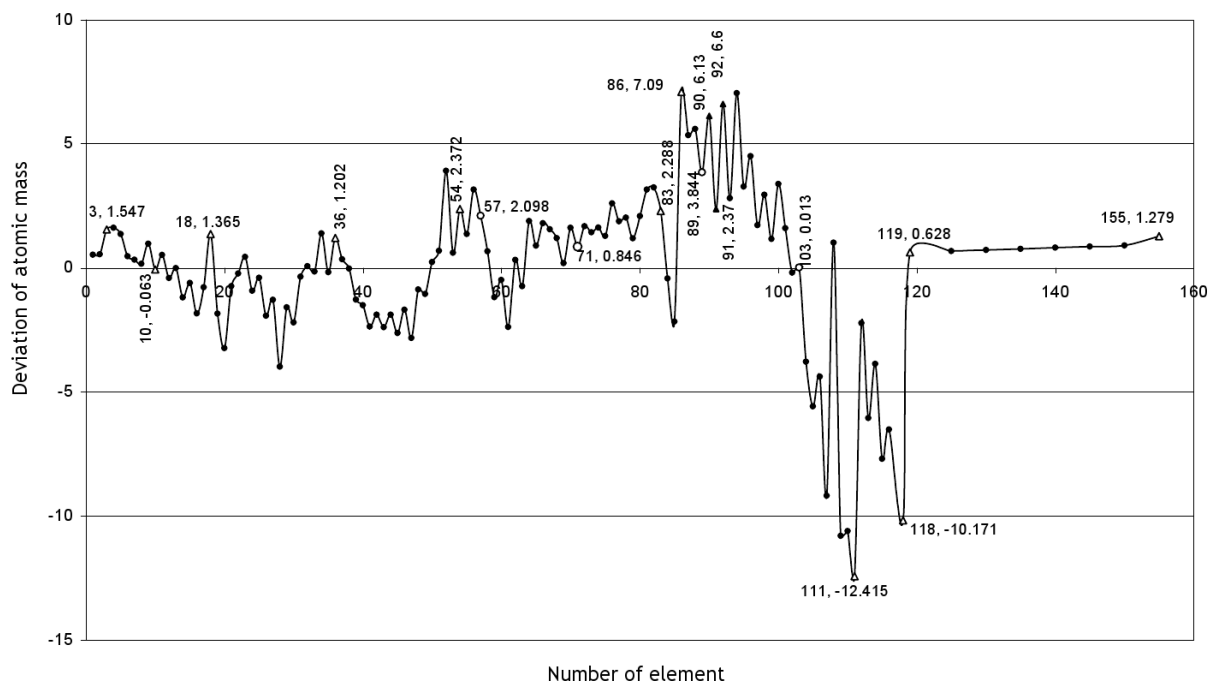


Fig. 2: Absolute deviations of atomic masses of the elements from the line of the trend (including element 155).

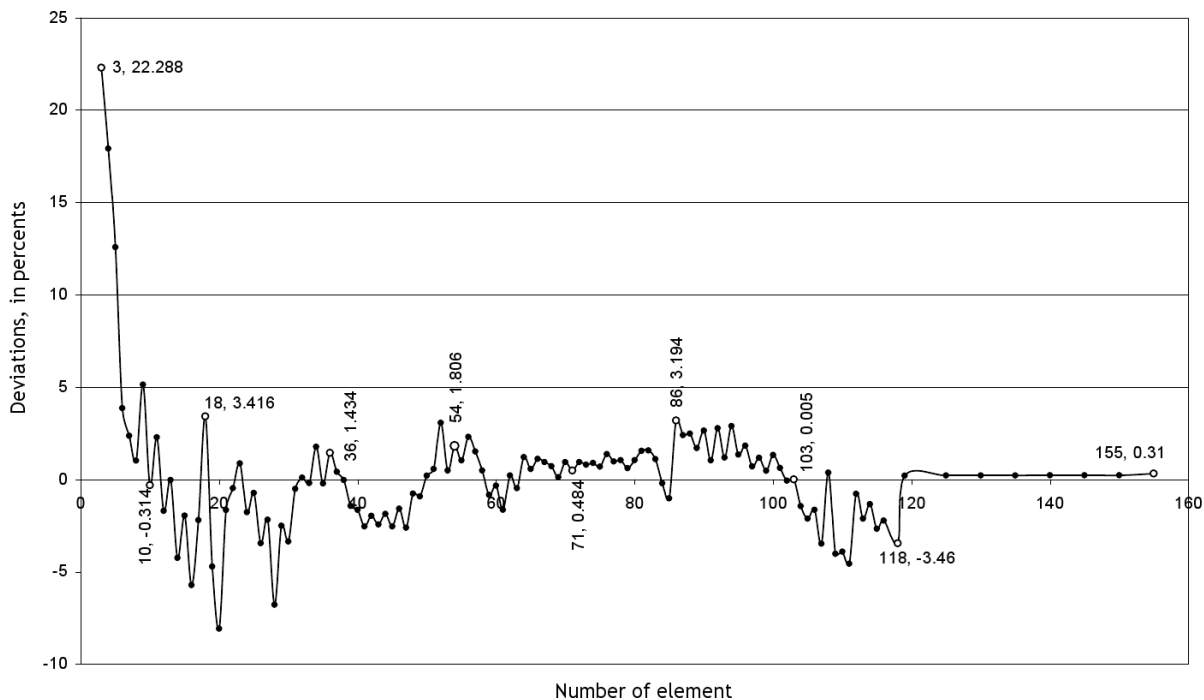


Fig. 3: Relative deviation of the atomic masses from the line of the trend, in percents.

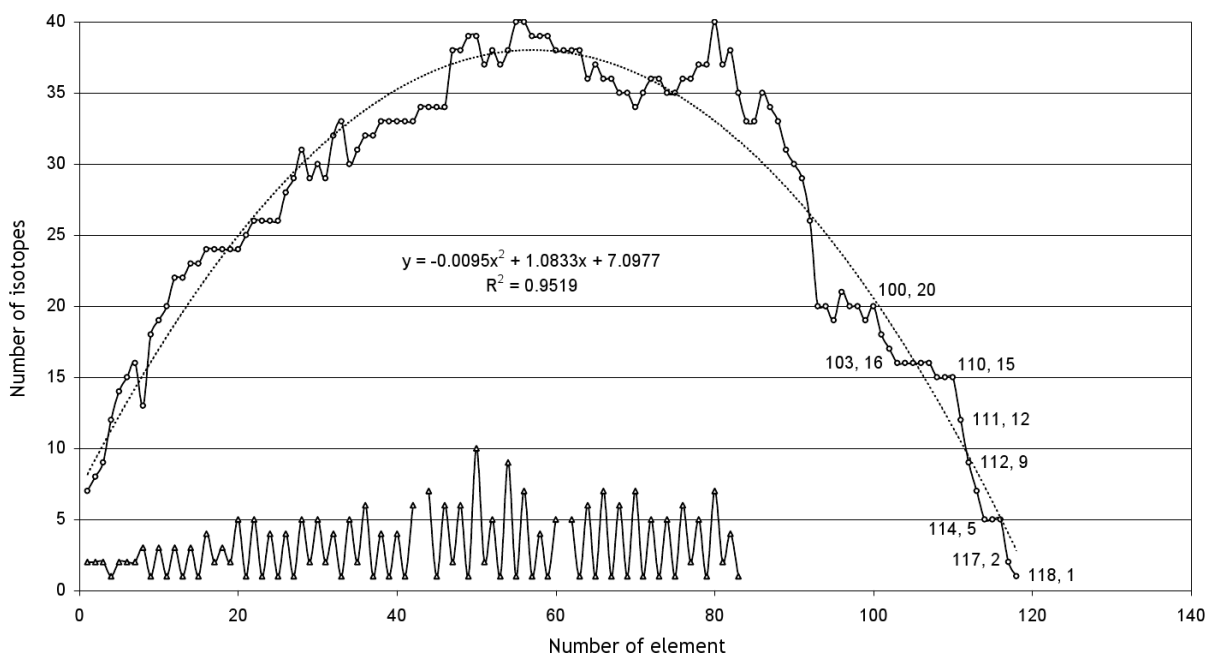


Fig. 4: Dependency between the number of the isotopes (3180) and the number of element in the Table of Elements. Location of the stable isotopes (256) is also shown. The data of Brookhaven National Laboratory, National Nuclear Data Center.

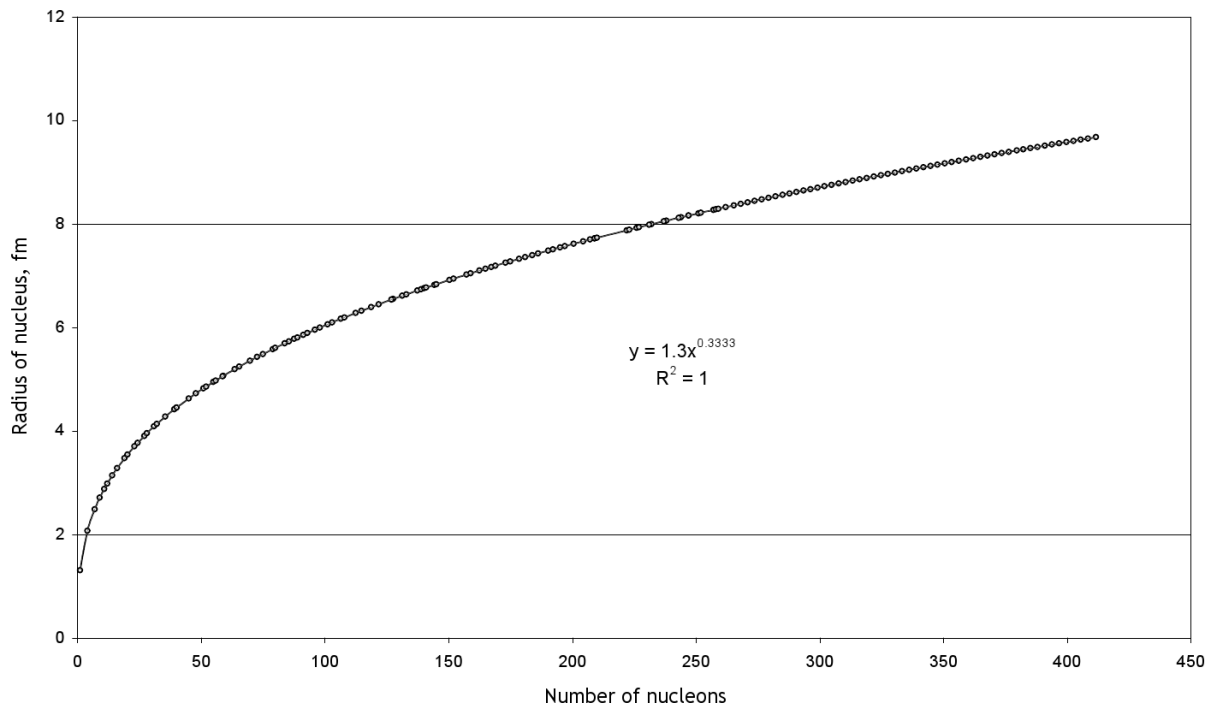


Fig. 5: Empirical dependency between the radius of the nucleus (fm) and the number of the nucleons.

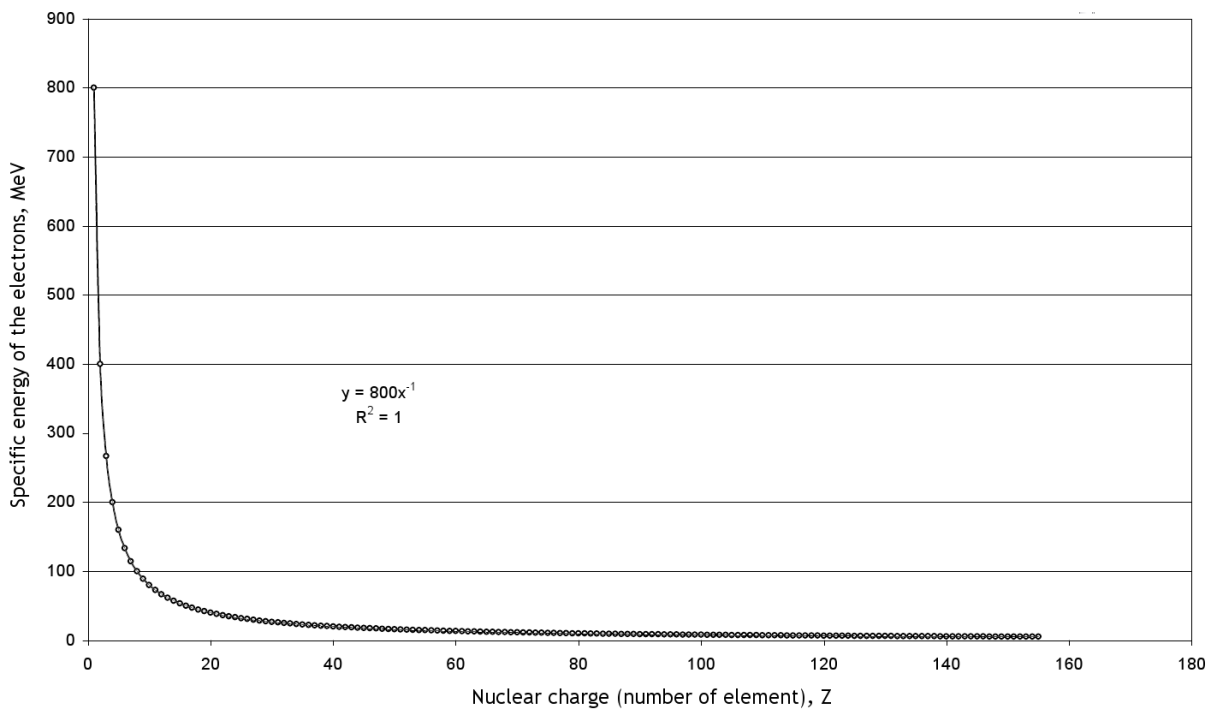


Fig. 6: Dependency between the critical energy of the electrons and the nuclear charge, according to formula $T = 800/Z$.

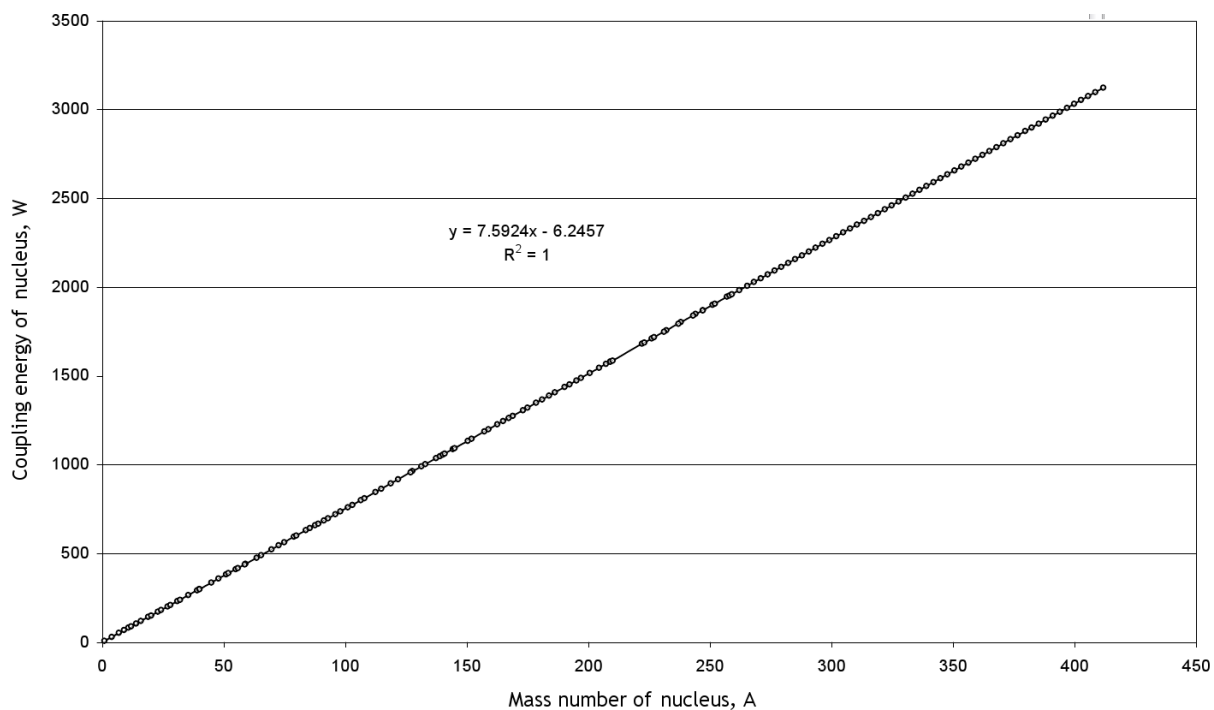


Fig. 7: Dependency between the coupling energy of the nuclei and the mass number (number of nucleons).

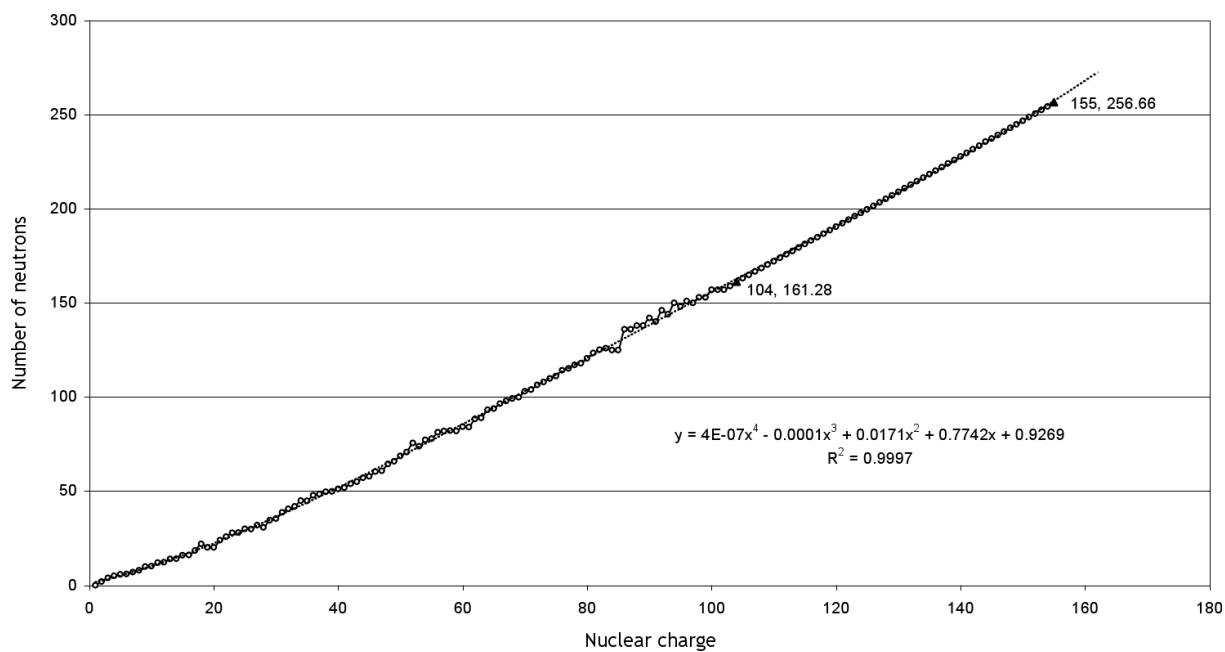


Fig. 8: Dependency between the number of neutrons and the number of protons in the atomic mass, for all elements of the Table of Elements. Our calculation data are given beginning from element 104.

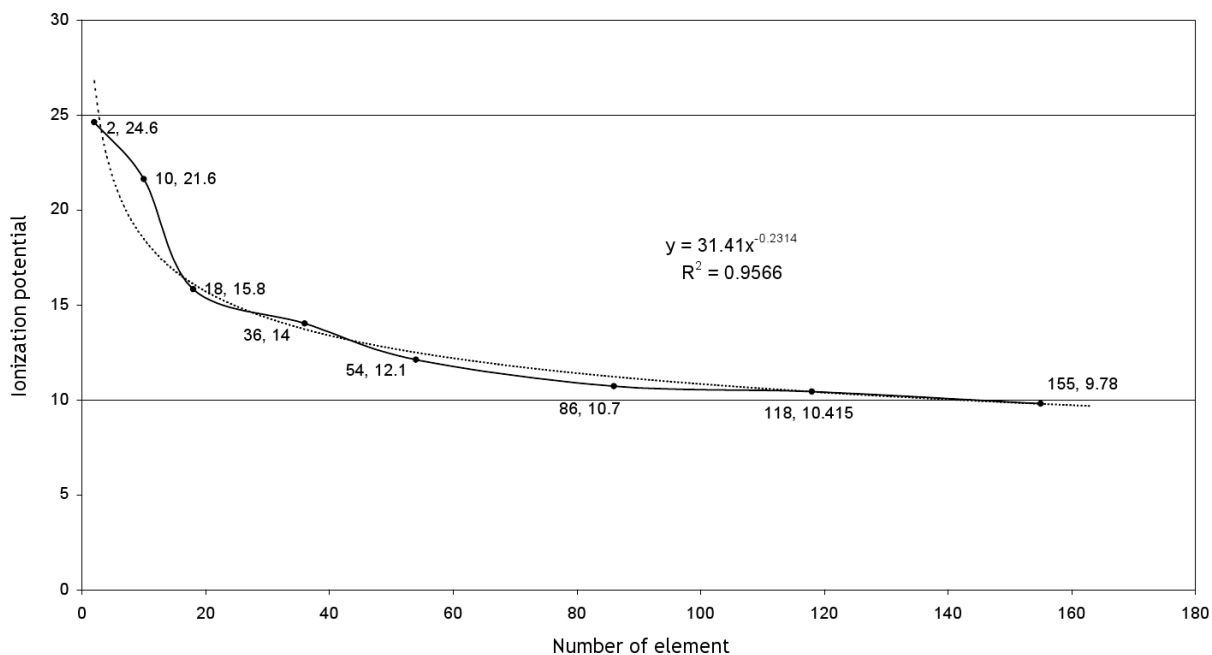


Fig. 9: Dependency between the ionization potential and the number of the elements (nuclear charge), for the neutral atoms of the elements ending the periods of the Table of Elements (including calculated element 118 and element 155).

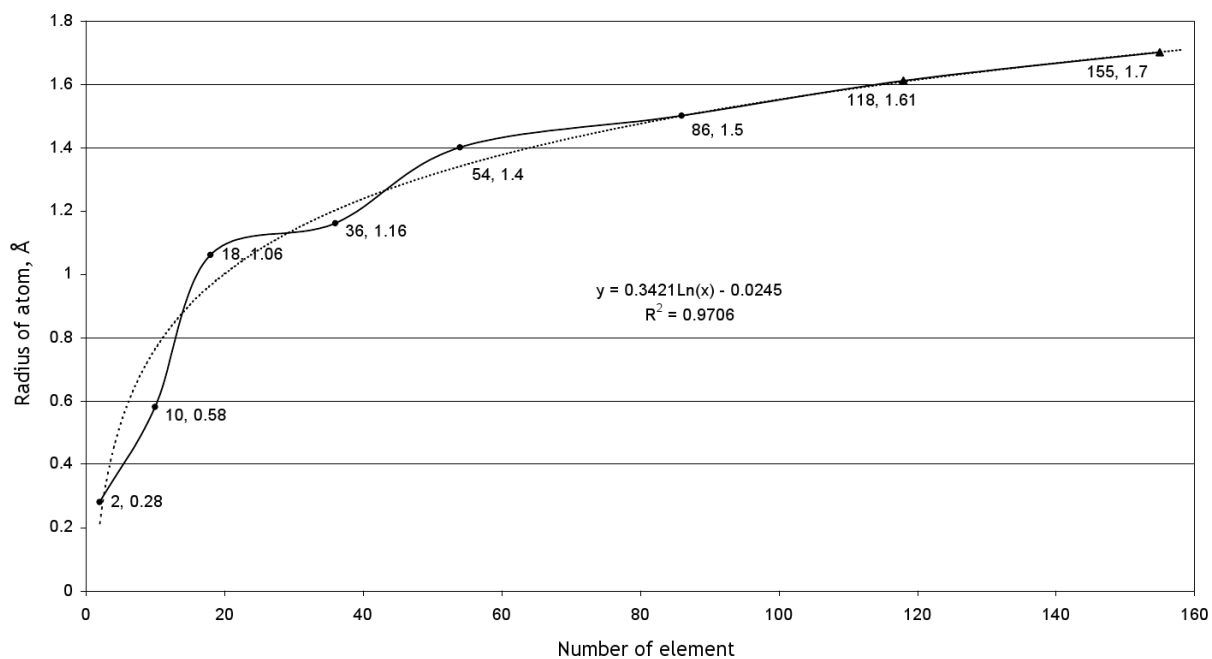


Fig. 10: Dependency between the atomic radius and the number of the elements in all periods of the Table of Elements, including the calculated elements No.188 in Period 7 and No.155 in Period 8.

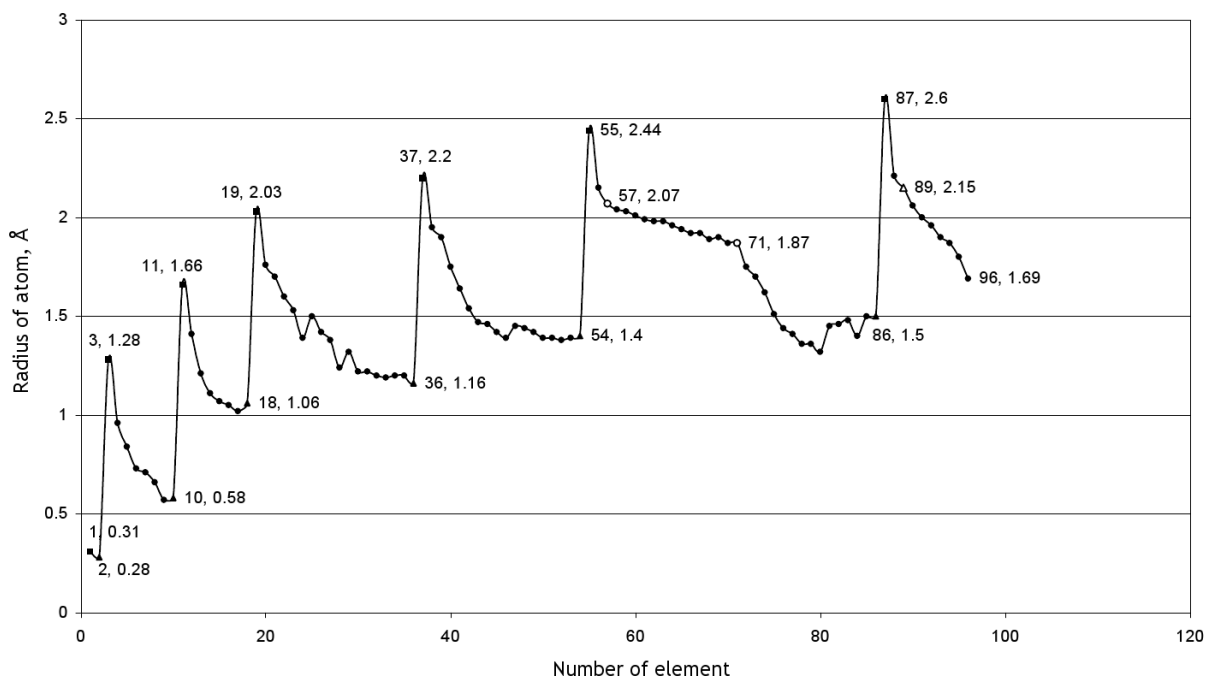


Fig. 11: Change of the numerical value of the atomic radius in each period with increasing number in the Table of Elements.

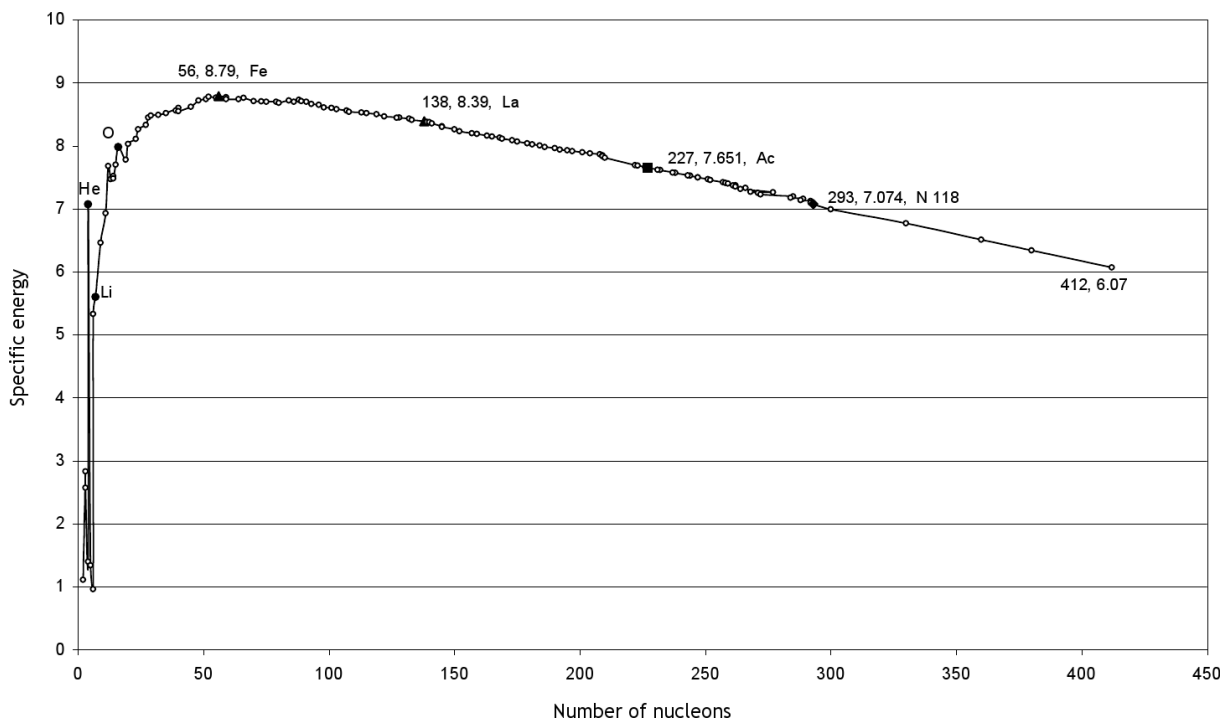


Fig. 12: Dependency between the specific energy of ther coupling in an atomic nuclei and the number of the nucleons in it.

List of Chemical Elements (on April 08, 2010), Ununseptium (No.117) bears atomic mass [295], while atomic mass of Unuoctium (No.118) is [294]. According to the calculation, produced in the framework of my theory, these quantities should be 301.95 and 304.79 respectively.

As was shown the theoretical studies according to the theory, and its comparing to the experimental data, the element bearing number 155 and atomic mass 411.66 a.m.u. answers all conditions necessary for including it into the Periodic Table of Elements.

Appendix I

As was already noted above, we took much attention to the dependency between atomic mass of the elements and their number in the Table of Elements. It was shown that the line of the trend continued upto No.155 provides obtaining very correct results. In verification of this fact, additional dependencies concerning the last element No.155 were studied [18].

Fig. 5 shows an empirical dependency between the radius of a nucleus and the number of nucleons in it (mass number). This graph manifests that this dependency is true upto element 155: the arc has the same shape without deviation along all its length.

Fig. 6 shows an arc, which manifests critical energies of the electrons for all elements of the Table of Elements, including No.155. A critical is that energy with whom energy loss for ionization and radiation become equal to each other. Formula for the critical energy is $T_{\text{crit}} = 800/Z$, where Z is the charge the nucleus (in units of the charge of the electron). As is seen from the graph, this formula is applicable to all elements of the Table of Elements.

Fig. 7 gives calculations of the coupling energy in nuclei. This graph shows that minimally energy required for destruction of the nucleus into its nucleons. It is seen, from the graph, that this dependency is strictly straight along all Table of Elements, including element 155.

Dependency between the number of the neutrons and the charge of the nucleus is shown in Fig. 8. As is seen, equation of the line of the trend describes, with a high level of probability ($R^2 = 0.9997$), the polynomial of the fourth order presented in the graph. This equation covers a large region along the axis x , from element 1 upto element 155 including. This dependency was also calculated, in order to compare it with the previous result, for a truncated region of the protons from element 1 upto element 104:

$$Y = 4E - 0.7x^4 + 2E - 0.5x^3 + 0.007x^2 + 1.0014x - 0.2176, \quad (6)$$

where $R^2 = 0.999$.

As is seen, certainty the level of the approximation differs only in 0.0007 from the previous. This manifests that fact that this dependency is as well true for the elements heavier than No.104, including element 155.

Appendix II

At the present time there are many versions of the periodic tables of elements, where each cell contains a property of a respective element (such as atomic radius, volume, density, first ionization potential, etc.). This information can also be obtained from the regular lists of the properties of chemical elements. This information has, however, a substantially lack: most data end in the beginning or the middle of Period 7.

Here we target continuing the list of numerous properties of the elements upto element 155, and also the compatibility of the properties with the reference data.

Fig. 9 shows a dependency between the ionization potential of the neutral atoms of the elements and the change of their nuclei. Each point corresponds to the last element of the period, from Period 1 to Period 6. The end of Period 7 and that of Period 8 were calculated according to the equation of the trend. As is seen, the points corresponding element 118 and element 155 are completely correlated with the initially data.

An important characteristic of atomic nucleus is the numerical value of its radius (see Fig. 10). This graph was created on the basis of the reference data known at the present time. This dependency between the atomic radius and the number of the last element in the period was created for all periods of the Table of Elements where it was possible. Coordinates of the points for Period 7 and Period 8 were calculated according to the equation of the line of the trend. As is easy to see, even the point of Period 6 meets the calculated data in complete.

Fig. 11 shows how the atomic radii change from period to period and inside each period of the Table of Elements (i.e. in the columns of the Table from up to down, and along the horizontal line). The upper maxima represent the beginning of the periods, while the lower points represent their ends. It should be noted that in lanthanides, which are No.57–No.71, a linear dependency between the radius and the number is observed. Further study of the correlation shows that there is a change of the linearity upto No.80 (Mercury). Another very interesting detail is that fact that, in the transfer from the alkaline to the alkaline earth elements, a valuable lowering the numerical values of the radii (for 0.3Å on the average) is observed in the periods.

In the calculations of nuclear reactions, the information about the stability of the nuclei as the systems consisting of protons and neutrons has a valuable meaning. The forces joining the particles altogether are known as nuclear forces; they exceed the forces of electrostatic and gravitational interactions in many orders.

The "resistance" of a nucleus can be bond by their coupling energy which shows the energy required for destroying the nucleus into its consisting nucleons (their number in the nucleus is equal to the mass number A expressed in atomic units of mass, a.m.u.). It is known that the sum of the masses

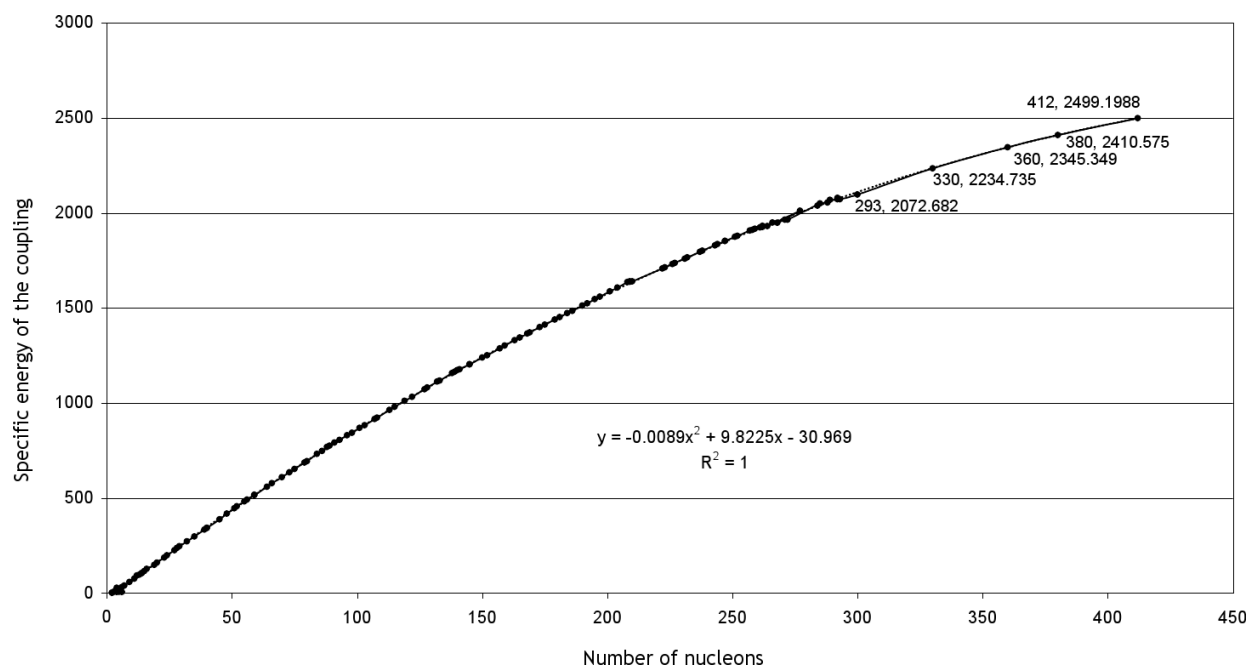


Fig. 13: Dependency between the specific energy of their coupling in an atomic nuclei and the number of the nucleons in it.

of the free nucleons is already larger than the mass of the nucleus they consist. The difference of the masses is known as the mass defect, according to which Einstein's formula $E = \Delta mc^2$ gives a possibility for calculating the coupling energy of the nucleus, thus the specific energy in it per one nucleon.

Fig. 12 shows an arc, created according to the table data, which manifests the dependency between the specific energy of the coupling in a nucleus and the number of nucleons in it [19]. The left side of the graph shows several isotopes of Hydrogen and the nucleus of several light elements, which bear close numerical values of the specific energy of the coupling and, thus, a large deviation of the data. The arc becomes more smooth with increasing the number of the nucleons. The maximum is reached in a region of $A = 50-60$, then it falls slowly down. The main advantage of this graph is that we produced the calculation beyond element 118 (at which the table data ended): we showed that the results of our calculation *completely meet* the table data known from the reference literature. Decreasing the specific energy of the coupling in the region of heavy nuclei is explained by increasing the number of protons that leads to increasing the Coulomb forces thus the need of additional neutrons appears.

This is well manifested in Fig. 13. The arc described by the quadratic three-term equation has the numerical value of real approximation $R^2 = 1$. In the region of the nuclei consisting of about 120 nucleons, this dependency is actually linear. Then this dependency transforms into an arc of a very large curvature radius. Data before the point of the nuclear charge 118 (203, 2072.582) were taken from the previous Fig. 12,

then the calculation was produced on the basis of the coordinates of the suggested last element No.155. As is seen, the arc approaches the horizontal location, where the number of nucleons in a nucleus is not affected by its coupling energy. According to our calculation, this happens in a region of the coordinates (530, 2670) — (550, 2673) — (600, 2659). This is the ultimate high energy of the coupling of nuclei. If a nucleus has a higher coupling energy, it becomes unstable: even a small external influence is needed in order to destroy it.

Therefore, Oganessian's claim that the theoretical physicists discuss the properties of an element with number 400 and bearing 900 neutrons in its nucleus [9] has not any ground or reason.

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References

1. Seaborg G.T. and Bloom J.L. The synthetic elements, *Scientific American*, 1969, v.220, no.4, 56.
2. Goldanskii V.I. About connections nuclear and chemical physics. *Progress in Physical Sciences*, 1976, v.118, issue 2.
3. Flerov G.N., Druin Z.A., and Pleve A.A. Stability of heavy nucleus and borders of Periodic System of elements. *Uspekhi Fizicheskikh Nauk*, 1970, v.100, no.11, 45-92.
4. Penionzhkevich Yu.E. Physics of exotics of nucleus. *Soros' Educational Journal*, 1995, 1.
5. Goepfert-Mayer M. Nuclear shell structure. In: *Modern Physics for the Engineer*, McGraw Hill, 1961, 40.
6. Goepfert-Mayer M., Jensen J.H.D. Elementary theory of nuclear shell. Foreign Literature, Moscow, 1958.
7. Eisenbood L. and Wigner E.P. Structure of the nucleus. Foreign Literature, Moscow, 1959.

8. Oganessian Yu. New area of the nucleus stability. *Herald of Russian Academy of Sci.*, 2001, v.71, no.7, 590–599.
 9. Oganessian Yu. Superheavy race. Flerov Laboratory, JINR, Dubna, Russia, *Atomium* 1 [5], 2003. http://flerovlab.jinr.ru/linkc/flerov/atomium/atomium_ogan.html
 10. Scientific medium. *Literaturnaya Gazeta*, May 8–14, 2002, no.18–19 (5877), in Russian.
 11. Oganessian Yu. Islands of the stability. *Scientific American Russian Edition*, 2005, no.3.
 12. Oganessian Yu. We revive elements of the timeless of the creation of the world. *Moscow News*, December 15, 2006.
 13. Mendeleev's year began in Dubna. Weekly of the United Institute of the Nucleus Research (UINR), February 06, 2009, no.5 (3944) in Russian; <http://wwwinfo.jinr.ru/jinrmag/win/2009/5/me5.htm>
 14. The scientists try to extend Mendeleev's Table upto 150 elements. *Izvestiya*, February 09, 2009 in Russian; <http://www.izvestia.ru/news/20/news197601/index.html>
 15. Prehistory of the synthesis of the 117th of the element. *Nezavisimaya Gazeta*, April 14, 2010 in Russian; <http://www.ng.ru/science/2010-04-14/15.117th.html>
 16. *RIA News*, Science and Technologies, August 03, 2009 in Russian; <http://rian.ru/science/20090803/179595691.html>
 17. Khazan A. Upper limit of the Periodic Table and synthesis of super-heavy elements. *Progress in Physics*, 2007, v.2, 104–109.
 18. Ishanov B.S., Kebin E.I. Nuclear physics on-line. Physics of nuclei and particles. XX century. Moscow, Moscow University Press, 2000.
 19. Audi G., Wapstra A.H., and Thibault C. The AME2003 atomic mass evaluation (II). Tables, graphs, and references. *Nuclear Physics A*, 2003, v.729, 337–676.
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