«Atom structure. The periodic table»

Lector is an Associate Professor

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Lecture plan

1. The theory of the structure of the atom.
2. Quantum numbers.
3. Electron configurations for atoms.
4. Periodic law. The structure of periodic table.
5. Some characteristics of atoms of elements.

1. The theory of the structure of the atom

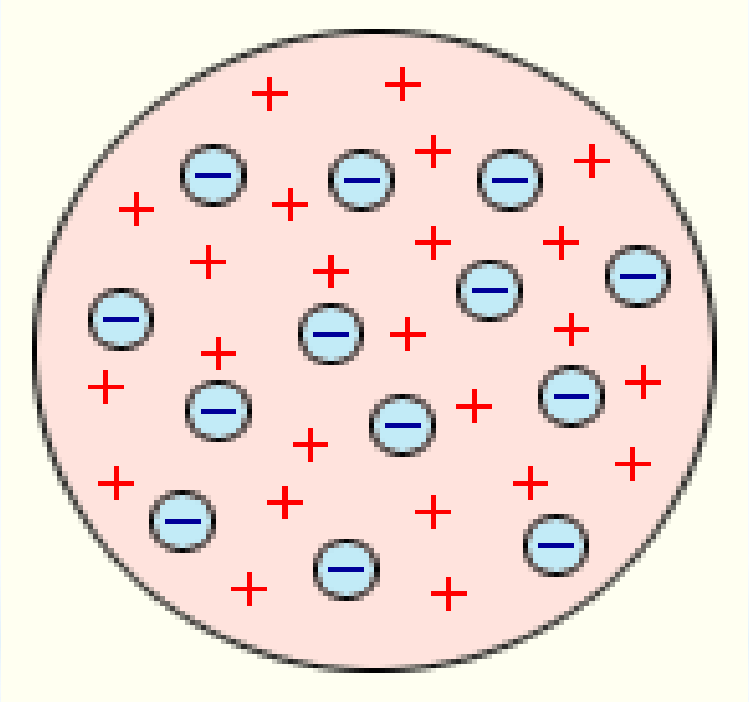
1859 **G. Kirchhoff and R. Bunsen -** spectral analysis**.**

1859 **W. Crooks -** cathode rays.

1888 **Stolepov -** photoelectric effect.

1897 **D. Thomson** discovered the electron and estimated its mass $m_e=9{,}1\cdot10^{-31}$kg. He proposed the **first model of the atom structure.**

Model of the atom by John Thomson



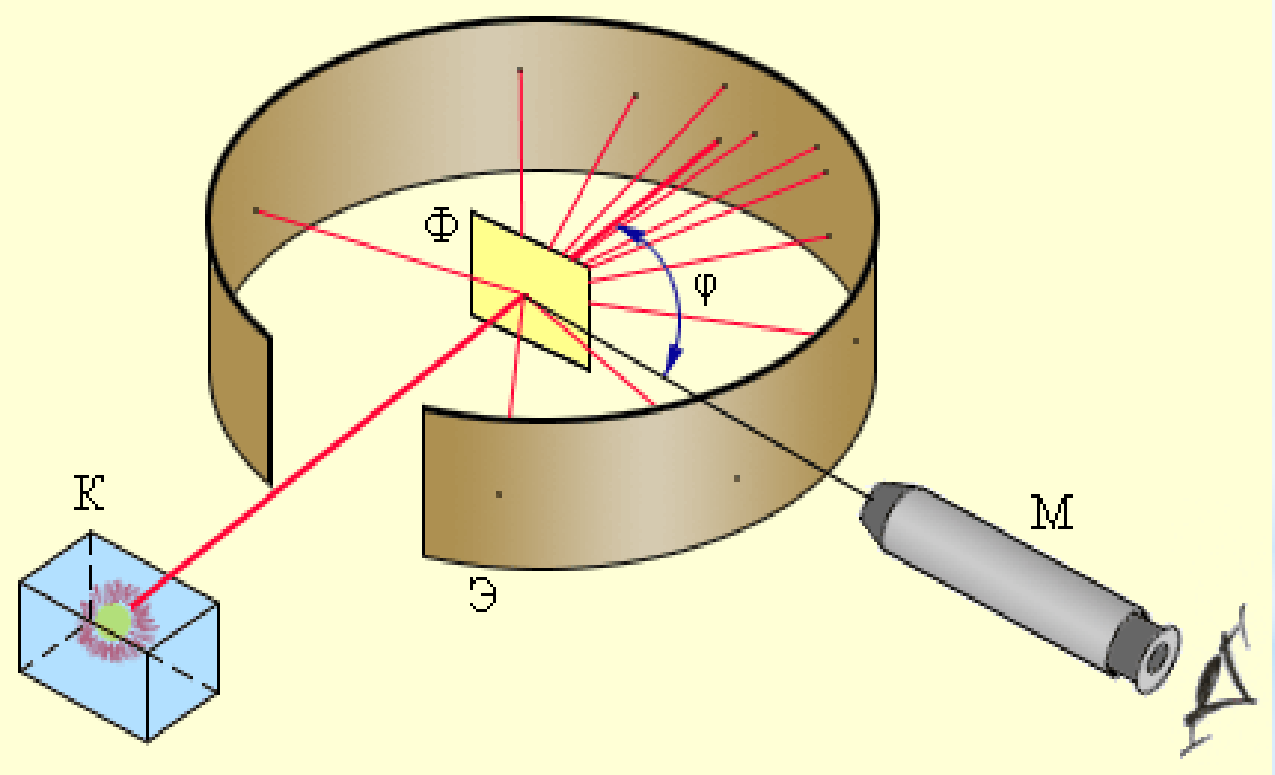
"Plum pudding"

1. The theory of the structure of the atom

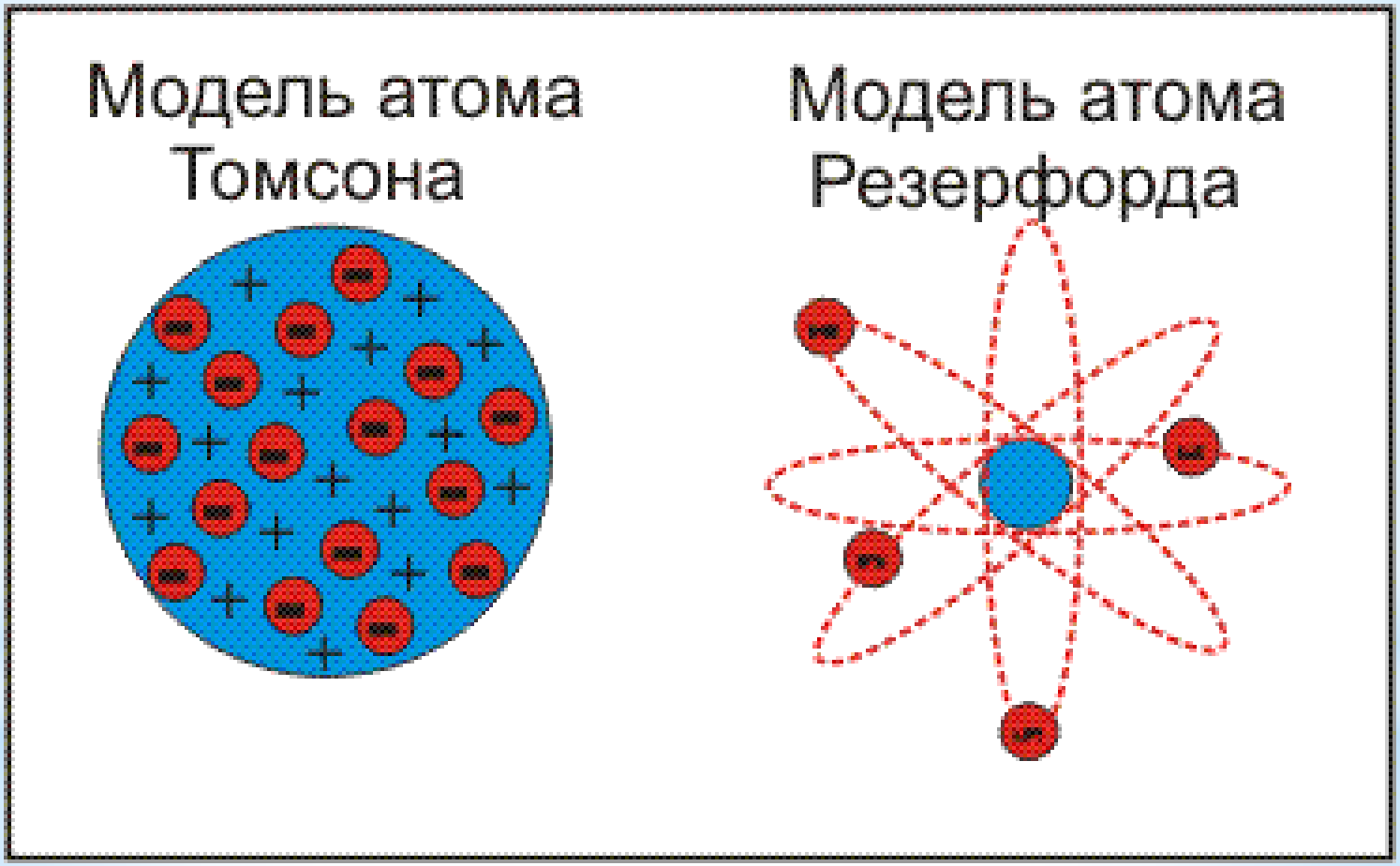
1909 г. **R. Mulliken** determined the charge of an electron $q_e=1,6\cdot10^{-19}$Кл

1910 г. **E. Rutherford** proposed a nuclear planetary model of the atom (**the second model**).

Scheme of Rutherford's experiment on the scattering of α-particles



1. The theory of the structure of the atom



1. The theory of the structure of the atom

1913 **N. Bohr -** model of the structure of the hydrogen atom.

(1920) Quantum-mechanical model of the atom model

1924 **Louis de Broglie -** corpuscular-wave properties of an electron. The electron is both a wave and a particle.

1926 **W. Heisenberg -** the principle of uncertainty**.**

1926 **E. Schrödinger** established a mathematical model describing the behavior of an electron in an atom. The Schrödinger equation showed that the probability of finding an electron near the nucleus depends on three quantum numbers**.**

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The equation of Schrodinger

$$\psi E = -\frac{h^2}{8\pi^2 m}\left(\frac{\partial^2\psi}{\partial x^2}+\frac{\partial^2\psi}{\partial y^2}+\frac{\partial^2\psi}{\partial z^2}\right)+\psi U$$

Ψ – wave function,

E – total energy,

U – potential energy of an electron.

1. The theory of the structure of the atom

* **The atomic orbital** is called the area inside the atom in which the electron can be detected with a certain degree of probability.

* **The atomic orbital** is a wave function. It describes an electron in atom. Each wave function is the solution of the equation of Schrodinger.

2. Quantum numbers

<u>Principal quantum number</u> (n)

– characterizes energy of electron and the orbital size;

− corresponds to the period number in the periodic system;

− changes from 1 to ∞.

An energy level is a totality of electrons in an atom with the same value of n

2. Quantum numbers

Orbital quantum number(*l*)

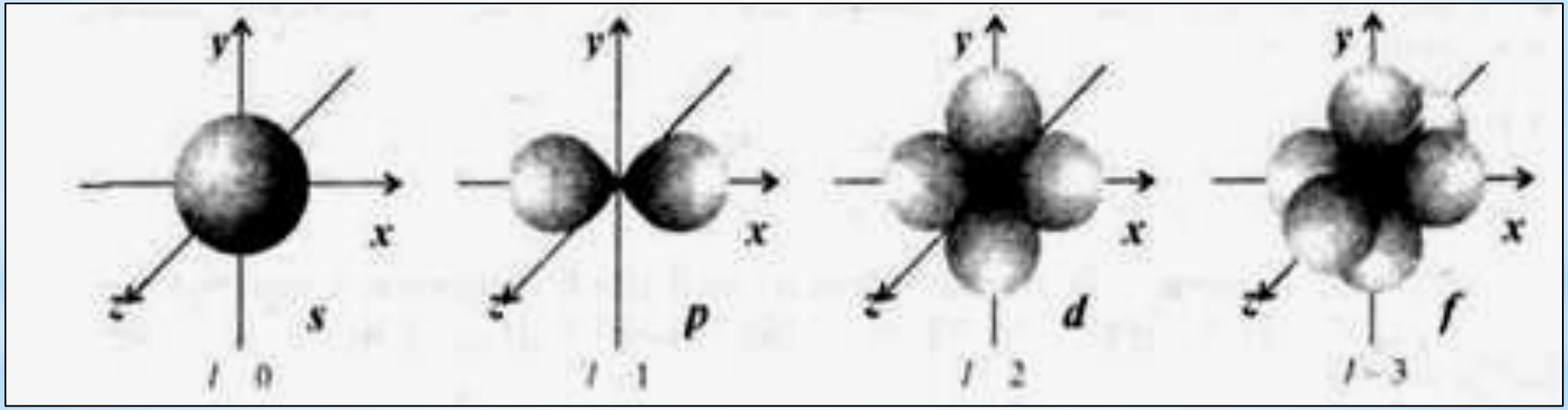
– determines the shape of the atomic orbital,

– changes from 0 to (n-1).

Energy sublevel is a totality of electrons in an atom with the same value of l (when equal to n)

2. Quantum numbers

Value *l*	0	1	2	3
Symbol	s	p	d	f



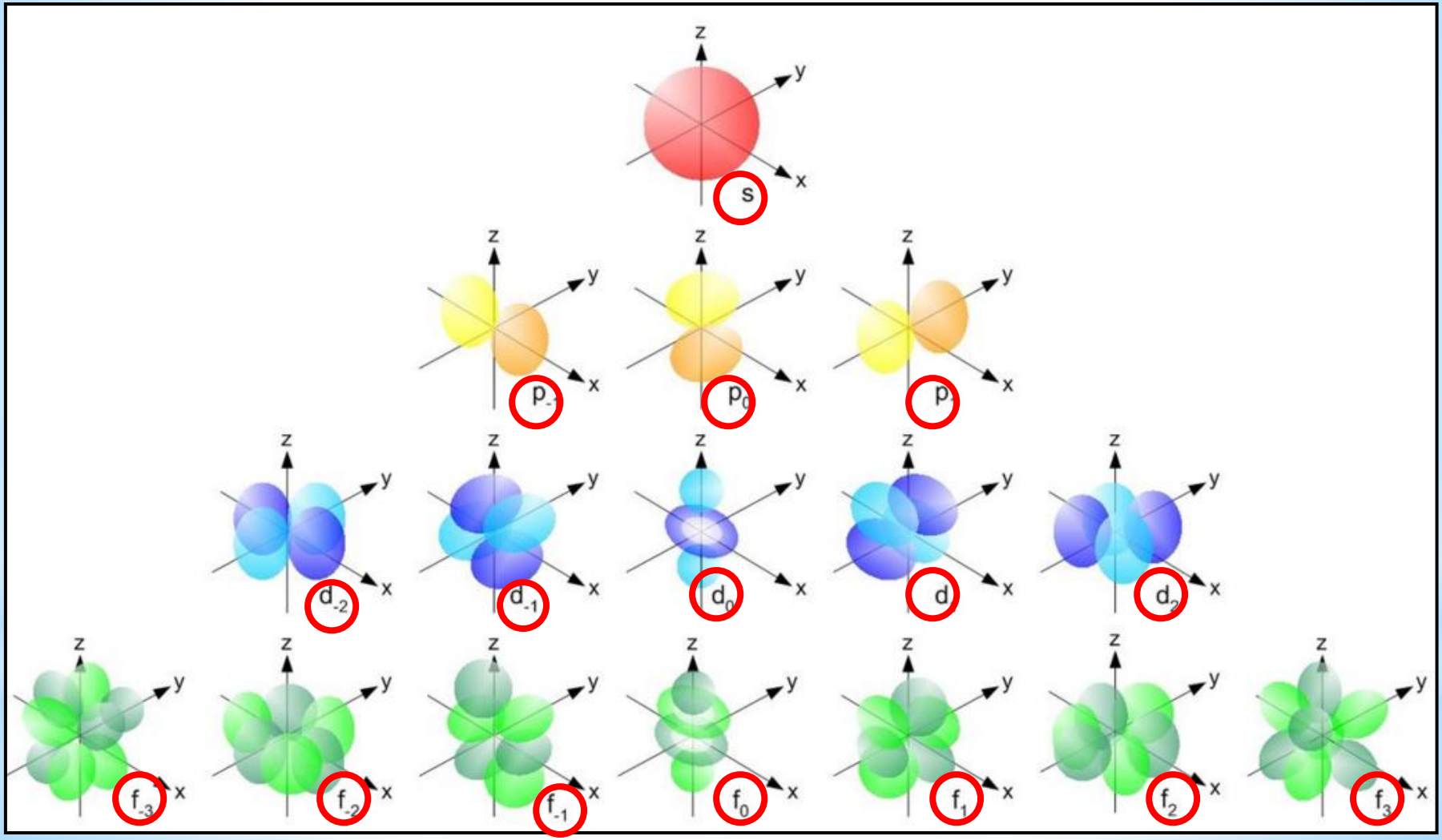
2. Quantum numbers

3) **Magnetic quantum number (m_l)**

– characterizes the orientation of the atomic orbital in space

– changes from $-l$ *to* $+l$, including 0.

2. Quantum numbers



2 Quantum numbers

4) **Spin quantum number (m_s)**

– characterizes the proper motion of an electron in space,

– takes values

3. Electron configurations for atoms

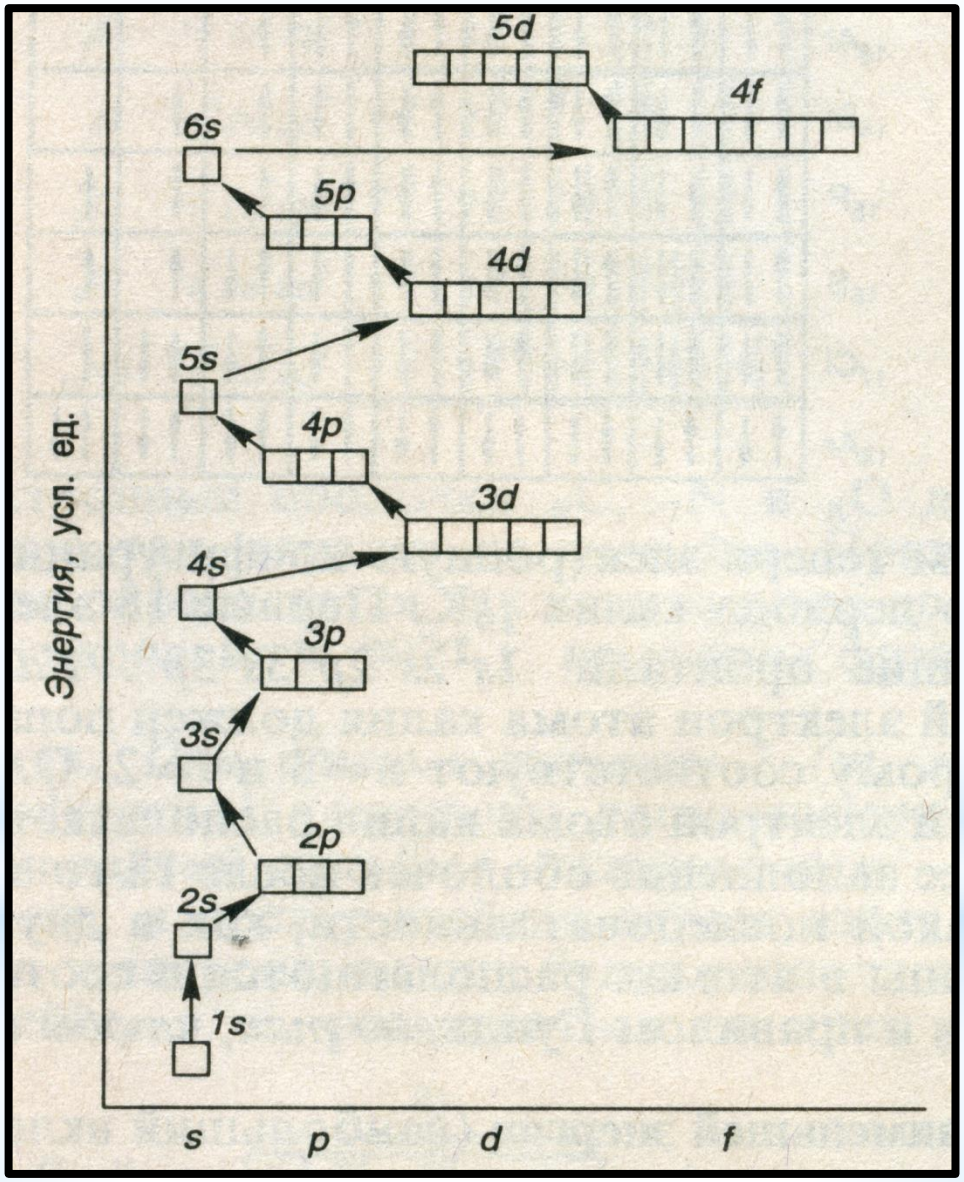
***The principle of least energy :**

the electrons in the ground state occupy the orbital with the lowest energy.

The energy of sublevels grows in a row :

$$1s < 2s < 2p < 3s < 3p < 4s \approx 3d < 4p < 5s \approx 4d < 5p < 6s < 4f \approx 5d < 6p < 7s < 5f \approx 6d \ldots$$

3. Electron configurations for atoms



3. Electron configurations for atoms

*Rules by V. M. Klechkovsky :

1. The filling of atomic orbitals occurs in ascending order of the sum of quantum numbers n+l.

2. With an equal sum (n + l) - in ascending order of the number n.

	$1s^2$	$2s^2$	$2p^6$	$3s^2$	$3p^6$	$4s^2$	$\mathbf{3d^{10}}$	$\mathbf{4p^4}$
Sum n+*l* :	1	2	3	3	4	4	5	5

3<4

3 Electron configurations for atoms

*Pauli principle:

there are no more than two electrons on each orbital.

* Hund's rule:

when more than one orbital has the same energy, electrons occupy separate orbitals.

3. Electron configurations for atoms

$^{34}_{79}Se$ (p = 34, e = 34)

* Full electronic formula :

Se $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^4$

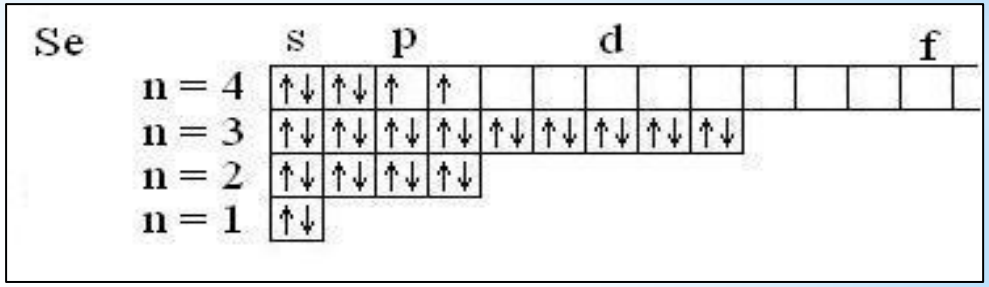
* Shortened electronic formula :

Se [Ar]$4s^2 3d^{10} 4p^4$

* Formula of valence electrons :

Se..$4s^2 4p^4$

* Graphic form **:**



3. Electron configurations for atoms

The phenomenon of "failure" of the electron

— the transition of ē from the external energy level to a lower one, which is explained by the greater energy stability of the resulting electronic configurations.

1)when the level and sublevel are filled, the stability of the electronic configuration increases

2) filled (s^2, p^6, d^{10}, f^{14}) and half-filled (p^3, d^5, f^7) configurations are especially stable.

4. Periodic law. The structure of periodic table

(*opened in 1869 by D.I. Mendeleev*)

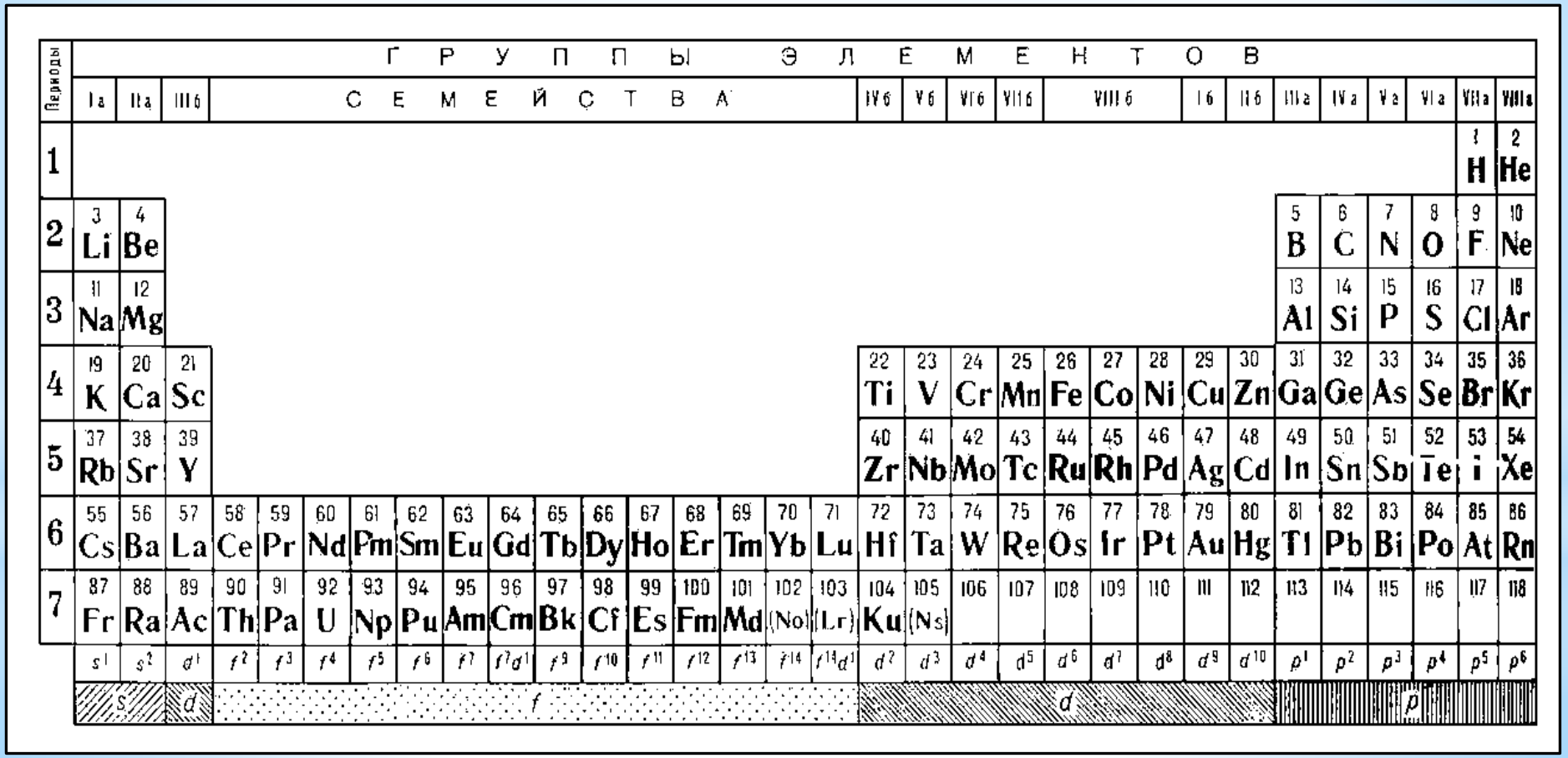
«the properties of chemical elements, as well as the forms and properties of the simple substances and compounds they form, are in a periodic dependence on the magnitude of the charges of the nuclei of their atoms»

4. Periodic law. The structure of periodic table

Variant of the short period form

4. Periodic law. The structure of periodic table

Long form variant



4. Periodic law. The structure of periodic table

Modern periodic table

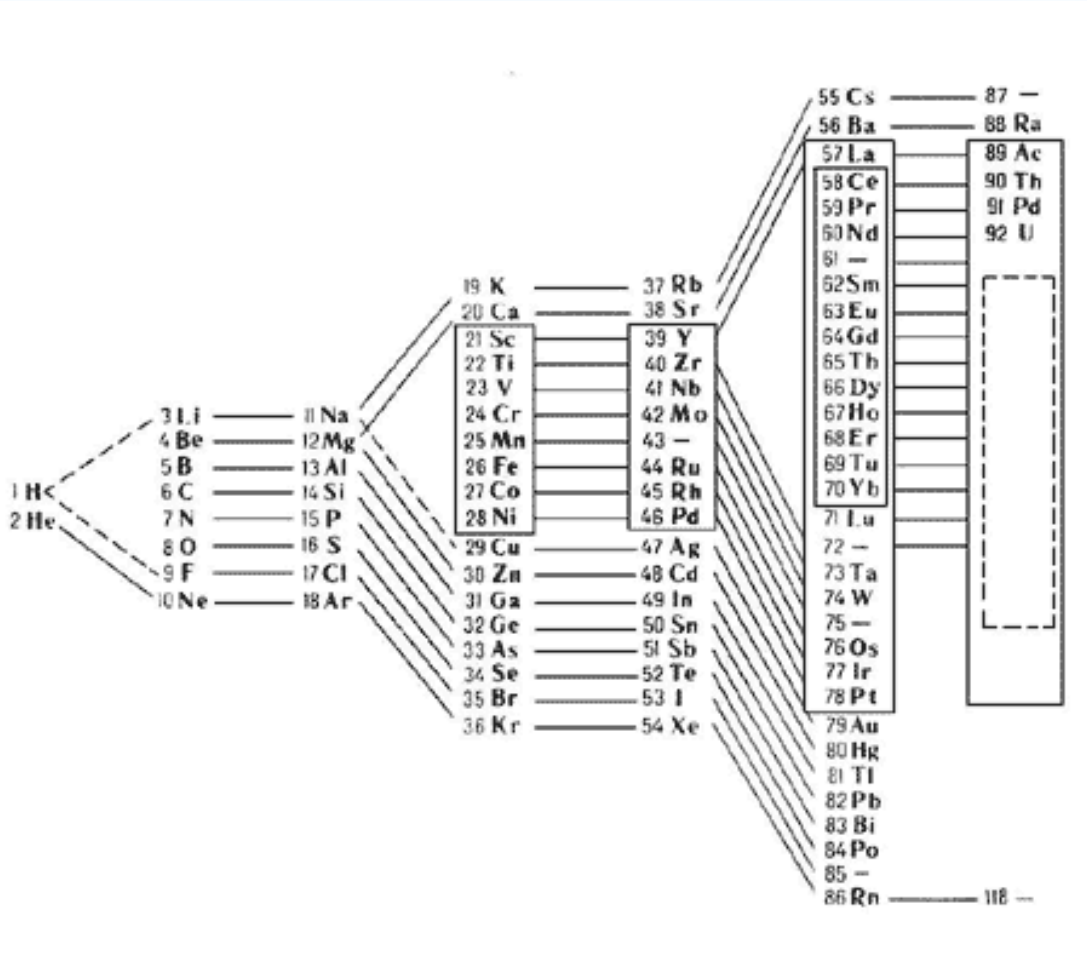
Периодическая таблица (длиннопериодный вариант)

Период	1 IA	2 IIA	3 IIIБ	4 IVБ	5 VБ	6 VIБ	7 VIIБ	8	9 VIIIБ	10	11 IБ	12 IIБ	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
	s-блок		**d-блок**										**p-блок**					
I	**1 H**																	**2 He**
II	**3 Li**	**4 Be**											**5 B**	**6 C**	**7 N**	**8 O**	**9 F**	**10 Ne**
III	**11 Na**	**12 Mg**											**13 Al**	**14 Si**	**15 P**	**16 S**	**17 Cl**	**18 Ar**
IV	**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**
V	**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**
VI	**55 Cs**	**56 Ba**	**57 La**	**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**
VII	87 **Fr**	88 **Ra**	89 **Ac**	104 **Rf**	105 **Db**	106 **Sg**	107 **Bh**	108 **Hs**	109 **Mt**	110 **Ns**								

f-блок													
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 **Yr**	71 **Lu**
90 **Th**	91 **Pa**	92 **U**	93 **Nb**	94 **Pu**	95 **Am**	96 **Cm**	97 **Bk**	98 **Cf**	99 **Es**	100 **Fm**	101 **Md**	102 **No**	103 **Lr**

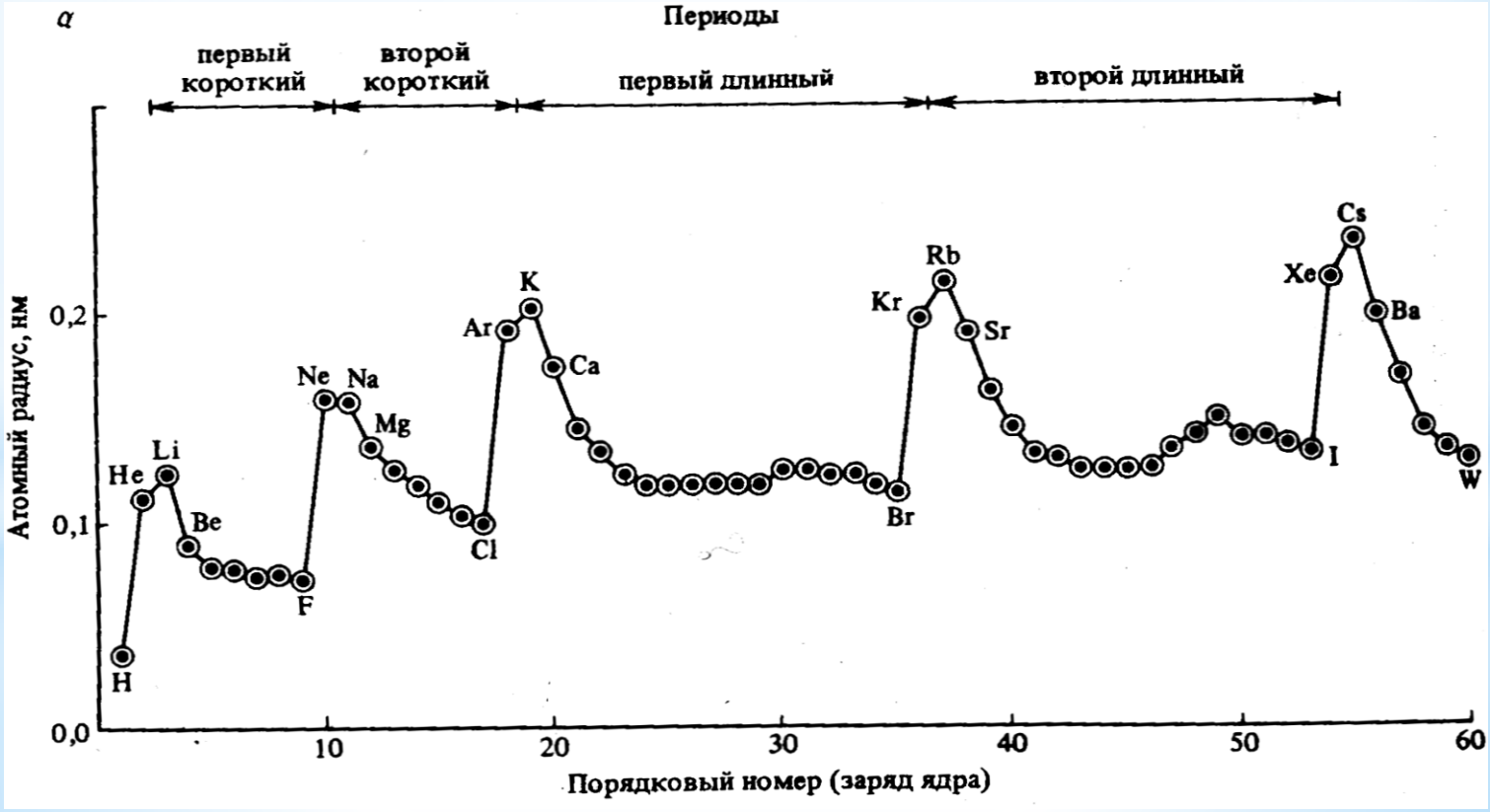
4. Periodic law. The structure of periodic table

Ladder form of the periodic system of elements
(according to N. Bohr, 1921)



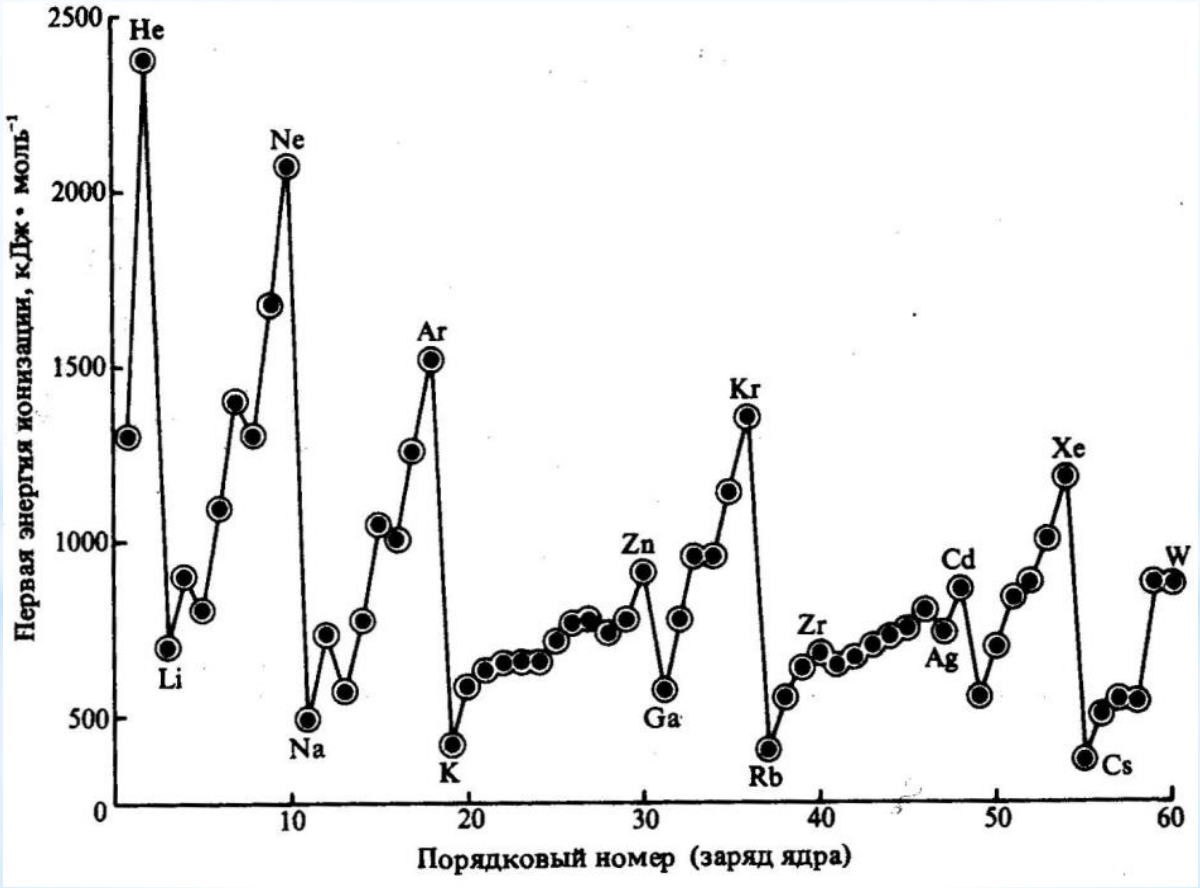
5. Some characteristics of atoms of elements

- **Atomic radii (r_a)** is the distance from the center of the nucleus to the maximum electron density.



5. Some characteristics of atoms of elements

- **Ionization energy (E_{ion}) is** the energy required to remove an electron from atom. $A + E_{ion} = A^+ + e$



5. Some characteristics of atoms of elements

- **Electron affinity** is the energy released or expended when an electron is added to a neutral atom.

$$A + \bar{e} = A^-$$

5. Some characteristics of atoms of elements

- **Electronegativity (χ)** is the ability to drag and drop elements of the atom electrons to itself in the formation compounds.

Electronegativity value according to Pauling

	A I Б	A II Б	A III Б	A IV Б	A V Б	A VI Б	A VII Б	VIIIБ		A VIII Б
1	H 2,1									He –
2	Li 1,0	Be 1,5	B 2,0	C 2,5	N 3,0	O 3,5	F 4,0			Ne –
3	Na 0,9	Mg 1,2	Al 1,5	Si 1,8	P 2,1	S 2,5	Cl 3,0			Ar –
4	K 0,8	Ca 1,0	Sc 1,3	Ti 1,5	V 1,6	Cr 1,6	Mn 1,5	Fe 1,8	Co 1,8	Ni 1,8
	Cu 1,9	Zn 1,6	Ga 1,6	Ge 1,8	As 2,0	Se 2,4	Br 2,8			Kr –
5	Rb 0,8	Sr 1,0	Y 1,2	Zr 1,4	Nb 1,6	Mo 1,8	Tc 1,9	Ru 2,2	Rh 2,2	Pd 2,2
	Ag 1,9	Cd 1,7	In 1,7	Sn 1,8	Sb 1,9	Te 2,1	I 2,5			Xe –
6	Cs 0,7	Ba 1,9	La* 1,1	Hf 1,3	Ta 1,5	W 1,7	Re 1,9	Os 2,2	Ir 2,2	Pt 2,2
	Au 2,4	Hg 1,9	Tl 1,8	Pb 1,8	Bi 1,9	Po 2,0	At 2,2			Rn –
7	Fr 0,7	Ra 0,9	Ac** 1,1							

* Лантаноиды.
** Актиноиды.

5. Some characteristics of atoms of elements

Change in oxidation states in the main groups

		Main group						
		I	II	III	IV	V	VI	VII
Periods	1							
	2							+7
	3					+5	+6	+5
	4	+1	+2	+3	+4 +2	+3 +1	+4 +2	+3 +1
	5	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	6				**-2** -4	**-1** -3	-2	-1
	7							

5. Some characteristics of atoms of elements

Change in oxidation states in the side groups

		Side group						
		I	II	III	IV	V	VI	VII
Periods	1	+1 **0**	+2 +1 **0**	+3 +2 +1 **0**	+4 +3 +2 +1 **0**	+5 +4 +3 +2 +1 **0**	+6 +5 +4 +3 +2 +1 **0**	+7 +6 +5 +4 +3 +2 +1 **0**
	2							
	3							
	4							
	5							
	6							
	7							

5.1. Periodic change of connection properties

Change of acid-basic properties

VI main group	Type of oxide
SO_3	acidic
SeO_3	acidic
TeO_3	amphoteric
PoO_3	basic

5.1. Periodic change of compounds properties

Change of acid-basic properties of oxides and hydroxides of elements in the highest oxidation number

Increased acid properties

Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl_2O_7
basic oxide	basic oxide	amp. oxide	acidic oxide	acidic oxide	acidic oxide	acidic oxide
NaOH	**$Mg(OH)_2$**	**$Al(OH)_3$**	**H_2SiO_3**	**H_3PO_4**	**H_2SO_4**	**$HClO_4$**
basic	basic	amp.	acid	acid	acid	acid

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