ATOMIC ELECTRON SHELLS FORMATION LAWS.

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The analysis based on experimental characteristics of atoms shows, that the theory of electron "movement" in atom in its modern state is essentially erroneous. It is impossible to consider electrons in atoms as separate particles because in each electron shell they form a Bose-condensate. Therefore real electron "collectives" absolutely not resemble drawn by the theory stochastic orbital "spread" in space.

Recently published my article [1], devoted to atom theory, has caused many positive responses, but the significant part of readers considers, that because of great volume of article and its general orientation on the examination of atom physics, not enough attention was given to the description of actually electron shells (in the second half of article).

*Answering these remarks, I completely devote this article to the analysis of **electron shells** (used as the general term) of atoms.*

In the article physical characteristics data of atoms repeatedly confirmed by experiments are used. Therefore disclosed laws, undoubtedly, have objective character and will be a reliable basis for further researches.

1. The Resonant nature of electron shells of atoms

Properties and structure of atomic electron shells are naturally determined by reliably proven electron *wave-corpuscle* properties distinctly revealed in the most different experiments.

Therefore, proceeding from electron wave properties, the known Bohr postulate on quantization of angular momentum actually is more logical to consider as a **resonance condition**: the integer number of electron wave-lengths *h/p* should go into length of an orbit (though mathematically it is one and the same):

$$2\pi R = n\lambda = n\frac{h}{p}, \qquad pR = n\hbar, \qquad (h = 2\pi\hbar). \tag{1}$$

The integer number *n* is *the principal quantum number*, R - radius of an orbit, p - electron momentum, h - Planck's constant.

Formula (1) actually shows the "permissible" resonant values of spatial phase factor for an electron shell

$$k = \frac{2\pi}{\lambda} = \frac{n}{R}. \tag{2}$$

Such «practical approach», without appealing to the "high" theory as we shall see, is quite sufficient and effective for research of experimental data and has enabled to reveal the most important electron shell features.

Electron shells nearest to atom nucleus

Consideration of the most simple electron shells shows the exact conformity of calculations based on usual resonant conditions (1) to available experimental data.

As is known, first of all it relates to the atom of hydrogen [2].

In an electron shell of hydrogen there is only one electron which undergoes the force of nucleus attraction and as a counterbalance - centrifugal force.

This equality of forces determines the electron kinetic energy:

$$\frac{mv^2}{R} = \frac{e^2}{4\pi\varepsilon R^2}, \qquad \frac{mv^2}{2} = \frac{p^2}{2m} = \frac{e^2}{8\pi\varepsilon R}. \tag{3}$$

In consideration of (1) and (3) probable values of orbit radius are determined

$$R = n^2 \frac{\varepsilon h^2}{\pi m e^2} = n^2 R_B, \qquad R_B = \frac{\varepsilon h^2}{\pi m e^2} \approx 0{,}529 \cdot 10^{-10} \, \text{м}. \tag{4}$$

At *n=1* the radius has the minimum value equal to Bohr radius.

In conformity with *the virial theorem* kinetic energy (3) is equal to the half of absolute value of electron negative potential energy. Therefore total energy of electron is also negative and numerically equal to kinetic energy

$$W = -\frac{e^2}{4\pi\varepsilon R} + \frac{mv^2}{2} = -\frac{e^2}{8\pi\varepsilon R}. \tag{5}$$

In view of (4) total electron energy possesses discrete values:

$$W = -\frac{me^4}{8\varepsilon^2 h^2} \frac{1}{n^2}. \tag{6}$$

This result in due time has enabled to understand the spectrum of hydrogen. The minimum energy (6) at *n=1* has appeared precisely equal to the known value of ionization potential of atom of hydrogen 13,6 eV.

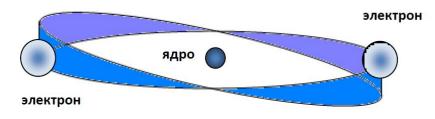Such simple and exact calculations are possible in some other cases.

In particular, complete concordance of calculated value of ionization potential for *the last electron* with experimental data occurs in all atoms (nucleus charge *ze*)

$$\varphi_{iz} = \frac{z^2 e}{8\pi\varepsilon R_B} = z^2 \cdot 13{,}6 eV. \tag{7}$$

For example, experimental value of ionization potential of the last (tenth) electron of neon is about 1360,2 eV [3].

As contrasted with atom of hydrogen where electron is located in one of the two antinodes of a resonance, **in atom of helium** the electron shell also has one period *n=1*, but contains two electrons which occupy both antinodes of a resonance, being on the opposite sides from a nucleus (fig. 1).

Let's notice, that properties of helium as inert gas are determined just by this circumstance - in an electron shell of helium there is no vacant place for other electrons (both antinodes of a resonance are occupied by electrons).

Fig. 1. The schematic image of helium atom.

The radius of the electron shell of helium is almost twice less, than of hydrogen atom, because its electrons undergo greater attracting force of helium atom nucleus which charge is equal to two electron charges.

Let's analyze, proceeding from forces applied to electrons of the shell - electrostatic (centripetal) force and centrifugal force

$$F_{цс} = \frac{2e^2}{4\pi\varepsilon R^2} - \frac{e^2}{4\pi\varepsilon(2R)^2}, \qquad F_{цб} = \frac{mv^2}{R} = \frac{p^2}{mR}. \qquad (8)$$

Whereas a resonance condition *(n=1)*

$$2\pi R = \lambda = \frac{h}{p}, \qquad (9)$$

and equating differently directed forces (8), we derive:

$$R = \frac{4}{7}\frac{\varepsilon h^2}{\pi m e^2} = \frac{4}{7}R_Б. \qquad (10)$$

Electrons are symmetrically located in regard to the nucleus and consequently have identical energy. However in process of ionization when as a result of external action one of two electrons leaves atom, the second electron simultaneously comes nearer to a nucleus and gives some energy to the first electron. Hence the ionization potential of the first electron decreases accordingly. But when there is a second act of ionization (removal from atom of the second electron) expenditures of energy increase on the same amount which has been given to the first electron.

Therefore, not to be engaged in such "redistribution" of energy, comparison of calculations output with experimental data is convenient to make using *accumulative value of ionization potentials*.

Analyzing hydrogen atom, we ascertained, that the ionization potential numerically corresponds to kinetic energy of electron. Taking it into consideration, from (9) and (10) we obtain value of electron kinetic energy (conditional magnitude of ionization potential):

$$e\varphi_i = \frac{p^2}{2m} = \frac{h^2}{2m(2\pi R)^2} = \frac{49}{16}\frac{e^2}{8\pi\varepsilon R_Б} = \frac{49}{16}\cdot 13,6eV = 41,65eV. \qquad (11)$$

Hence, the double magnitude (11) should be equal to the sum of two real ionization potentials (at consecutive removal of the first electron and then - of the

second electron). The total sum of two ionization potentials, thus, has to be 83,3 *eV*, and the sum of experimental values is 24,58+54,4≈79 *eV*.

Such computational accuracy of elementary approach is more than satisfactory, but not "ideal" as it was in cases with only one electron in the atomic shell.

But maybe it is casual result?

We have an opportunity to verify it, as **electron shells closest to a nucleus of all other atoms** as well as the electron shell of helium, also have two electrons *(n=1)*.

Calculations analogous with those of electron shell of helium, but assuming the charge of a nucleus equal ***ze***, give formulas for electron shell radius and for the sum of ionization potentials:

$$R = \frac{4}{4z-1} R_Б, \qquad \varphi_1 + \varphi_2 = \frac{(4z-1)^2}{8} \cdot 13,6 eV. \tag{12}$$

Computing results and experimental data [3] are shown in table 1.

Table 1

Parameters of the electron shell (two electrons) nearest to a nucleus

Atom	Calc. $\varphi_1+\varphi_2$, eV	Exper. $\varphi_1+\varphi_2$, eV	Calc/Exper.	R/R_B
2 (He)	83,3	79	1,0544	0,571
3 (Li)	205,7	198	1,0389	0,364
4 (Be)	382,5	371,51	1,0296	0,267
5 (B)	613,7	599,43	1,0238	0,211
6 (C)	899,3	881,83	1,0198	0,174
7 (N)	1239,3	1218,76	1,0168	0,148
8 (O)	1633,7	1610,23	1,0146	0,129
9 (F)	2082,5	2057,6	1,0121	0,114
10 (Ne)	2585,7	2555,6	1,0118	0,102

Table 1 (the column computation/experiment) makes it evident that at increase of a nucleus charge relative difference between computing results of ionization potentials and corresponding experimental data decreases (from 5,44 % to 1,18 %). That is, computing results become closer to actual values.

It is noteworthy that atomic shells containing two electrons are very close to a nucleus (already the tenth element of a periodic table - atom of neon has the nearest to nucleus shell radius of about 0,054 Á).

Facts and intermediate conclusions:

- Along with atom of hydrogen, calculations based on the model of resonant electron shells give close fit to experimental data for electron shells nearest to a nucleus *(n=1)* of all kinds of atoms.

- Electron in atom, being on the closed trajectory, figuratively speaking, «gets a self-resonance». If two electrons are on one common trajectory they form (and are built-in) the common resonance being in different antinodes of resonance.

Resonant electron shells of hydrogen-like atoms

R. Feynman in well-known "Lectures" repeatedly affirmed that the solution of a problem is useful to begin with the analysis of simple special cases as the general solution may be a combination of such special cases.

But the principal advantage of such approach is the opportunity to receive exact results and not to miss important regularities which can "be lost" in errors and complexities of the general solution.

Such "special case" convenient for obtaining the most exact results, are hydrogen-like atoms.

Let's begin with **atom of lithium.** The charge of lithium nucleus is equal to three electron charges and, thus, the second (external) shell is presented by only one electron (fig. 2).
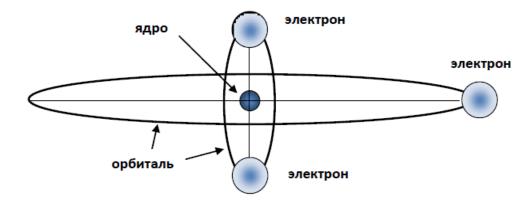

Fig. 2. Diagrammatic representation of lithium atom.

External electron is rather wide apart from a nucleus and from two electrons of internal shell – i.e. from the atomic core. The dimensions of this atomic core as it was found earlier are rather small - about $0,364R_B$ (table 1). Therefore it is possible to consider, that valent electron is in the field of a total positive unit charge of atomic core. In this respect such atoms are hydrogen-like.

It would seem that this external electron should completely replicate the behavior of electron in atom of hydrogen and satisfy formulas (3-6).

But it is not exactly so.

If radius of the external electron shell of lithium atom is as one of hydrogen *(n=1)* so its ionization potential would be equal to the ionization potential of hydrogen (13,6 eV). But lithium ionization potential is only 5,39 eV and specifies that the radius of external electron shell of atom of lithium is essentially (in 2,523 times) more, than of hydrogen. It follows from formula (5), which shows interdependence of electron energy in atom of hydrogen (numerically equal to potential of ionization) and radius of its electron orbit:

$$W = -\frac{e^2}{4\pi\varepsilon R} + \frac{mv^2}{2} = -\frac{e^2}{8\pi\varepsilon R}, \qquad e\varphi_i = \frac{e^2}{8\pi\varepsilon R}, \qquad R = \frac{e}{8\pi\varepsilon\varphi_i}. \qquad (13)$$

It means that external shell of lithium atom should contain more than one spatial period, and number n should be more then 1.

But assuming $n=2$, we obtain too big distance R equal to four Bohr radiuses. The ionization potential with such distance should be equal 3,4 eV, that mismatches actual value 5,39 eV.

Nevertheless, this situation has the logical settlement.

Let's determine wave length of electron proceeding from its kinetic energy which, as we saw, numerically corresponds to ionization potential. Hence

$$\frac{p^2}{2m} = e\varphi_i, \qquad p = (2me\,\varphi_i)^{1/2}. \qquad (14)$$

So we receive wave length of electron and corresponding radius

$$\lambda = 2\pi R_\lambda = \frac{h}{p} = \frac{h}{(2me\,\varphi_i)^{1/2}}, \qquad \frac{R_\lambda}{R_B} = \frac{h}{2\pi R_B(2me\,\varphi_i)^{1/2}}. \qquad (15)$$

Substituting in (15) ionization potential of lithium 5,39 eV, we get:

$$\lambda = 5{,}296 \cdot 10^{-10}\,\text{м}, \qquad R_\lambda = 0{,}843 \cdot 10^{-10}\,\text{м} = 1{,}593\,R_Б.$$

Here we used new notation R_λ for conditional radius (spatial phase factor), parameter characterizing rate of spatial wave change. Actually this parameter was used already in formula (2).

As we expected, *the external electron shell of lithium atom is characterized by number (n=1,593) which, unlike hydrogen (n=1), is not integer and is in an interval between 1 and 2!*

However actually the external electron shell of lithium atom also is resonant and is characterized by the integral number of wave-lengths. It is achieved *due to excitation of higher harmonic*.

That is, some unknown to us the integer number of wave-lengths N_1, describing a shell resonance, should be result of multiplication of number 1,593 by other number N_2 - number of harmonic. Therefore we should make some simple calculations and select suitable numbers.

For example, having divided number $N_1=8$ by n=1,593, we receive $N_2=5{,}02$, that is, the fifth harmonic enables to obtain eight wave-lengths resonance of electron shell of lithium atom. Moreover the formula (4) for real shell radius appears valid when n is not an integer number

$$R = n^2 R_B. = (1{,}593)^2 R_B = 2{,}54\,R_B. \qquad (16)$$

This value really meets actual magnitude of external electron shell radius of lithium atom, starting from formula (13)

$$e\varphi_i = \frac{e^2}{8\pi\varepsilon R}, \qquad R = \frac{e}{8\pi\varepsilon\varphi_i} = 2{,}52\,R_B \qquad (\varphi_i = 5{,}39eV). \qquad (17)$$

There are many atoms similar to lithium with one electron on the external electron shell, so we have an opportunity to make analogous calculations in these cases too. Results of all calculations are shown in table 2.

We attach such importance to these calculations to be convinced of natural character of results. Data represented in table 2 let us make a conclusion on validity of hypothesis.

The nature, really, uses resonances generated on multiple harmonics, therefore atoms become more compact and in electron shells meanwhile can be "placed" greater number of electrons!

Table 2

Atom	φ_1, eV	n	n^2	$R/R_Б$	$n \approx N_1/N_2$
3 (Li)	5,39	1,593	2,54	2,52	8/5,02
11 (Na)	5,138	1,632	2,66	2,65	5/3,06
19 (K)	4,339	1,775	3,15	3,13	7/3,94
55 (Cs)	3,893	1,875	3,51	3,49	15/8,00
37 (Rb)	4,176	1,81	3,27	3,26	9/4,97
47 (Ag)	7,574	1,342	1,8	1,79	4/2,98
78 (Pt)	8,96	1,236	1,53	1,52	5/4,04
81 (Tl)	6,106	1,498	2,24	2,23	3/2,00

Here it is necessary to stipulate, that figures in the right column of table 2 were obtained by trial-and-error method and should be confirmed by further researches (for example, by studying spatial symmetry of chemical compounds with these atoms). In particular, numbers N_1 and N_2, obviously, can have values multiple of the numbers specified in the table.

However it is not so important, whether there will be numbers multiple or commensurable as in any case these findings are extremely important for atom structure understanding.

Similar laws became apparent in characteristics of the excited states of atoms, and, hence, they can be used for **the analysis and systematization of atoms spectra**.

As an example let us examine spectrum of lithium atom. On fig. 3 there is Grotrian diagram of lithium atom [4] which represents excited states (energy levels) and transitions between them.

It is necessary to make some additional calculations to ease analysis of the diagram.

First, energy levels in this case are more suitable for measuring not from the lowest level corresponding ionization energy (as it is on the diagram), but from "absolute" zero (that is, from energy level at infinite separation from atom).
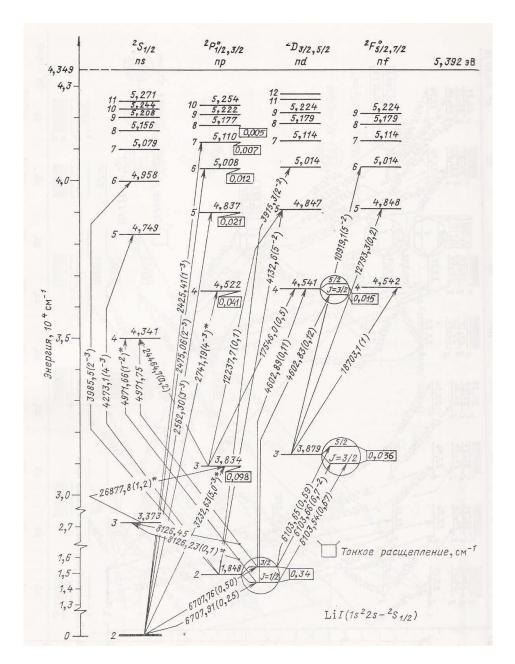
Secondly, we will need to calculate all the same electron characteristics at excited levels, as it was done in table 2.

Final table 3 includes also the principal quantum number n (the first column) which is attributed to each excited level on the diagram (fig. 3). It was made to have opportunity of comparison with the results of calculating n (relation N_1/N_2).

Displayed in table 3 data are rather eloquent. Calculated values of the principal quantum number (n calc.) in most cases with good accuracy coincide with integer

figures in the first column by which the corresponding excited levels on Grotrian diagram are marked.

Fig. 3. Grotrian diagram of lithium atom [4].

However in six cases (almost each third excited level) authors of the diagram, probably, could not be sure with the principal quantum number because it should be fractional (N_1/N_2), instead of integer as it is specified on the diagram. Thus numbers N_1 and N_2 are detected with good accuracy by means of simple calculations.

Impressive also is the remoteness (R/R_B) of external electron from atom nucleus at high excited levels (large n).

Table 3

n diagr.	W, eV diagr.	W, eV absol.	n calc.	n^2 calc.	R/R_B	$n \approx N_1/N_2$
2	1,848	3,544	1,963578	3,85564	3,837472	2
3	3,373	2,019	2,601519	6,7679	6,736008	13/4,997
3	3,834	1,558	2,961498	8,770468	8,72914	3
3	3,879	1,513	3,005216	9,031321	8,988764	3
4	4,341	1,051	3,605735	13,00132	12,94006	18/4,998
4	4,522	0,87	3,963104	15,70619	15,63218	4
4	4,541	0,851	4,007101	16,05686	15,9812	4
4	4,542	0,85	4,009458	16,07575	16	4
5	4,749	0,643	4,60988	21,25099	21,15086	23/4,99
5	4,837	0,555	4,961907	24,62052	24,5045	5
5	4,847	0,545	5,007222	25,07227	24,95413	5
5	4,848	0,544	5,011822	25,11836	25	5
6	4,958	0,434	5,611129	31,48477	31,33641	28/4,99
6	5,008	0,384	5,965262	35,58435	35,41667	6
6	5,014	0,378	6,012419	36,14918	35,97884	6
7	5,079	0,313	6,607284	43,6562	43,45048	33/4,99
7	5,11	0,282	6,960983	48,45528	48,22695	7
7	5,114	0,278	7,010883	49,15248	48,92086	7
8	5,156	0,236	7,609202	57,89995	57,62712	38/4,99

In more complex atoms spectra thousands excited levels are observed, and to analyze them is much more difficult task. Besides fractional principal quantum numbers there are also other "complicating" factors. In particular, energy of the excited level is influenced by disturbing factor in the form of various mutual spin states of atomic core and external electron.

Naturally, greater work to detail parameters of all electron shells of atoms is needed. These extremely interesting and important questions, undoubtedly, will attract attention of many researchers.

Facts and intermediate conclusions:

- External shells of hydrogen-like atoms (with one-electron external shell) in not excited state have *fractional principal quantum number*. It means, that shells "resonate" on multiple harmonics.

- The excited energy levels of lithium atom approximately in 2/3 cases correspond to integer (usual) numbers *n*, and in 1/3 cases - to fractional values of the principal quantum number. These last excited energy levels on Grotrian diagram are «forced» marked by the nearest integer number.

2. Model of spherical atom electron shells

Let's look at atom electron shells from one more not less interesting point of view.

The carried out analysis makes it clear that electrons in atoms belong to **level-by-level arranged electron shells**. Each of these layers (which we call *a resonant electron shell)* involves a set of electrons, incorporated in general resonance.

Thus, **the many-electron shell can be represented in the form of sphere** with symmetrically located on it electrons (for example, on tops of the polyhedron mentally inscribed in a spherical surface).

Such electron shell configuration enables at the analysis to use the simplest model - in the form of the charged sphere. Thus the structure of atom reminds "nested doll" in which center the nucleus is located, and concentric electron shells are around of it - one inside of another.

How such electron shells structure effect atom properties? We shall examine it taking as example atoms of inert gases, which external electron shells "are densely populated" and really resemble charged spheres.

As is known, electrostatic energy of the charged sphere is [5]

$$W_e = \frac{Q^2}{8\pi\varepsilon R}.$$
(18)

Electron shell charge *Q* is determined by number of electrons in the shell. Recollect also, that the ionization potential corresponds to the half of absolute value of binding energy of electron in shell structure.

Hence and in view of (18), the total sum of ionization potentials of all electrons of external shell, for example, of neon atom is determined by the formula:

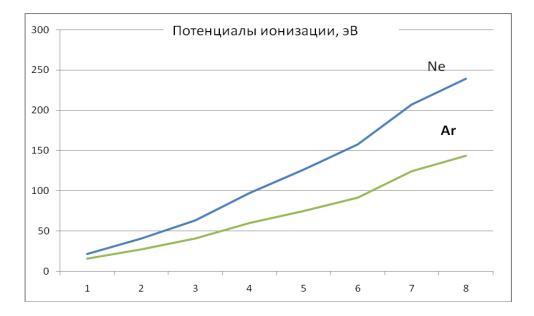$$e\sum_1^8 \varphi_i = \frac{(8e)^2}{16\pi\varepsilon R}.$$
(19)

Really, removal of any electron from the shell (act of ionization) is accompanied by "penetration" of a corresponding part of not compensated electric field of atomic core beyond the limits of external shell that *is perceived as increase of its charge*. Therefore removal of each subsequent electron from the shell demands increasing energy consumption, and the total result will just correspond to the formula (19).

Using formula (19), it is possible to determine each potential of ionization separately (as energy change at removal of one electron), and the total energy to represent as the sum of such energy changes

$$e\sum_{1}^{8}\varphi_i = \frac{(8e)^2}{16\pi\varepsilon R} = \frac{1}{16\pi\varepsilon R}\left[((8e)^2 - (7e)^2) + ((7e)^2 - (6e)^2) + ... + ((2e)^2 - e^2) + e^2\right] =$$

$$= \frac{1}{16\pi\varepsilon R}(15e^2 + 13e^2 + 11e^2 + 9e^2 + 7e^2 + 5e + 3e^2 + e^2).$$

(20)

As expected, ionization potentials are proportional to the degree of ionization (formula (20) is written down in reverse order relative to degree of ionization). Electron shells, certainly, are not regularly charged spheres (especially when there is small number of electrons in the shell); nevertheless, results of experiments in whole confirm applicability of model (fig. 4). Deflections from linear dependence, obviously, are connected among other things also with processes of reorganization of electron shells after each act of ionization. As a result, the total energy of an electron shell is additionally redistributed between ionization potentials.

However the total sum (20) "absorbs" all redistributions and, as in already examined case of the shell with only two electrons, enables most evidently and simply to compare results of calculations with experimental data.

Fig. 4. Ionization potentials of a neon and argon subject to degree of ionization

Let's verify the validity of formula (19). But for this purpose it is necessary to determine radius of external electron shell as precisely as possible.

For this purpose as it was already shown, the best variant is of an electron shell with only one electron. Therefore radius of the external shell of neon atom is determined on the bases of the eighth degree ionization potential

$$R = \frac{8e}{8\pi\varepsilon\varphi_8} = 0,455\,R_Б, \qquad (\varphi_8 = 239,1eV).$$

(21)

There are other methods of calculation of radius which also give close results.

Having substituted concrete values in (19), we obtain

$$\frac{64e}{16\pi\varepsilon \cdot 0,455 R_{Б}} = \frac{32 \cdot 13,6}{0,455} = 956,48 eV, \qquad \sum_{1}^{8}\varphi_i = 21,56 + 41,07 + 63,5 + 97,16 +$$

$$+126,4 + 157,9 + 207,2 + 239,1 = 953,89 eV. \tag{22}$$

Thus, the right and the left parts of (19), really, are close to each other. Results of similar calculations for other noble gases are shown in table 4.

<div style="text-align:right">Таблица 4</div>

Atom	φ_8, eV	$R/R_Б$	Calc. $\Sigma\varphi_i$, eV	Exper. $\Sigma\varphi_i$, eV	Calc/Exper.
10 (Ne)	239,1	0,455	956,48	953,89	1,003
18 (Ar)	143,4	0,759	573,39	577,64	0,993
36 (Kr)	126	0,863	504,29	508,16	0,992
54 (Xe)	126	0,863	504,29	484,43	1,041

External shell of halogens atoms has only one electron less, than noble gases; therefore we can expect exact fit of calculations and experiments in this case too. However, formulas are "to be corrected" accordingly:

$$e\sum_{1}^{7}\varphi_i = \frac{(7e)^2}{16\pi\varepsilon R}. \tag{23}$$

$$R = \frac{7e}{8\pi\varepsilon\varphi_7}. \tag{24}$$

Calculations output and actual values are represented in table 5.

<div style="text-align:right">Table 5</div>

Atom	φ_7, eV	$R/R_Б$	Calc. $\Sigma\varphi_i$, eV	Exper. $\Sigma\varphi_i$, eV	Calc/Exper.
9 (F)	185,14	0,514	648,25	658,75	0,984
17 (Cl)	114,2	0,834	399,52	408,61	0,978
35 (Br)	103	0,924	360,6	367,94	0,98
53 (J)	104	0,915	364,15	362,44	1,005

As we see, calculations output and actual values for external electron shells of halogens (as well as noble gases) correspond with each other.

Whether these laws are also distinctly valid for internal atom shells? To answer this question, let us make similar calculations for the filled shells which are directly under external shells of univalent and bivalent atoms.

Here also quite obvious changes in formulas are required. First we write down these formulas for atoms with only one electron on an external shell:

$$e\sum_{2}^{9}\varphi_i = \frac{(9e)^2 - e^2}{16\pi\varepsilon R}, \tag{25}$$

$$R = \frac{9e}{8\pi\varepsilon\varphi_9}. \tag{26}$$

Similarly we can modify formulas for atoms with two electrons on an external shell:

$$e\sum_{3}^{10}\varphi_i = \frac{(10e)^2 - (2e)^2}{16\pi\varepsilon R}, \qquad (27)$$

$$R = \frac{10e}{8\pi\varepsilon\varphi_{10}}. \qquad (28)$$

Calculations output and actual values are represented accordingly in tables 6 and 7.

Thus, made analysis convincingly shows, that electrons in atoms really concentrate layer-by-layer in spherical electron shells.

Exact correspondence of calculation results to experimental data also testifies high accuracy of determining of electron shells radiuses.

Table 6

Atom	φ_9, eV	$R/R_Б$	Calc. $\Sigma\varphi_i$, eV	Exper. $\Sigma\varphi_i$, eV	Calc/Exper.
11 (Na)	299,7	0,408	1333,33	1299,31	1,026
19 (K)	176	0,695	782,73	769,01	1,018
37 (Rb)	150	0,816	666,67	660,76	1,009
55 (Cs)	150	0,816	666,67	621,7	1,072

Table 7

Atom	φ_{10}, eV	$R/R_Б$	Calc. $\Sigma\varphi_i$, eV	Exper. $\Sigma\varphi_i$, eV	Calc/Exper.
12 (Mg)	367,2	0,370	1764,32	1702	1,037
20 (Ca)	211,3	0,644	1013,66	982	1,032
38 (Sr)	177	0,768	850	830,4	1,024

In conclusion of electron shells structure analysis it is necessary shortly talk about so-called **"shielding action" on the charge of a nucleus (or atomic core) by shells electrons**.

What is the mechanism of "screening effect"? The model of spherical electron shells enables to specify this question.

According to Gauss theorem [5] each subsequent charged sphere is exposed to the electric field of the total charge which sits inside of this sphere. So, the charge of shells of greater radius cannot influence shells of smaller radius (according to the model of spherical electron shells, fig. 5).

However in this simple scheme there is one not so obvious feature. The matter is that each charged sphere besides has «self-action». The charges being on sphere surface are subjected to electric field equal to the half value of the field created by this charged sphere close to the external surface:

$$E = \frac{Q}{8\pi\varepsilon R^2}. \qquad (29)$$

This formula can be deduced by integration of contributions of all elementary charges located on a surface of sphere.

Fig. 5. Model of spherical electron shells of atom.

So each unit charge on the sphere surface is exposed to the action of force numerically equal to the value of electric field (29), generated by all other charges. Consequently total force acting on a charge of sphere will be in Q times more

$$F = \frac{Q^2}{8\pi\varepsilon R^2}.$$
(30)

The force (30) acting on a charge of sphere, it is possible to derive direct by R differentiation of formula for charged sphere energy (18).

As force of "self-action" is always directed from the center it reduces total force of attraction to a nucleus (atomic core). In particular, if the external electrons shell of atom "is densely enough populated", the total force of attraction acting on each one electron of the shell is half as great!

Let's notice that calculation data in tables 4, 5, 6 and 7, are based on the charged spheres model and "automatically" take into account the examined *effect of electron interference in shell structure*.

Therefore conformity of calculations outcome with experimental data testifies *to a simultaneous and constant location of electrons in spherical shells structure*.

So electrons *are not independent particles* and are not "spread" all over quantum-mechanical probability "clouds"!

Keeping in mind that these electron shells are resonant formations and have the spherical form, we should mention here the corresponding mathematical solution [6]. It refers to spherical harmonics on a surface of sphere

$$(A\cos m\varphi + B\sin m\varphi)\cdot P_n^m(\cos\theta).$$
(31)

Not striking into mathematics, we shall note, that formula (31) has three particular solutions: a zone harmonic *(m=0)*, tesseral harmonic (*0 <m <n*) and sectoral harmonic *(m=n)*. It is proved also, that any function can be expanded in spherical surface harmonics.

These mathematical solutions are important with a view to probable resonance modes and degenerate energy levels.

Facts and intermediate conclusions:

- The model of spherical electron shells is confirmed by experimental data (the sum of ionization potentials of the shell fits with the energy of charged sphere, simulating a shell).

- The disclosed structure singularity of electron shells requires simultaneous compliance of two basic conditions:

Atom structure electrons *are not independent particles*;

All electrons *constantly and all together* have to be located on spherical shells (otherwise the model of spherical electron shells would not be confirmed by experimental data).

The conclusion

The principal result of this research, certainly, is the revelation of the resonant nature of electron shells of atoms which naturally arise from wave-corpuscle electron properties.

It is a key concept for understanding of all other questions!

Resonances in electron shells are the physical reason of electron "condensation", that is, their integration in the common resonance with "fixing" in resonance antinodes. This effect is the essence of electrons collective properties formation in shell structure.

On the other hand, shell resonance is accompanied by intensive energy (mass) exchange of electrons being in antinodes. As a result there is the centrifugal force compensating force of attraction, so that electrons motionlessly "hang" above a nucleus of atom. Thus, there is an imitation of electrons movement without their real movement.

And at last, electron condensation in resonant shells is the reason of the spherical shells form because "hanging" electrons follow equipotential surfaces, getting thus the "necessary" frequency to be tuned in the general resonance.

These conclusions about the physical nature of electron shells are based on the analysis of experimental characteristics of atoms. Therefore fundamental results of the research can be formulated as

Laws of formation of atom electron shells:

1. Electron shells of atoms are resonant formations which can be excited both on the basic frequency, and on harmonious components. Thus the principal quantum number accordingly can be integer, or fractional.

2. Many-electron atom shells have the spherical form, so the total sum of ionization potentials of a shell meets (subject to the virial theorem) the energy of the charged sphere of the same radius with electrical charge determined by the number of electrons on the shell.

3. Electrons of the atom electron shell are built in the common resonance, losing their individual properties, owing to what the electron shell obtains properties of Bose-condensate.

Notes:

1. In order not to overburden the article, the description of features of electron shells of the atoms not includes the dependence on radius value (exceeds it or not the Bohr radius). This question can be examined as analogical extension by means of calculations similar to those carried out in the article.

Separate consideration demands also a question of a distribution of electrons in atom over shells. We can only note that this distribution should correspond to a principle of minimum atom energy in whole.

2. Some readers of my article [1] propose for the convenience of citing and references to results of the research and in compliance with the tradition to name disclosed laws of atom electron shells formation by author's name.

Answering this proposal, I have to confess not to experience pleasure in connection with revelation of inconsistency of the modern atom theory because I as well as many other people have spent a lot of time and forces to study this theory and to overcome mistakes connected with it.

As of giving author's name to scientific discovery, it is really tradition, but it would be desirable, that it occurs as a result of discussion by scientific community.

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