4.1. Introduction

MENDELEEV (1869) proposed a classification of elements in increasing order of mass number (A). The modern periodic classification of elements is based on the increasing order of atomic number (Z); because an element is defined by its atomic number, and not by its mass number.

4.2. Description of the periodic table

4.2.1. Period (Line)

A line (horizontal) represents a "period". The period corresponds to an electronic shell identified by its principal quantum number (n). There are seven (7) periods numbered from n = 1 to n = 7.

The period is given by **the highest principal quantum number** in the electronic configuration.

Examples :

*$_{11}Na : 1s^2 2s^2 2p^6 \mathbf{3}s^1$ → The period of Na is : **3**.

*$_{21}Sc : 1s^2 2s^2 2p^6 3s^2 3p^6 \mathbf{4}s^2 3d^1$ → The period of Sc is : **4**.

4.2.2. Group (Column)

A column (vertical) represents a "group". There are 18 groups including 8 in sub-group A and 10 in sub-group B.

The group is indicated by a Roman numeral and designated by the number of electrons located in the last shell (or valence shell); except groups: **$VIII_B$, I_B** and **II_B**.

Group	Valence structure
$VIII_B$	$ns^2 (n\text{-}1) d^6$ $ns^2 (n\text{-}1) d^7$ $ns^2 (n\text{-}1) d^8$
I_B	$ns^1 (n\text{-}1) d^{10}$
II_B	$ns^2 (n\text{-}1) d^{10}$

Reminder: I(1), II(2), III(3), IV(4), V(5), VI(6), VII(7), VIII(8), IX(9), X(10)

4.2.3. Sub-group

The groups of the periodic table are divided into two **sub-groups: A** and **B.**

***Sub-group A**: the valence electrons are of types "s"; Or ; "s" and "p".

***Sub-group B**: the valence electrons are of types "s" and "d".

Examples :

*$_{11}Na : 1s^2 2s^2 2p^6 \mathbf{3s^1}$ → the group of Na is : **I_A.**

*$_{10}Ne : 1s^2\ \mathbf{2s^2\ 2p^6}$ → the group of Ne is : **$VIII_A$.**

*$_{21}Sc : 1s^2 2s^2 2p^6 3s^2 3p^6 \mathbf{4s^2 3d^1}$ → the group of Sc is : **III_B.**

4.2.4. Block

On the basis of electronic configuration of valence shell, the elements may be divided into four blocks (s, p, d, f).

Valence structure of an element		Block
ns^x	$(x = 1, 2)$	s
$ns^2\ np^x$	$(1 \leq x \leq 6)$	p
$ns^2\ (n-1)d^x$	$(1 \leq x \leq 10)$	d
$ns^2\ (n-2)f^x$	$(1 \leq x \leq 14$, and, $n = 6, 7)$	f

For the case of **Helium**, although belonging to the **s block**, it is placed in the **p block** (rare gas family).

Bloc s	Bloc d	Bloc p
1s		
2s		2p
3s	3d	3p
4s	4d	4p
5s	5d	5p
6s	6d	6p
7s	7d	7p

Bloc f
4f
5f

4.2.5. Families

The main families of the periodic table are:

* **Alkali metals**: group $\mathbf{I_A}$ (Except: $\mathbf{_1H}$)

* **Alkaline earth metals**: group $\mathbf{II_A}$

***Non metals**: groups: ($\mathbf{III_A; IV_A; V_A; VI_A}$)

* **Halogens**: group $\mathbf{VII_A}$

* **Noble gases (Rare gases)**: group $\mathbf{VIII_A}$

***Transition metals**: groups: ($\mathbf{III_B; IV_B; V_B; VI_B; VII_B; VIII_B; I_B; II_B}$), these are elements which have the orbitals (d) incompletely filled

***Rare earths (internal transition metals)**, these elements have the orbitals (f) being filled,

- Lanthanides (6^{th} period) : elements which correspond to the filling of the **4f** orbital

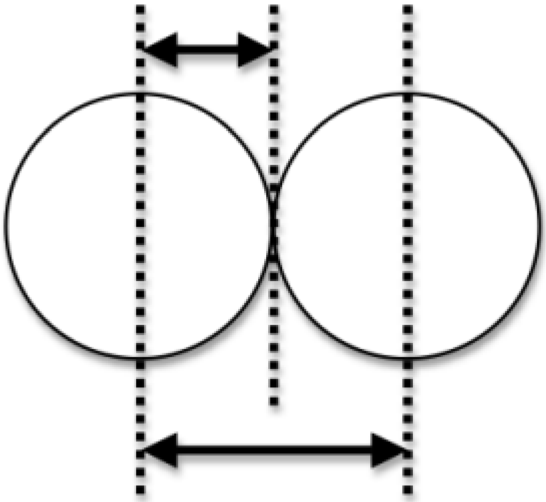
- Actinides (7^{th} period) : elements which correspond to the filling of the **5f** orbital

4.3. Evolution and periodicity of the physicochemical properties of the elements

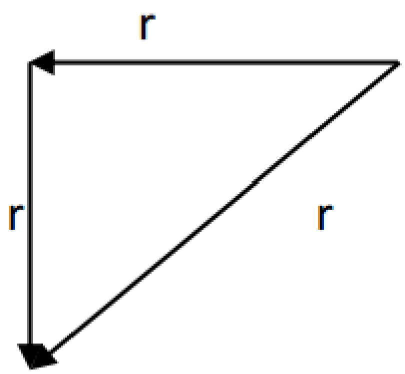
The physicochemical properties of an element essentially depend on the electronic configuration of the valence shell. Being the most energetic, it therefore contains the most reactive electrons.

4.3.1. Atomic radius (Ra)

The atomic radius is defined as half the distance between the nuclei of two adjacent atoms of an element (atoms assumed to be spherical).



• Over the same **period**: if **Z** increases then **Ra** decreases
• On the same **group**: if **Z** increases then **Ra** increases



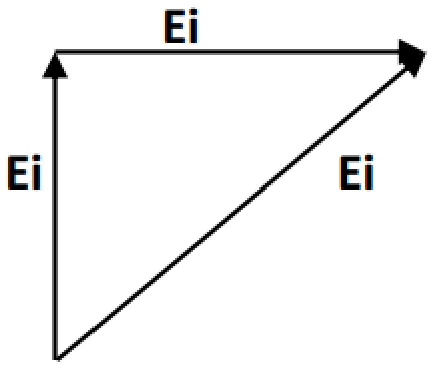
Remark: r (X^+) < r (X) < r (X^-)

4.3.2. Ionization energy (E_i)

It is the energy required to remove an electron from an atom (or an ion) in the gaseous state.

$X_{(g)} \rightarrow X_{(g)}^{+} + 1e^-$ **(1st ionization)**

• Over the same **period**: if **Z** increases then $\mathbf{E_i}$ increases.
• On the same **group**: if **Z** increases then $\mathbf{E_i}$ decreases.



Remark:

$X_{(g)}^{+} \rightarrow X_{(g)}^{2+} + 1e^-$ **(2nd ionization)**

$X_{(g)}^{2+} \rightarrow X_{(g)}^{3+} + 1e^-$ **(3rd ionization)**, etc…

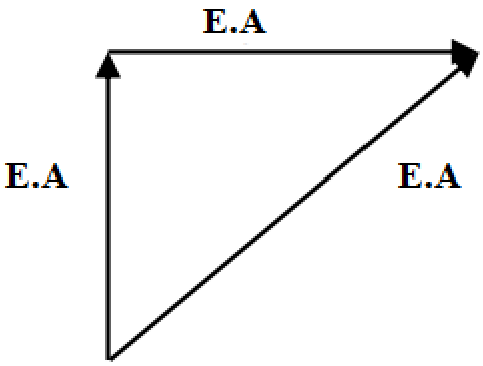
4.3.3. Electron affinity (E.A)

It is the energy released when an electron is added to an atom in the gaseous state.

$X_{(g)} + 1e^- \rightarrow X_{(g)}^-$

• Over the same **period**: if **Z** increases then **E.A** increases.

• On the same **group**: if **Z** increases then **E.A** decreases.



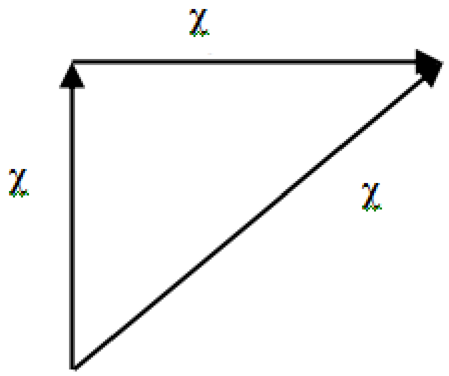
4.3.4. Electronegativity (χ)

It is the tendency of an atom in the gaseous state to attract electrons towards it during the formation of a chemical bond with another element.

$A_{(g)} + B_{(g)} \rightarrow A^+_{(g)} + B^-_{(g)}$ (we say that B is more electronegative than A)

• Over the same **period**: if **Z** increases then χ increases.

• On the same **group**: if **Z** increases then χ decreases.



Exercise

Consider the elements : $_{29}Cu$, $_{35}Br$, $_{42}Mo$, $_{54}Xe$.

1. Provide the electronic structures of these elements.
2. Locate these elements in the periodic table.
3. Which of these elements are transition metals?
4. Which element is chemically inert, indicate its external structure.
5. Assign and explain the values of the first ionization energies (E_i) and electronegativities (χ) of the following elements: Cu, Br, and Mo.

E_i (eV)	7.7	11.8	7.2
χ	1.9	2.8	1.8

6. An element belongs to the sixth period and group IVB. What is its electronic structure? Give its atomic number

Correction

Note

The electronic configuration of an element can be written in condensed form:

[configuration of a noble gas] + external shell.

The noble gas will be the one whose atomic number is as close as possible to the atomic number of the element considered while remaining inferior to it:

He for **2 < Z < 10**

Ne for **10 < Z < 18**

Ar for **18 < Z < 36**

Kr for **36 < Z < 54**

Xe for **54 < Z < 86**

Rn for **Z > 86**

Example

$_{26}Fe$: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^6$, so the rare gas will be $_{18}Ar$ because Z = 26 (18 < Z < 36)

$_{26}Fe$: [Ar] $4s^2\ 3d^6$

1. Electronic structures

$_{29}Cu$: $1s^2 2s^2 2p^6 3s^2 3p^6 \mathbf{4s^2 3d^9}$ $\mathbf{4s^1 3d^{10}}$

$_{35}Br$: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^5$

$_{42}Mo$: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 \mathbf{5s^2 4d^4}$ $\mathbf{5s^1 4d^5}$

$_{54}Xe$: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6$

2.

Elément	période	groupe
$_{29}Cu$	4	I_B
$_{35}Br$	4	VII_A
$_{42}Mo$	5	VIB
$_{54}Xe$	5	VIIIA

3. The transition metals are: $_{29}Cu$, and $_{42}Mo$ because they have an incomplete (d) subshell.

4. The chemically inert element is an element with all its sub-shells fully occupied by electrons. So: xenon ($_{54}Xe$) is the inert element (rare gaz).

Its external structure is: $5s^2 4d^{10} 5p^6$

5. Ei(Br) > Ei(Cu) > Ei(Mo) ; and; χ (Br) > χ (Cu) > χ (Mo)

	E_i	χ
Mo	7.2	1.8
Cu	7.7	1.9
Br	11.8	2.8

6. The element belongs to the 6^{th} period, so: n = 6

And in group IV_B, therefore: it has 4 electrons in the outer sub-shell.

The structure of its outer shell (valence shell) is: $6s^2 4f^{14} 5d^2$

Hence, the electronic configuration is: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^2 6s^2 4f^{14} 5d^2$

Its atomic number is: Z = 72; and the element is: $_{72}Hf$