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Article

Picoscopy Discoveries of the Binary Atomic Structure

Olexandr Kucherov [1],*, and Andrey Mudryk [2]

[1] Institute of Structural Information Technology, Kyiv 01042, Ukraine
[2] Company “GIGAHARD” Ltd. EUROPE, Plovdiv 4000, Bulgaria; info@picoscopy.com
* Correspondence: O.Kucherov@i.ua

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Abstract: In this article, we present a discovery of the binary atomic structure. Through picoscopy experiments, it was revealed that electronic structure is divided into core and functional structures. Internal chemically neutral electrons form the core of an atom and are spherical in pink, while the outer functional electrons are elongated in green being chemically active. A spherical yellow layer separates these two parts. It significantly simplifies the Schrödinger equation and leads to a solution for all 118 chemical elements. As a result, the Kucherov-Mudryk formula $w = n + \tfrac{3}{4}l$ was derived. That formula allowed for organizing the periodic table in ascending order of the whole energy where en electron first fills the level with the lowest energy, according to the Minimum Potential Energy general principle of nature.

Keywords: Electron configuration, Periodic table of elements, Atomic structure, Multi-electron atom, Picoscopy, Minimum Potential Energy principle, Schrödinger equation, Electron energy level, Electron shell

1. Introduction

The first periodic table was generally accepted after being proposed by the Russian chemist Dmitri Mendeleev in 1869 who formulated the periodic law that depends on the chemical properties and atomic mass. However, the periodic law does not explain such dependence. The quantum mechanical theory allows the explanation. According to the theory, the energy of an electron depends on the principal quantum number *n*, which characterizes the electrical interaction of a negatively charged electron with a positively charged nucleus of an atom. Therefore, the electron configuration becomes logical for the increase in energy. The Minimum Potential Energy (MPE) general principle [1] or least action is the origin of all systems in nature, both classical [2] and quantum physics [3]. According to the MPE principle [4], in the ground states of atoms the electrons configure the minimization of the energy of the whole system. Electrons first occupy the lowest energy level taking into account the Pauli exclusion principle. That is, energy levels must be filed under the increasing principal quantum number *n*, e.g.,: cesium *Cs* $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^6\ 6s$ [4]. However, as the periodic table was built according to the Madelung rule [5], cesium *Cs* $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6\ 6s$ [6] has electrons occupying the $4s^2$ level before the $3d^{10}$ level. That is, after the first level with higher energy is filled, the level with less energy is filled, which contradicts the MPE general principle. Thanks to the phenomenal possibilities of the picoscopy, we explained such a contradiction. Through a large number of experiments with the picoscopic images of valence electrons in various atoms [7], we found the reason for this contradiction and a solution to the Schrödinger equation for all chemical elements. As a result, the whole energy of the atoms was found, which shows that the system of elements is built according to the MPE principle, just as all other systems in nature.

2. Experiments

The picoscopy is defined as the visual study of an atom`s electron cloud. Picoscopy is used to visualize an atom due to the electron cloud densitometry [8]. A massively diverse set of picoscopic images [7] shows the fundamental difference between internal (neutral) and external (chemically active) electrons. The picoscopy allows for observing an atom with a single covalent bond [9] or with several [10]. Based on an insight into the nature of quantum mechanics, it is interesting to study the situation when the atoms are free and not connected by chemical bonds. From a traditional point of view, these allotropes without bonds are new and unstudied. Amorphous carbon and amorphous silicon were chosen in the experiments so that effectively the each valence electron could be seen. The picoscopic image of a carbon atom in the amorphous state without hybrids was obtained according to the method in [8]. The picoscopic image of a silicon atom in the amorphous state without hybrids was obtained according to the method proposed in [11].

Fig. 1 shows the binary atomic structure which consist of the core and functional electrons. The core has a sphere-shaped form of pink color and consists of chemically inert electrons. The outer functional electrons are chemically active with an elongated shape in green. A spherical yellow layer separates these two parts. A carbon atom (Fig. 1a) is divided into a core with the electron configuration of helium [He] and outer functional electrons consisting of four valence electrons $2s\ 2p^3$. A silicon atom (Fig. 1b) is divided into a core with the electron configuration of [Ne] and outer functional electrons consisting of four valence electrons $3s\ 3p^3$. The core is a closed sphere in pink regardless of the number of its electrons. Any of the usually brightly colored petals, on the contrary, together form an atom mostly. Their color can be green or blue. Figures 1a and 1b show yellow spherical layers that separate the core electrons from the outer ones. Space without clouds has zero intensity and black color. With picoscopy, we obtained images of multi-electron atoms to understand the atomic structure in general. The binary atomic structure is important to understand quantum theory and the structure of the periodic table.

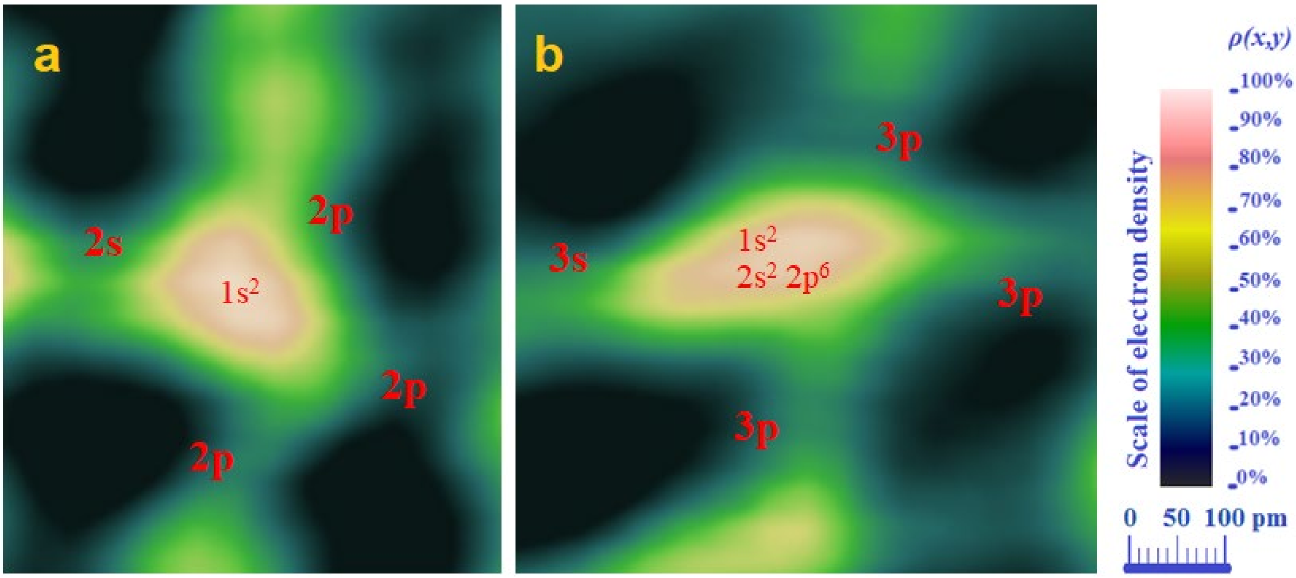


Fig. 1. Picoscopic images of the binary atomic structure. Image (**a**) shows a carbon atom in an amorphous state with pink core form helium [He] atom and four green outer valence electrons $2s\ 2p^3$. Image (**b**) shows a silicon atom in an amorphous state with a pink core form neon [Ne] atom and four green outer valence electrons $3s\ 3p^3$.

3. Theory

For multi-electron atoms, the analytical solution of the Schrödinger equation has not yet been found [4]. A large volume of visual material obtained by the picoscopy method showed the fundamental difference between internal and external electrons, which is caused by the joint action of both electric and magnetic forces. Recent studies have shown that a magnetic field changes the electron configuration of atoms [12]. Based on this fact, we added magnetic forces to the Schrödinger equation and found its solution for all chemical elements of the periodic table considering this problem as the motion of an electron with mass m in the Coulomb field $V(r)$ of a nucleus with Z of protons and the magnetic field $M(r)$ of the rest of the orbiting electrons. Therefore, the Schrödinger equation can be written as

$$\{(-\hbar^2/2m)\,\nabla^2 + V(r) + M(r)\}\,\Psi = E\,\Psi. \tag{1}$$

The solution of Eq. (1) for a Coulomb potential ($M(r) = 0$), is applied to atomic physics [4].

$$E(n) = -R/n^2, \tag{2}$$

where R is the Rydberg constant, n is the principal quantum number [13].

To understand the structure of the system of electronic states, a magnetic field needs to be added to Eq. (1). The joint action of the Coulomb and an additional potential has been widely studied [14]. In the study, the principal quantum number n was added a quantity δl that Schrödinger called a quantum defect. In this case, the expression for the energy $E(n,l)$ is approximated by

$$E(n,l) = -R/(n + \delta l)^2, \tag{3}$$

where R is the Rydberg constant, n is the principal quantum number, and l is the azimuthal quantum number.

Due to the presence of an electron in rotational motion around the nucleus, the electron creates a magnetic field μ, which, is characterized by the azimuthal quantum number l, which is related to the magnetic moment as follows.

$$\mu = \mu_B \times l. \tag{4}$$

The quantity μ_B is called the Bohr magneton.

We determined the constant δ to describe all chemical elements. Let us assume that the quantum defect δl depends proportionally on l and we will look for it in the form of $x \times l$, where x is a constant value for all chemical elements. The constant x can be found from the condition that in the eighth period subshell $5g$ (*i.e.*, $n = 5$, $l = 4$) must follow subshell $8s$ (*i.e.*, $n = 8$, $l = 0$). This is presented in Table 1. This leads to the following relation between the energies $E(5,4)$ and $E(8,0)$.

$$-R/(5+ x \times 4)^2 = -R/(8+ x \times 0)^2. \tag{5}$$

We shortened the same coefficients and took the square root.

$$5 + x \times 4 = 8+ x \times 0. \tag{6}$$

This is a linear equation with a solution $x = ¾$. Thus the whole quantum number w is

$$w = n + ¾l. \tag{7}$$

Thereby, all atoms are organized according to the MPE principle. The increase in electron energy is proportional to the whole quantum number w, which is the sum of the principal quantum number (electric energy) n and the azimuthal quantum number (magnetic energy) l with a weight of three quarters. The Kucherov-Mudryk formula (Eq. (7)) describes the structure of the periodic table and forms the basis of atomic physics and chemistry.

Equations (3) and (7) are combined for whole energy $E(n,l)$ of all elements of the periodic table, deriving Eq. (8)

$$E(n,l) = R/(n + ¾l)^2. \tag{8}$$

Equation (8) specifies the energy of the electron configuration depending on the sum of two quantum numbers.

4. Electron Configuration

Thus, the Kucherov-Mudryk formula (7) shows that each chemical element is built according to the same principle as all systems in nature. For an atom, the MPE principle can be formulated as follows: the electron occupies the lowest free level of the whole quantum number $w = n + ¾l$ around the nucleus.

Fig. 2 shows the Madelung ordering rule [5]. The filling of electron shells energy levels of electrons in atoms are determined by the main quantum number n (Eq. (2)). The sequence of filling electron shells is shown by a red broken line. Electrons first fill levels with higher energy, and then with lower energy, which contradicts the MPE principle. Fig. 3 shows the order of arrangement of chemical elements according to the MPE principle. The electrons first fill levels with lower energy, and then with higher energy. According to the level of whole quantum number $w = n + ¾l$, (7), the ground states of the elements have the following electron configurations [15].

$$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6\ 6s^2 4f^{14} 5d^{10} 6p^6 7s^2 5f^{14} 6d^{10} 7p^6 \{8s^2 5g^{18} 6f^{14} 7d^{10} 8p^6 \text{ and } 9s\}. \tag{9}$$

The subshells in the curly brackets represents the chemical elements that are still unknown to science. According to Eq. (7), due to the additional energy from the magnetic field, the elements of subshell d fall into period $n + 1$, and the elements of subshell f fall into period $n + 2$. Having the formula for whole energy, the general principles of atomic structure underlying the periodic table of the elements is understood. In the ground states of the atoms, the electrons configure the minimization of the energy of the whole system. The electrons do not fall into the lowest orbital with $n = 1$ because the Pauli exclusion principle restricts the number of electrons in a given subshell—two electrons cannot have the same set of quantum numbers. This leads to the 'building-up' principle: electrons fill up higher and higher shells as the atomic number Z increases across the periodic table. Electrons first occupy the levels of the lowest whole energy $E(n,l) = R/w^2$, where the whole quantum number $w = n + ¾l$. It accords with the MPE general principle of nature: the system occupies the state corresponding to the smallest energy reserve. Therefore, to establish the order of filling the shells of chemical elements with electrons, we arranged them in order of increasing whole energy w. That is, a diagram of the dependence of the whole quantum number w was constructed on the sum of the main and three-quarters of the azimuthal quantum number l, according to formula (7).

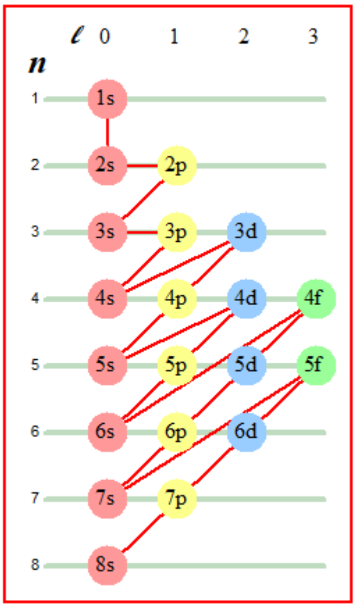


Fig. 2. The Madelung ordering rule. The order of energy minimization is violated.

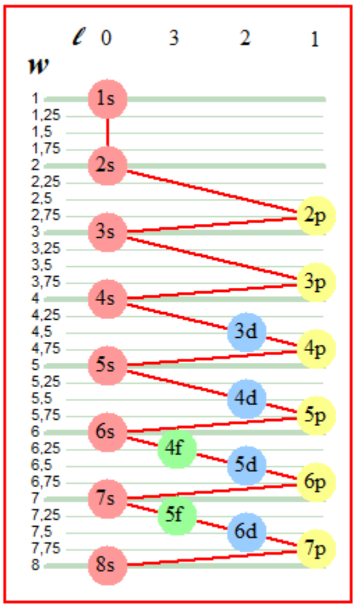


Fig. 3. The electron in an atom occupies the lowest available level of whole quantum number $w = n + ¾l$, in accordance with the MPE principle.

In 1869, D.I. Mendeleev formulated the periodic law using the dependence of chemical properties on atomic mass. However, his periodic law did not explain the reasons for such dependence. Equation (7) reveals the reasons for the dependence of the chemical properties and allows us to formulate the periodic law as follows. In the periodic law, chemical elements are built according to the growth of the whole quantum number $w = n + ¾l$, and their chemical properties are directly dependent on the azimuthal quantum number l. The order for filling electron energy levels is summarized in Table 1.

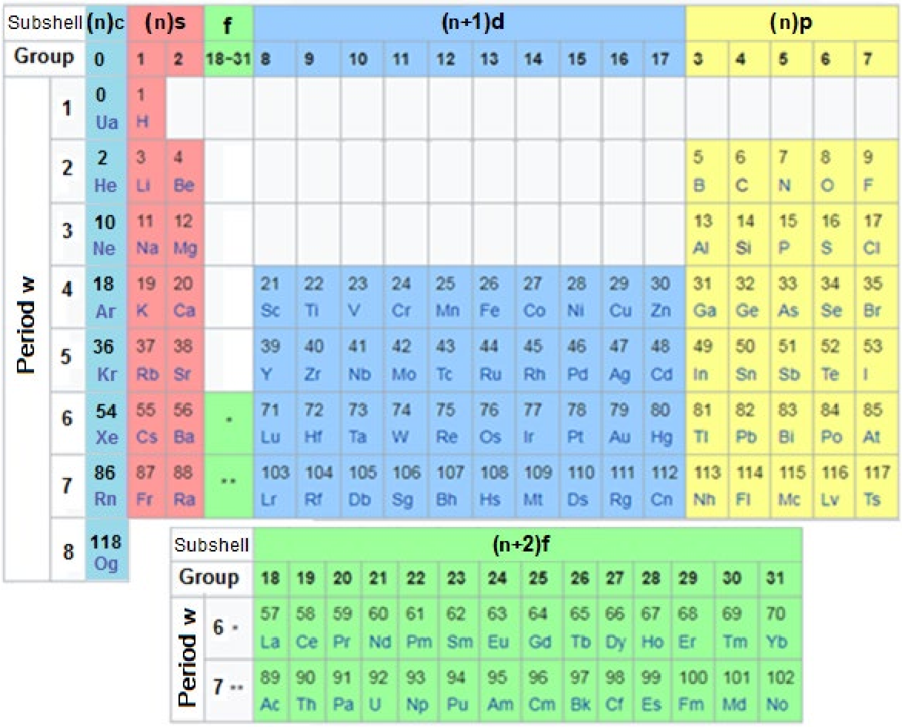
Table 1. The ground configurations of elements according to the binary atomic structure.

	↓Shell\Subshell→	***s*(*l* = 0)**	***g*(*l* = 4)**	***f*(*l* = 3)**	***d*(*l* = 2)**	***p*(*l* = 1)**
↓Period\Group→	**0**	**1–2**	**32–49**	**18–31**	**8-17**	**3–7**
1	[Ua]	1s				
2	[He]	2s				2p
3	[Ne]	3s				3p
4	[Ar]	4s			3d	4p
5	[Kr]	5s			4d	5p
6	[Xe]	6s		4f	5d	6p
7	[Rn]	7s		5f	6d	7p
8	[Og]	{8s}	{5g}	{6f}	{7d}	{8p}

The groups are numbered in the order of increasing azimuthal quantum number l, and the subshells are located in the order of their actual filling in the periodic table. The subshells in the curly brackets represent the chemical elements that are still unknown to science. A core does not have valence electrons and serves as a basis for filling outer shells, while outer electrons determine valence and chemical properties. Regardless of the period, all inert gases differ sharply from other elements in their chemical neutrality, which is associated with a zero number of valence electrons. That is, they occupy the zero group on the left, as did D.I. Mendeleev and the subshell is assigned the letter *c* (core). The electron configuration of chemical elements begins with the zero elements (preliminarily named ukrainium Ua) [16]. Ua is the chemical element of the periodic table in which D.I. Mendeleev numbered zero. It occupies a cell in the first row of a zero group, it precedes hydrogen with the number one and zero to make the periodic table complete. This element is stable, in its natural form it is widely found on Earth, in comets, and in astrophysical masers [17].

5. Kucherov-Mudryk Quantum Periodic Table of Chemical Elements

As both experimental (Fig. 1) and theoretical (Eq. (7)) physics show, the atom consists of two parts: core and functional. Therefore, the periodic table should be compiled similarly. The logic of the arrangement of chemical elements in the periodic table is as follows. The chemical properties of atoms do not depend on the atomic weight, the nuclear charge, or the principal quantum number n. These properties depend on the outer electron configuration, which, in turn, depends on the rotational moment l. This rotational movement creates a magnetic field. Therefore, the magnetic field itself is responsible for the chemical properties of the elements.



Subshell		(n)c	(n)s		f	(n+1)d										(n)p				
Group		0	1	2	18-31	8	9	10	11	12	13	14	15	16	17	3	4	5	6	7
Period w	1	0 Ua	1 H																	
	2	2 He	3 Li	4 Be												5 B	6 C	7 N	8 O	9 F
	3	10 Ne	11 Na	12 Mg												13 Al	14 Si	15 P	16 S	17 Cl
	4	18 Ar	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
	5	36 Kr	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
	6	54 Xe	55 Cs	56 Ba	*	71 Lu	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
	7	86 Rn	87 Fr	88 Ra	**	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts
	8	118 Og																		

Subshell		(n+2)f													
Group		18	19	20	21	22	23	24	25	26	27	28	29	30	31
Period w	6 *	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
	7 **	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

Fig. 4. The Kucherov-Mudryk quantum periodic table of chemical elements.

The whole quantum number $w = n + \frac{3}{4}l$ explains the real nature of the periodic table of chemical elements. Electron shells of atoms are filled in accordance with the whole quantum number, and their chemical properties are found in direct dependence on the azimuthal quantum number l. Figure 4 shows the Kucherov-Mudryk quantum periodic table, which consists of 118 cells arranged in 32 vertical columns and seven horizontal rows. The position of an element is given by quantum numbers n and l. Thus, the chemical properties of elements are determined by the electron configuration on the outer shell. In the quantum periodic table, subshells are numbered in order of increasing the azimuthal quantum number l. The subshell $s(l = 0)$ has numbers 1–2, $p(l = 1)$ has numbers 3–7, $d(l = 2)$ has numbers 8–17, $f(l = 3)$ has numbers 18–31.

Full shells are found at atomic numbers $Z = 0$, 2, 10, 18, 36, 54, 86, and 118 corresponding to helium and the other inert gases. In inert gases, all electrons are located on the core shells. Inert gases have a zero number of valence electrons and belong to subshell c (core). Inert gases occupy the column on the left under the zero number of the periodic table. D.I. Mendeleev did that in his table. They are grouped because of their similar chemical properties, i.e., the difficulty in removing an electron from closed shells means that they do not readily undergo chemical reactions. As they are reluctant to share electrons from their filled core electron shells, inert gases are generally considered unreactive.

6. Discussion

The Kucherov-Mudryk formula, $w = n + \frac{3}{4}l$, indicates that electrons first fill the levels with the lowest energy, according to the MPE general principle of nature. This allowed the periodic law to be formulated as follows. Chemical elements are defined according to the growth of total energy $w=n+ \frac{3}{4}l$, and their chemical properties are directly dependent on the azimuthal quantum number l. The new quantum periodic table, based on the Kucherov-Mudryk formula, represents a significant progress in understanding of the quantum nature of the universe. The formula is imperfect, as it includes only the principal n and azimuthal l

quantum numbers. The formula is completed if two other quantum mechanical coordinates are added to it: magnetic m and spin s. Thus, the completed formula is expressed as $w = n + ¾l + xm + ys,$ where x and y are real numbers. The rotation of electrons around the nucleus of an atom is described by the proposed formula.

7. Conclusions

Picoscopy is gradually solving the mysteries of the functional properties of materials. The atom has a simple binary structure. Quantum physics follows the same laws as the classical world. There is a simple logic in the construction of atoms. Therefore, we established the system of electrons in an atom which is organized to minimize the whole energy. Picoscopy is a profound new insight into the nature of quantum mechanics that stimulates important theoretical and experimental works. The result of this research provides a new clue to applying quantum chemistry. The developed mathematical apparatus and software can be used to determine the properties of new chemical compositions. This allows scientists to find solutions to complex problems for new materials. Also, the latest theory and mathematical apparatus of picoscopy allow for designing new applied functional materials for the space and aviation industry that are lighter than aluminum and stronger than titanium. In medicine, picoscopy is also used to create effective drugs by visually controlling their effect at the molecular level.

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