ALMUSTAQBAL UNIVERSITY COLLEGE

Biomedical Engineering Department

Stage : Second year students

Subject : Chemistry 1 - Lecture 3

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(Electron configuration and periodic table)

ELECTRON CONFIGURATION

The properties of the elements are determined by the arrangement of electrons in their atoms.

Various elements have different numbers of electrons, these electrons are configured around the nucleus in the atom, in an order called the electron configuration. Therefore, atoms of every element have a unique electron configuration whereby the electrons are ordered The electrons in an atom are grouped around the nucleus into **shells**, roughly like the layers in an onion, according to the energy of the electrons. The farther a shell is from the nucleus, the larger it is, the more electrons it can hold. The first shell (the one nearest the nucleus) can hold only 2 electrons, the second shell can hold 8, the third shell can hold 18, and the fourth shell can hold 32 electrons. Within shells, electrons are further grouped into **subshells** of four different types, identified in order of increasing energy by the letters *s*, *p*, *d*, and *f*. Here is a summary of the types of orbitals and how many electrons each can contain:

Principle energy level (n)	Type of sublevel	Number of orbitals per type	Number of orbitals per level(n ²)	Maximun number o electrons (2n ²)		
1.	s	1	1	2		
	s	s 1				
2	р	3	4	8		
	s	1	1			
3	р	3	9	18		
	d	5				
	s	1				
	р	3	16			
4	d	5	16	32		
	f	7				



Example:

How many electrons are present in an atom that has its first and second shells filled and has 4 electrons in its third shell? Specify its atomic number (Z).

ANSWER:

The first shell of an atom holds 2 electrons in its 1s orbital, and the second shell holds 8 electrons (2 in a 2s orbital and 6 in three 2p orbitals).

Thus, the atom has a total of 2 + 8 + 4 = 14 electrons.

atomic number = number of protons = number of electrons in the atom. Then the atomic No. (Z)=14.

Exercise:

How many electrons are present in an atom in which the 1S, 2S, and 2p sub- shells are filled?

Exercise:

What is the atomic number of the atom having the first and second shells and the 3S subshell are filled with electrons ?

Electron Configurations

The exact arrangement of electrons in an atoms shells and subshells is called the **electron configuration** and can be predicted by applying three rules:

RULE 1. (Aufbau Principle)

This principle shows that secondary energy levels are filled with electrons according to their energy level ,from the lowest to the highest, **Electrons occupy the lowest-energy orbitals available, beginning with 1S and continuing in the order shown in the following Figure.** Within each shell, the orbital energies increase in the order *S*, *p*, *d*, *f*. they follow this order:





Orbital (1S) is filled first with electrons then 2S then 2P then 3S then 3P then 4S then 3d and so far: IS 2S 2P 3S 3P 4S 3d 4P 5S 4d 5P 6S 4f

Example : the electronic configuration of ₁₂Mg is as follows:



RULE 2.

Each orbital can hold only two electrons, which must be of opposite spin.

RULE 3. (Hunds rule)

Two or more orbitals with the same energy(the three p orbitals or the five d orbitals in a given shell, for example) are each half filled by one electron before any one orbital is completely filled by addition of the second electron.



Example 1: Write the electron configuration for the elements (₁H , ₂He, ₃Li , ₄Be).

Soluti	on:		
Eleme	nts Electron configuration		
$_{1}\mathrm{H}$	$1S^1$	₂ He	$1S^2$
₃ Li	$1S^2 2S^1$	₄ Be	$1S^2 2S^2$

Example 2:

Write the electron configuration for each of the elements (${}_{5}B$, ${}_{8}O$, ${}_{10}Ne$, ${}_{13}A1$)

Exercise 1:

Write the electron configuration for the elements ($_{9}F$, $_{14}Si$, $_{15}P$, $_{18}Ar$, $_{19}K$)

PERIODIC TABLE

The periodic table is a table that logically organize all the known elements. Each **element** has a specific location according to its atomic structure. Each row and column has specific characteristics. it is considered the most important tool for those who study chemistry, it is useful in predicting and understanding some properties of elements.

Periods:

In the modern periodic table each horizontal row of the table is called a **period**. Along a period, a gradual change in chemical properties occurs from one element to another. The periodic table consists of seven periods.

GROUPS

The modern periodic table of the elements contains 18 groups, or vertical columns. elements in a group are different but have almost similar chemical properties because they have the same number of outer electrons. Each column is called a **group** where the elements have the same number of electrons in the outer **orbital**.

Every element in the first column (group one) has one electron in its outer shell. Every element in the second column (group two) has two electrons in the outer shell ...etc..



Figure 2 : Periodic table scheme

CLASSIFICATION OF ELEMENTS IN THE PERIODIC TABLE ACCORDING TO ELECTRON CONFIGURATION

In the periodic table Elements can be divided into four blocks, according to the types of the secondary level with which the electron configuration of the elements ends with (s, p, d, f), as illustrated in fig. 3.



Figure 3: periodic table blocks

1. S- Block Elements:

They are elements on the far left of the periodic table including groups IA and IIA, whose electron configuration ends with (s), except for helium (He) ,it is added to the noble elements at the far right.

Group IA includes elements whose last secondary energy level (S) have one electron, for Group IIA, it includes elements whose last secondary energy level (S) have two electrons

2. P-Block Elements:

These elements are located on the right side of the periodic table, (see figure 3) whose electron configuration ends with (P) and include six groups, the first five of which are (IIIA, IVA, VA, VIA, VIIA) and the last group on the far right of the periodic table (group VIIIA), it is called the noble gases group.

3. d -Block Elements:

These are metal elements whose electron configuration ends with (S and d), they are called transition elements or d- block elements, at the center of the periodic table. Figure (3)

4. f -Block Elements:

These elements are located at the bottom of the periodic table whose electron configuration ends with (f), and called the inner transition elements, including 14 groups belonging to sixth and seventh periods.

Blo	ock s													Bl	ock	р	
I IA																	18 VIII
H	2 IIA											13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	2 He
³ Li	Be]	Bloc	k d					5 B	°C	7 N	80	°F	10 Ne
¹¹ Na	Mg	3 111B	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB		11 1B	12 11B	13 Al	¹⁴ Si	15 P	16 S	¹⁷ Cl	IB 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	36 Kı
37 Rb	38 Sr	³⁹ Y	40 Zr	41 Nb	42 Mo	43 Tc	H Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	92 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	71 Hf	73 Ta	74 W	75 Re	76 Os	π Ir	78 Pt	79 Au	80 Hg	TI	82 Pb	⁸³ Bi	Po 84	At 85	86 Ri
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	Uun ¹¹⁰	III Uuu	Uub				•		



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

Figure 4: periodic table(atomic number is written on the top left corner in this table).

FINDING PERIOD AND GROUP NUMBER OF ANY ELEMENT

IN GROUP A

To find the period number and group number for group A, the following steps should be followed:

1 - Write the electron configuration of the element.

2- The number of the period is the highest number of the (n), at which the electron configuration of the element ends.

- 3- The number of the group can be found as follows:
- *a* If the electron configuration ends with (S), thus the number of electrons in this level is the number of the group.
- *b* If the electron configuration ends with the (p), thus the number of electrons at this level as well as the secondary level(s) in the primary level which fills before it represents the number of the group. If the total number of electrons is 8, then it means that this element is in the noble gases group, except for helium, the last energy level of it ends with(S) and contain two electrons only.

Example 3:

What are the period and group for the following elements? **80**, 10Ne, 17C1, 19K, Solution:

$_{8}O = IS^{2} 2S^{2} 2p^{4}$

The last main level is level (2). Thus, the period is the second period. The last secondary level (p) contains (4) electrons. 2 electrons from (S) are added and the total number is : 2 + 4 = 6 (group six) Oxygen is in the **second period in group 6** A in the periodic table.

$_{10}Ne = 1S^2 2S^2 2P^6$

The last main level is level (2) so it is 2nd period.

The last secondary level (p) contains (6) electrons in addition to (2) electrons from the underlying level (2S). The total number is (8). Thus, its group is the eighth.

Accordingly, Neon belongs to the **second period in the (VIIIA) group** of the periodic table.

$_{17}C1 = 1S^2 2S^2 2P^6 3S^2 3P^5$

The last main level is level (3). Thus, its period is the third period. Its last secondary level (p) contains (5) electrons in addition to (2) electrons from the underlying level (3S). The total number is (7). Chlorine belongs to group seven of the periodic table. Thus, chlorine is in the **third period of group (7 A)** of the periodic table.

19K 1S² 2S² 2p⁶ 3S² 3p⁶ 4S¹

The last main level is level (4) and its period is the fourth. The last secondary level (S) contains one electron and its group is the first. Based on this, potassium belongs to the **fourth period and group 1 A**.

Exercise 2:

What are the period and group for the following elements? $_{3}\text{Li}$, $_{6}\text{C}$, $_{13}\text{AI}$

Example 4:

What is the common property between the locations of the following elements in the periodic table? $_{3}Li$, $_{11}Na$, $_{12}Mg$.

 $_{3}\text{Li} = 1\text{S}^{2} 2\text{S}^{1}$ group (1 A) / 2nd period

 $_{11}$ Na= 1S² 2S² 2P⁶ 3S¹ group (1 A) / 3rd period

 $_{12}Mg = 1S^2 2S^2 2P^6 3S^2$ group (2A) / *3rd* period

According to the above, the common property between Li and Na is that they both have the same group (Group 1 A). The common property between Na and Mg is that they have the same period 3rd period.

Example 5:

What is the common property between the locations of the elements $(_4Be, _5B, _7N)$ in the periodic table?

Solution:

 $\label{eq:Be} \begin{array}{ll} _4Be = 1S^2 \ 2S^2 & group \ (2A) \ / \ 2nd \ period \\ _5B = 1S^2 \ 2S^2 \ 2P^1 & group \ (3A) \ / \ 2nd \ period \\ _7N = 1S^2 \ 2S^2 \ 2P^3 & group \ (5A) \ / \ 2nd \ period \end{array}$

All these elements are in the same period (2nd period).

They differ from each other with respect to groups. Each element belongs to a different group. Beryllium (Be) is in the second group. Boron (B) in the third group and Nitrogen (N) in the fifth group.

Exercise 3:

What is the common property between the locations of the elements ($_{6}$ C, $_{14}$ Si, $_{15}$ P) in the periodic table?

PERIODIC PROPERTIES

The physical and chemical characteristics of the elements in the groups and periods of the periodic table vary according to their atomic radius, ionization energy, electron affinity and electronegativity as arranged below.

1. Electronegativity:

Electronegativity is an atoms ability to pull electrons towards itself. In many chemical compounds, the negative charge of the bonded electrons is centered near a certain atom. This greatly affects the chemical properties of the compound. Electronegativity is defined as: "The tendency of an atom to attract bonded electrons towards itself in any chemical compound".

Fluoride, of all other elements, has the greatest electronegativity .

The electronegativity values increase from left to right and bottom to top in the periodic table excluding the Noble gases. The most electronegative element is Fluorine.

From these electronegativity values we can derive the patterns of two other periodic properties: Ionization Energy and Electron Affinity.

2. Ionization Energy

Ionization energy is the amount of energy required to remove an electron from the outer energy level of an atom. The more electronegative the element, the higher the ionization energy.

			1243		< <u>10</u>	nizatio	n Ene	irgy In	creas	es	
		IA								VIIA	VIIIA
- 83		н								н	He
8		1312.0	IIA			IIIA	IVA	VA	VIA	1312.0	2372.3
8		Li	Be			в	C	N	0	F	Ne
1		520.2	899.4			800.6	1086.4	1420.3	1313.9	1681.0	2080.6
2		Na	Mg			Al	Si	P	S	Cl	Ar
		495.8	737.7			577.6	786.4	1011.7	999.6	1251.1	1520.5
		к	Ca	1000		Ga	Ge	As	Se	в	Kr
1		418.8	589.8			578.8	762.1	947	940.9	1139.9	1360.7
12		Rb	Sr			In	Sn	SЪ	Te	I	Xe
		403.0	549.5			558.3	708.6	833.7	869.2	1008.4	1170.4
2.2		Cs	Ba		1.0	T1	РЪ	Bi	Po	At	Rn
		375.7	508.1			595.4	722.9	710.6	821		1047.8
		Fr	Ra	1000							
	1		514.6	1.							

For example: In the ionization of Sodium atom:

Na + ionization energy —> Na⁺ + e

Ionization is not limited to the loss of a single electron from an atom. Two, three, or even more electrons can be lost sequentially from an atom, and the amount of energy associated with each step can be measured.

 $M + Energy \rightarrow M^+ + e$ - First ionization energy (Ei1)

 M^+ + Energy $\rightarrow M^{2+}$ + e- Second ionization energy(*E*i2)

 M^{2+} + Energy $\rightarrow M^{3+}$ + e- Third ionization energy (*E*i3) Successively larger amounts of energy are required for each ionization step because it is much harder to pull a negatively charged electron away from a positively charged ion than from a neutral atom. Removing the second electron from sodium takes nearly 10 times as much energy as removing the first one.

Third ionization energy (*E*i3) > second ionization energy (*E*i2) > first ionization energy (*E*i1)

3. ELECTRON AFFINITY(Eea)

The Electron Affinity of an element(*Eea*) is the amount of energy gained or released with the addition of an electron to the atom to form an anion. The electronegativity ,ionization energy and Electron Affinity increases in the same pattern in the periodic table. Left to right and bottom to top.



	1																	18
1	¹ H ^{-1,41}	1		Atomie	c)	/alence		Alkali m	netals	Lanthar	nides							² He [°]
	Hydrogen 1.008	2		Numb	er			metals	earth	Actinid	es		13	14	15	16	17	Helium 4.003
2	³ Li *1	⁴ Be ⁺²		S	Symbol			Transiti metals	ransition ietals		als		⁵ B ⁺³	6 +4,+3,+2,+1 C -4,-3 -2,-1	7 +5,+3,-3 N	⁸ O ⁻²	9 '	¹⁰ Ne [°]
-	Lithium 6.941	Beryllium 9.012		Ele	ement N	ame		Post-transition metals		Halogens			Boron 10.811	Carbon 12.011	Nitrogen 14.007	Oxygen 15.999	Fluorine 18.998	Neon 20.180
3	11 ···	¹² Ma ⁺²			Atomic	Mass (u)	ĺ	Metallo	id	Noble g	ases		¹³ AI ^{*3}	¹⁴ Si	15 +5.+33 P	16 ^{+6,+4,+2,-2} S	¹⁷ CI	¹⁸ Δr
	Sodium 22.990	Magnesium 24.305	3	4	5	6	7	8	9	10	11	12	Aluminium 26.982	Silicon 28.086	Phosphorus 30.974	Sulfur 32.066	Chlorine 35.453	Argon 39.948
4	19 *1	20 +2	21 *3	²² Ti ⁺⁴	23 +5 V	24 +6,+3	25 +7,+4,+2 M n	26 ^{+6,+3,+2}	27 +3,+2	28 +2 Ni	29 +2	³⁰ 7n	31 +3	32 +4.+2.4	33 +5,+3,-3 A S	34 ^{+6,+4,+2,2}	35 ^{+5,+3,+1,-1} Br	³⁶ K r ^{+2,0}
-	Potassium	Calcium 40.078	Scandium 44.956	Titanium 47.88	Vanadium 50.942	Chromium 51.996	Manganese 54.938	Iron 55.845	Cobalt 58.933	Nickel 58.693	Copper 63.54	Zinc 65.38	Gallium 69.723	Germanium 72.631	Arsenic 74.922	Selenium 78.971	Bromine 79.904	Krypton 84.798
5	37 Bb	³⁸ Sr ^{*2}	³⁹ y [*]	40 7 r	41 Nb	42 MO	43 +7,+4	44 HI	45 Bh	46 +4,+2 Pd	47 A a	48 d	49 +3 In	50 +4.+24	⁵¹ Sh	52 ^{+5,+3,-3} Te	53 ^{+6,+4,+2,-2}	54 ^{+6,+4,+2,0}
5	Rubidium 85.468	Strontium 87.62	Yttrium 88.906	Zirconium 91.224	Niobium 92.906	Molyb - denum 95.95	Technetium 98.907	Ruthenium	Rhodium 102.906	Palladium 106.42	Silver 107.868	Cadmium 112.414	Indium 114.818	Tin 118.711	Antimony 121.760	Tellurium 127.6	lodine 126.904	Xenon 131.294
6	55 c *1	56 *2 Ra	57-71	72 *4	73 Ta **	74 w ^{+6,+4}	75 Re	76 *4	77 +4,+3 Tr	78 +4,+2 Pt	79 +3	80 +2,+1	81 ~1	82 Ph	83 Bi	84 +4,+2,-2 PO	85 +11 A +	86 +2,0 Rn
	Cesium 132.905	Barium 137.328		Hafnium 178.49	Tantalum 180.948	Tungsten 183.85	Rhenium 186.207	osmium 190.23	Iridium 192.22	Platinum 195.08	Gold 196.967	Mercury 200.59	Thallium 204.383	Lead 207.2	Bismuth 208.980	Polonium [208.982]	Astatine 209.987	Radon 222.018
7	87 *1 Fr	88 +2 Ba	89-103 **	¹⁰⁴ Rf	¹⁰⁵ Db	¹⁰⁶ Sa ^{**}	¹⁰⁷ Bh	¹⁰⁸ Hs	109 Unknown Mt	110 ^{Unknown}	111 Unknow	¹¹² Cn	113 Unknown	114 ^{Unknown} FI	115 ^{Unknown}	116 ^{Unknown}	117 Ts	118 Oa
'	Francium 223.020	Radium 226.025		Ruther- fordium ₍₂₆₁₎	Dubnium [262]	Seaborgium	Bohrium (264)	Hassium [269]	Meitnerium [278]	Darmst - adtium [281]	Roent- genium (280	Copernicium (285)	Nihonium [286]	Flerovium [289]	Moscovium [289]	Livermorium [293]	Tennessine [294]	Oganesson (294)
			57. +3	58 *4.+3	59 +3	60 +3	61_ +3	62 +3	63_ ^{+3,+2}	64+3	65+3	66 +3	67. *3	68_ ⁺³	69_ ⁺³	70 *3	71. *3	
La	nthanide	series*	Lanthanum	Cerium	Praseo- dymium	Nd Neodymium	Promethium	Samarium	Eu	Gd	Tb Terbium	Dysprosium	Holmium	Erbium	Thulium	Ytterbium	Lu	
			130,903	140,110	140.908	144.243	144.212	1.30.30	131.304	137.63	1.50.94.	162.500	104,930	107.235	100.924	173.033	174.907	

The Periodic Table of Elements

Lanthanide Series*	57 La	58 Cerium 140.116	59 *3 Praseo- dymium 140.908	60 +3 Nd Neodymium 144.243	61 +3 Promethium 144.913	62 +3 Samarium 150.36	63 +3,+2 Europium 151.964	64 Gadolinium	65 Tb Terbium 158.925	66 +3 Dy Dysprosium 162.500	67 +3 Ho Holmium 164.930	68 Er Erbium 167.259	69 +3 Tm Thulium 168.934	70 *3 Yb Ytterbium 173.055	71 Lutetiu 174
Actinide Series**	89 Actinium	90 Th Thorium	91 +5 Pa Protac- tinium	92 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 +3 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 +3 Fermium	101 +3 Md Mende	102 +2 No Nobelium	103 Lawrenc

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