The Upper Limit of the Periodic Table of Elements Points out to the "Long" Version of the Table, Instead of the "Short" One

Albert Khazan
E-mail: albkhazan@gmail.com

Herein we present an analysis of the internal constitution of the "short" and "long" forms of the Periodic Table of Elements. As a result, we conclude that the second (long) version is more correct. We also suggest a long version of the Table consisting of 8 periods and 18 groups, with the last (heaviest) element being element No. 155, which closes the Table.

1 Introduction

Many research papers have been written about the discovery of the Periodic Law of Elements. Many spectacular versions of this law have likewise been suggested. However the main representation of this law is still now a two-dimensional table consisting of cells (each single cell manifests a single element). The cells are joined into periods along the horizontal axis (each row represents a single period), while the cells are joined into groups along the vertical axis (each column represents a single group). The resulting system is represented in three different forms: the "short version" (short-period version); the "long version" (long-period version); and the "super-long version" (extended version), wherein each single period occupies a whole row.

Our task in this paper is the consideration of the first two versions of the Periodic System.

There are hundreds of papers discussing the different versions of the Periodic Table, most of whom have been suggested by Mark R. Leach [1].

To avoid any form of misunderstanding of the terminology, we should keep in mind that, in each individual case, the Periodic Law sets up the fundamental dependence between the numerical value of the atomic nucleus and the properties of the element, while the Periodic System shows how we should use this law in particular conditions. The Periodic Table is a graphical manifestation of this system.

On March 1, 1869, Dmitri Mendeleev suggested the first "long" version of his Table of Elements. Later, in December of 1970, he published another, "short" version of the Table. His theory was based on atomic masses of the elements. Therefore, he formulated the Periodic Law as follows:

"*Properties of plain bodies, and also forms and properties of compounds of the elements, have a periodic dependence on the numerical values of the atomic masses of the elements*".

After the internal constitution of each individual atom had been discovered, this formulation was changed to:

"*Properties of plain substances, and also forms and properties of compounds of the elements, have a periodic dependence from the numerical value of the electric charge of the respective nucleus*".

All elements in the Periodic Table have been numbered, beginning with number one. These are the so-called atomic numbers. Further, we will use our data about the upper limit of the Periodic Table [2–4], when continuing both the short and long versions of the Table upto their natural end, which is manifested by element No. 155.

2 The short version of the Periodic Table

2.1 The Periods

The Periodic System of Elements is presented with the Periodic Table (see Table 1), wherein the horizontal rows are known as Periods. The first three Periods are referred to as "short ones", while the last five — "long ones". The elements are distributed in the Periods as follows: Period 1 — by 2 elements, Periods 2 and 3 — by 8 elements in each, Periods 4 and 5 — by 18 elements in each, Periods 6 and 7 — by 32 elements in each, Period 8 — by 37 elements. Herein we mean that Period 7 is full upto its end, while Period 8 has been introduced according to our calculation. Each single Period (except for Hydrogen) starts with an alkaline metal and then ends with a noble gas. In Periods 6 and 7, within the numbers 58–71 and 90–103, families of Lanthanoids and Actinides are located, respectively. They are placed on the bottom of the Table, and are marked by stars. Chemical properties of Lanthanides are similar to each other: for instance, they all are "reaction-possible" metals — they react with water, while producing Hydroxide and Hydrogen. Proceeding from this fact we conclude that Lanthanides have a very manifested horizontal analogy in the Table. Actinides, in their compounds, manifest more different orders of oxidation. For instance, Actinium has the oxidation order +3, while Uranium — only +3, +4, +5, and +6. Experimentally studying chemical properties of Actinides is a very complicate task due to very high instability of their nuclei. Elements of the same Period have very close numerical values of their atomic masses, but different physical and chemical properties. With these, and depending on the length of the particular Period — each small one consists of one row, while each long one consists of two rows (the upper even row, and the lower odd row), — the rate of change of the properties is smoother and slower in the second case. In the even rows of the long Periods (the rows 4, 6, 8, and 10 of the Table), only metals are located. In the odd rows of the long Periods (these are the rows 5, 7, and 9), properties of the elements change from left to right in the same row as well as those of the typical elements of the Table.

The main sign according to which the elements of the long Periods are split into two rows is their oxidation order: the same numerical values of it are repeated in the same Period with increase of atomic mass of the elements. For instance, in Period 4, the oxidation order of the elements from K to Mn changes from +1 to +7, then a triad of Fe, Co, Ni follows (they are elements of an odd row), after whom the same increase of the oxidation order is observed in the elements from Cu to Br (these are elements of an odd row). Such distribution of the elements is also repeated in the other long Periods. Forms of compounds of the elements are twice repeated in them as well. As is known, the number of each single Period of the Table is determined by the number of electronic shells (energetic levels) of the elements. The energetic levels are then split into sub-levels, which differ from each one by the coupling energy with the nucleus. According to the modern reference data, the number of the sub-levels is n, but not bigger than 4. However, if taking Seaborg's suggestion about two additional Periods of 50 elements in each into account, then the ultimate high number of the electrons at an energetic level, according to the formula $N = 2n^2$, should be 50 (under $n = 5$). Hence, the quantum mechanical calculations require correction.

2.2 The Groups

The Periodic Table of Elements contains 8 Groups of the elements. The Groups are numbered by Roman numbers. They are located along the vertical axis of the Table. Number of each single Group is connected with the oxidation order of the elements consisting it (the oxidation number is manifested in the compounds of the elements). As a rule, the positive highest oxidation order of the elements is equal to the number of that Group which covers them. An exception is Fluorine: its oxidation number is -1. Of the elements of Group VIII, the oxidation order +8 is only known for Osmium, Ruthenium, and Xenon. Number of each single Group depends on the number of the valence electrons in the external shell of the atom. However it is equally possible to Hydrogen, due to the possibility of its atom to loose or catch the electron, to be equally located in Group I or Group VII. Rest elements in their Groups are split into the *main* and *auxiliary* sub-groups. Groups I, II, II include the elements of the left side of all Periods, while Groups V, VI, VII — the elements located in the right side. The elements which occupy the middle side of the long Periods are known as the transferring elements. They have properties which differ from the properties of the elements of the short Periods. They are considered, separately, as Groups IVa, Va, VIa, VIII, which include by three elements of each respective long Period Ib, IIb, IIIb, IVb. The main sub-groups consist of the typical elements (the elements of Periods 2 and 3) and those elements of the long Periods which are similar to them according to their chemical properties. The auxiliary sub-groups consist of only metals — the elements f the long Periods. Group VIII differs from the others. Aside for the main sub-group of Helium (noble gases), it contains three shell sub-groups of Fe, Co, and Ni. Chemical properties of the elements of the main and auxilary sub-groups differ very much. For instance, in Group VII, the main sub-group consists of non-metals F, Cl, Br, I, At, while the auxiliary subgroup consists of metals Mn, Tc, Re. Thus, the sub-groups join most similar elements of the Table altogether. Properties of the elements in the sub-groups change, respectively: from up to down, the metalic properties strengthen, while the non-metalic properties become weak. It is obvious that the metalic properties are most expressed on Fr then on Cs, while the non-metalic properties are most expressed on F then on O [5].

2.3 Electron configuration of the atoms, and the Periodic Table

The periodic change of the properties of the elements by increase of the ordinal number is explained as the periodic change of their atoms' structure, namely by a number of electrons at their outer energetic levels. Elements are divided into *seven periods* (*eight according to our dates*) in accordance with energetic levels in electron shells. The electron shell of Period 1 contains one energetic level, Period 2 contains two energetic levels, Period 3 — three, Period 4 — 4, and so on. Every Period of the Periodic System of Elements begins with elements whose atoms, each, have one electron at the outer level, and ends with elements whose atoms, each, have at the outer shell 2 (for Period 1) or 8 electrons (for all subsequent Periods). Outer shells of elements (Li, Na, Ka, Rb, Cs); (Be, Mg, Ca, Sr); (F, Cl, Br, I); (He, Ne, Ar, Kr, Xe) have a similar structure. The number of the *main sub-Groups* is determined by the maximal number of elements at the energetic level which equals 8. The number of common elements (elements of auxiliary sub-Groups) is determined by maximal electrons at d-sub-level, and it equals 10 for every large Period (see Table 2).

As far as one of auxiliary sub-Groups of the Periodic Table of Elements contains at once three common elements with similar chemical properties (so called triads Fe-Co-Ni, Ru-Rh-Pd, Os-Ir-Pt), then the number, as of common sub-Groups as main ones, equals 8. The number of Lanthanoids and Actinides placed at the foot of the Periodic Table as independent rows equals the maximum number of electrons at the f-Sub-level in analogy with common elements, i.e. it equals 14.

A Period begins with an element the atom of which contains one s-electron at the outer level: this is hydrogen in Pe-

Group → Period ↓	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	**	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo
8	119 Uue	120 Ubn	***															
	155																	
Lanthanides *				57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
Actinides **				89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr
g-elements ***				121 Ubu	122 Ubb	123 Ubt	124 Ubq											
f-elements				125	126	127	128	129	130	131	132	133	134	135	136	137	138	139
Ubb-series				140	141	142	143	144	145	146	147	148	149	150	151	152	153	154

Table 1: The standard (long) version of the Periodic Table of Elements.

Period	Row	a I b	a II b	a III b	a IV b	a V b	a VI b	aVIIb	a VIII b		
1	1	H 1						(H)	He 2		
2	2	Li 3	Be 4	B 5	C 6	N 7	O 8	F 9	Ne 10		
3	3	Na 11	Mg 12	Al 13	Si 14	P 15	S 16	Cl 17	Ar 18		
4	4	K 19	Ca 20	Sc 21	Ti 22	V 23	Cr 24	Mn 25	Fe 26	Co 27	Ni 28
	5	Cu 29	Zn 30	Ga 31	Ge 32	As 33	Se 34	Br 35	Kr 36		
5	6	Rb 37	Sr 38	Y 39	Zr 40	Nb 41	Mo 42	Tc 43	Ru 44	Rh 45	Pd 46
	7	Ag 47	Cd 48	In 49	Sn 50	Sb 51	Te 52	I 53	Xe 54		
6	8	Cs 55	Ba 56	La* 57	Hf 72	Ta 73	W 74	Re 75	Os 76	Ir 77	Pt 78
	9	Au 79	Hg 80	Tl 81	Pb 82	Bi 83	Po 84	At 85	Rn 86		
7	10	Fr 87	Ra 88	Ac† 89	Rf 104	Db 105	Sg 106	Bh 107	Hs 108	Mt 109	Ds 110
	11	Rg 111	Uub 112	Uut 113	Uuq 114	Uup 115	Uuh 116	Uus 117	Uuo 118		

Lanthanides (the upper row) and Actinides (the lower row)

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

Period 8

8	12	119 Uue	120 Ubn	121 Ubu	122 Ubb	123 Ubt	124 Ubq	125 Ubp	126 Ubh	127 Ubs	128 Ubo
	13	129 Ube	130 Utn	131 Utu	132 Utb	133 Utt	134 Utq	135 Utp	136 Uth		
	14	137 Uts	138 Uto	139 Ute	140 Uqn	141 Uqu	142 Uqb	143 Uqt	144 Uqq	145 Uqp	146 Uqh
	15	147 Uqs	148 Uqo	149 Uqe	150 Upn	151 Upu	152 Upb	153 Upt	154 Upq		
	16	**155**									

121-124—g-elements
125-138---f-elements
155-Upp (Unpentpentium)—Last element

Table 2: The suggested (short) version of the Periodic Table of Elements, up to No. 155.

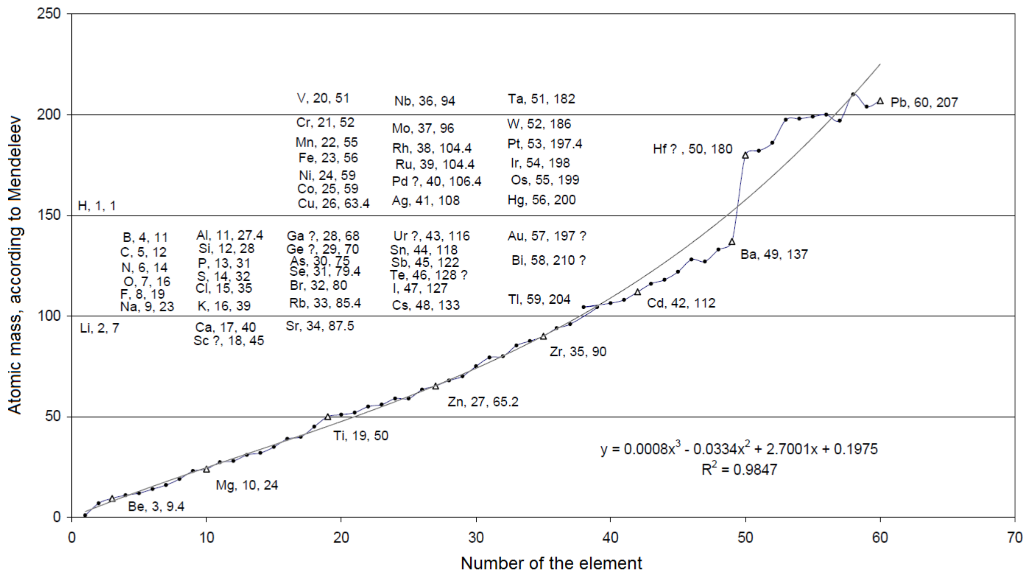

Fig. 1: Experience of the System of the Elements, based on their atomic mass (the table, according to Mendeleev). Dependence of the atomic mass from the number of the elements (the graphs, according to the suggested formulation). The triangles mean the beginning of each Period.

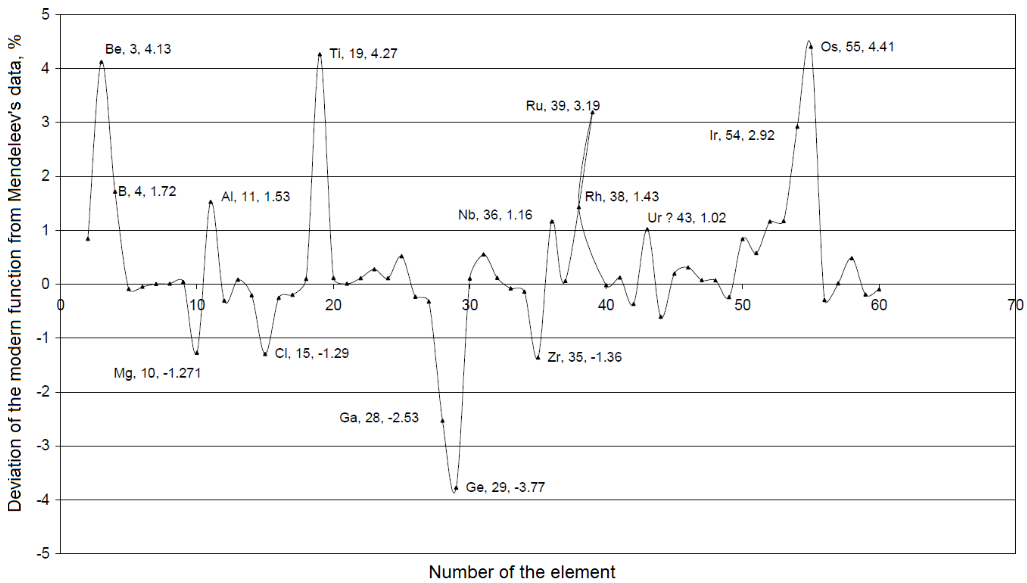

Fig. 2: Deviation of the modern (suggested) dependence of the atomic mass from the number of the elements from Mendeleev's data.

riod 1, and alkaline metals in the others. A Period ends with precious gas: helium ($1s^2$) in Period 1.

Detailed studies of the structure of an atom are not the aim of our paper, therefore we draw common conclusions concerning the corresponding locations of **elements in blocks**:

1. **s-elements**: electrons fill s-sub-shells of the outer level; two first elements of every Period are related to them;
2. **p-elements**: electrons fill p-sub-shells of the outer level; six last elements of every Period are related to them;
3. **d-elements**: electrons fill s-sub-shells of the outer level; they are elements of inserted decades of big Periods placed between s- and p-elements (they are called also common elements);
4. **f-elements**: electrons fill f-sub-shells; they are Lanthanoids and Actinides.

3 Drawbacks of the short version and advantages of the long version of the Periodic Table

The "short" form of the Table was cancelled officially by IUPAC in 1989. But it is still used in Russian information and educational literature, must probably, according to a tradition. But it follows by detailed consideration that it contains some moot points.

In particular, Group VIII contains in the common Group, together with precious gases (the main sub-Group), triads of elements, which have precisely expressed the properties of metals. The contradiction here is that the triad Fe, Co, Ni is near families of platinum metals although their properties differ from the properties of Groups of iron. Group I contains alkaline metals having very strong chemical activity, but simultaneously the sub-Group "b" contains copper, silver and gold which have not these properties but possess excellent electric conductivity. Besides gold, silver and platinum, metals have very weak chemical activity.

Group VII, where nearby halogens such metals as manganese, technezium and renium are placed, is also incorrect, because in the same Group two sub-Groups of elements possessing absolutely different properties are collected.

The "short" Table is sufficiently informative but it is difficult in terms of use due to the presence of the "long" and the "short" Groups, i.e. the small and big Periods divided by even and odd lines. It is very difficult to place f-elements inside eight Groups.

The "long" form of the Table consisting of 18 Groups was confirmed by IUPAC in 1989. Defect characteristics of the "short" Table were removed here: the sub-Groups are excepted, Periods consist of one stitch, elements are composed of blocks, the families of iron and platinum metals have disappeared, and so on.

The known Periodic Table consisting of 118 elements and 7 Periods where our dates for Period 8 are added must contain: 17 s-elements, 42 p-elements, 50 d-elements, 42 f-elements, and 4 g-elements.

The number 17 for s-elements follows from the fact that two of them are in Group I and Group II of Period 8, while element No. 155 (the last s-element, 17-th) is in Period 9 and Group I (the sole) closes the Table.

The extended Table consisting of blocks containing the number of elements calculated by us is published in [4].

3.1 From the Periodic Law to the Hyperbolic Law and the upper limit of the Periodic System

A note by Mendeleev, in March of 1869, was published and sent in Russian and French to scientists, titled "Experience of Systems of Elements Founded on Their Atomic Weights and Chemical Similarity" (with "atomic weight" to be understood as "atomic mass" here and in the future). This date is considered as the discovery date of the periodic law of chemical elements. The author dedicated the next two years to the work in this direction, which was a correction of atomic masses, an elaboration of studies about the periodical properties of elements, about the rôle of Groups, of big and small Periods, as well as about the places of chemical combinations in the Table. As a result, "Mendeleev's Natural System of Elements" which was the first periodic table of chemical elements was published in the first edition of his book "The Foundations of Chemistry", in 1871.

It is necessary to note that the dates published in the table of "Experience of Systems of Elements Founded on Their Atomic Weights and Chemical Similarity" permits us to use them in order to prove the correctness of Mendeleev's work.

The comprehensive table based the book "Experience of System of Element Found on Their Atomic Weight and Chemical Similarity", in terms of the dependence of each atomic mass on the number of the corresponding element, has been built by us and showed on Fig. 1. Because then it was not known yet that the ordinal number of each element characterizes its charge, it was simply the case that an element possessing a minimal mass was allowed to be designed as No. 1, and this order is conserved in the future: the next, in terms of mass, element will be designated as No. 2, the third as No. 3, and so on. Thus the ordinal number, which was attributed to the element after the theory of the atom was constructed has here another numerical value — symbolizing order of priority. The Table on Fig. 1 is the same as the one composed by Mendeleev, and the elements and the numbers are placed as the points on the arc where the triangles designate the beginning of the Periods. As is clear, the arc goes smoothly, preceding the elements and the atomic mass ~100, and after that it deviates preceding Ba. The trend line equation can be easily described by the multinomial of the third degree, i.e. by $R^2 = 0.9847$, in spite of a strong jump in the region of Lantanides. It should be noted that the part of the arc preceding Ba has $R^2 = 0.999$. It means that the direction of the trend line after Ba reflects correctly the further course of our dependence, which allows us to calculate easily the atomic weights of other elements.

It should be noted that the trend line of the curve constructed according to contemporary dates has $R^2 = 0.9868$. In order that compare the dependence of the atomic mass from the ordinal number according to contemporary dates and the dates of Mendeleev the graph of was constructed (see Fig. 2). As is clear, the maximal deviations (3–4%) are observed for 6 cases, (1–1.5%) — for 8 cases, the others are placed lower. Because the common number of elements is 60, this spread is negligible for the those time.

As follows from the indicated dates, Mendeleev showed by means of his works concerning the Periodic Law that it is true for 60–70 elements, opening the way for the extension of the Table up to No. 118.

But our studies of the Periodic Table distinctly show that a hyperbolic law takes place in it. The law determines the upper limit of the Table through element No. 155. This fact is indisputable and it is justified by numerous publications.

4 Conclusion

If it was allowed in the 1950s that a maximum value of an ordinal number in Periodic Table could not exceed the value $Z = 110$ due to a spontaneous division of the nucleus, then in the 1960s theoreticians proposed the hypothesis that the atomic nucleus could have anomalously high stability. Seaborg called these regions "islands of stability" in a "sea of instability". He hoped for a possible synthesis of superelements inside these regions, **"...but until [now] the problem of the upper bound of the Periodic System [remains] unsolved"** (and so: at that time)!

Since in order to solve any problem it is necessary to know a final goal and to define its bounds, we have realized experimental studies and constructed a mathematical apparatus for the determination of the upper bound of the Periodic Table. According to our calculations, the last element is estimated and its location is determined: Period 9, Group I, with atomic mass of 411.66 (approximately), for which $Z = 155$. The earlier-proposed extended tables by Seaborg for 168 and 216 elements simply cannot be realized, because **only 155 elements can be in the Table, in its entirety**.

Submitted on June 23, 2011 / Accepted on June 30, 2011
After re-submission, December 09, 2011

References

1. http://www.meta-synthesis.com/webbook/35_pt/pt_database.php
2. Khazan A. Upper limit in the Periodic Table of Elements. *Progress in Physics*, 2007, v. 1, 38–41.
3. Khazan A. Upper Limit in Mendeleev's Table — Element No. 155. 2nd edition, Svenska fysikarkivet, Stockholm, 2010.
4. Khazan A. Isotopes and the Electron Configuration of the Blocks in the Periodic Table of Elements, upto the Last Element No. 155. *Progress in Physics*, 2011, v. 2, 55–57.
5. Pauling L. General Chemistry. 3rd edition, W. H. Freeman & Co., San Francisco, 1970, p. 843.