$n_{O2} = \frac{m_{O2}}{M} = \frac{0,5}{32} = 0,0156mol.$

$n_{H2} = \frac{m_{H2}}{M} = \frac{0,8}{2} = 0,4mol.$

$n_{N2} = \frac{m_{N2}}{M} = \frac{3,6}{28} = 0,128mol.$

2) Calculation of the molar fraction :

$x_{O2} = \frac{n_{O2}}{\sum n_i} = \frac{0,0156}{0,0156+0,4+0,128} = 0,0286$

$x_{H2} = \frac{n_{H2}}{\sum n_i} = \frac{0,4}{0,0156+0,4+0,128} = 0,735$

$x_{N2} = \frac{n_{N2}}{\sum n_i} = \frac{0,128}{0,0156+0,4+0,128} = 0,235$

3) Calculation of partial pressures:

$P_{O2} = P_T.\ x_{O2} = 1x0,0286 = 0,0286atm$

$P_{H2} = P_T.\ x_{H2} = 1x0,735 = 0,735atm$

$P_{N2} = P_T.\ x_{N2} = 1x0,235 = 0,235atm$

$P_i = P_{g_1} + P_{g_2} + P_{g_3} + \cdots P_{g_n}$

According to DALTON's law :

$$P_t = \sum_{i=1}^{n} P_i$$

Note:

DALTON 's law is only rigorous for ideal gases at low pressures.

II-4- AVOGADRO's law:

Equal volumes of different gases taken under the same conditions of T and P contain the same number of molecules.

This AVOGADRO hypothesis will allow us to determine the molecular masses or relative masses of the gases.

Example:

1litre (liter) of O_2 has a mass of 1,43g and 1litre of CO oxyde of carbon has a mass of 1,25g in S.T.P (Standard temperature and pressure).

According to AVOGADRO's law, if the molecular mass of oxygen$M_{O_2} = 32 g/mol$.

What is the molecular mass of CO?

$M_{CO} = \frac{1,25}{1,43} x32 = 28$ So: $M_{CO} = 12 + 16 = 28$ g/mol.

II-3- The real gases :

Interactions between gas molecules are taken into account by introducing parameters known as interaction parameters. **(a and b)**.

If P $\longrightarrow$ +∞ v-b $\longrightarrow$ 0 hence v $\longrightarrow$ b

Some values of a and b for different gases:

Gas	A	B
H_2	0,2444	0,02661
N_2	1,370	0,03913
O_2	1,360	0,03183
CO	1,485	0,03985
CO_2	3,592	0,04267

Van Der Walls equation:

$$(P + \frac{a}{V}). v = (\frac{RT}{V-b}) . v \Longrightarrow PV + a = \frac{RTV}{V-b}$$

$$\frac{PV}{RT}+\frac{a}{RT}=\frac{V}{V-b}$$

$$\frac{PV}{RT}=\frac{V}{V-b}-\frac{a}{RT}$$

The ratio $\frac{PV}{RT}$ It is called the compressibility factor.

Ideal behaviour: V$\frac{a}{RTV}$ $\nearrow$ $\longrightarrow$ 0 and $\frac{PV}{RT}=\frac{V}{V-b}=\frac{V}{V(1-\frac{b}{V})}=\frac{1}{1-\frac{b}{V}}$

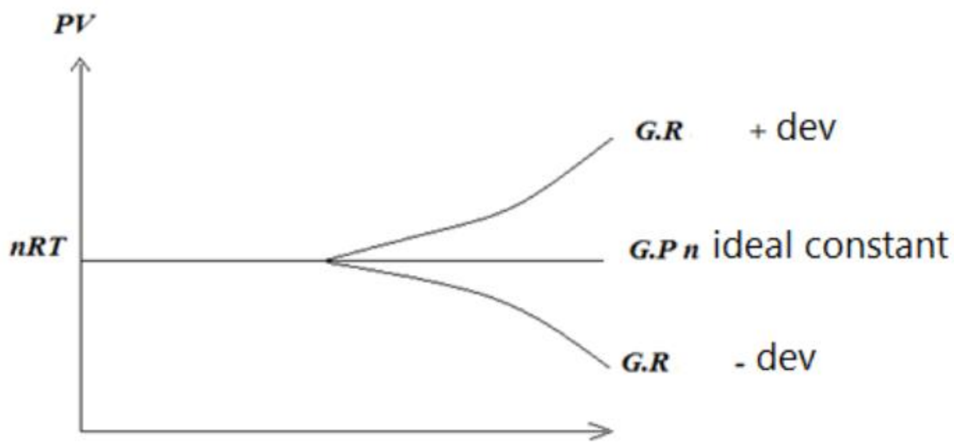
$\frac{PV}{RT}\longrightarrow$ 1 hence PV = RT (G.P).

Positive deviation : T $\nearrow$ $\frac{a}{RTV}\longrightarrow$ 0 et $\frac{PV}{RT}=\frac{V}{V-b}=\frac{1}{1-\frac{b}{V}}$

Negative deviation:$\frac{V}{V-b}=\frac{1}{1-\frac{b}{V}}=1+\frac{b}{V}$ $(1-\frac{b}{V}<<<<0)$.

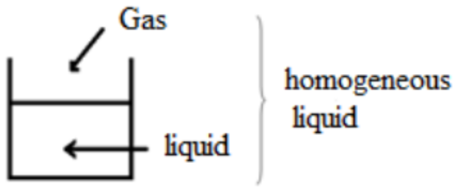
$$\frac{PV}{RT}=1+\frac{b}{V}-\frac{a}{RTV}=1+\frac{1}{V}(b-\frac{a}{RT})$$

If T$\frac{a}{RT}\nearrow$ $\longrightarrow$ 0 and $\frac{PV}{RT}=1+\frac{b}{V}>1$.

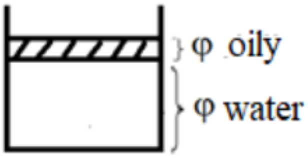


III- Liquid state:

The liquid state is an intermediate state between the liquid state and the solid state. We can distinguish either a pure liquid or a mixture of liquids (solvent + solute) called a solution. A solution can be homogeneous or heterogeneous. A homogeneous mixture has only one phase.



A heterogeneous mixture or liquid has two or more phases. (water +oil).



Liquids are generally characterised by a mass (m), a volume (V) and a density (ρ).

The density ρ it represents the mass of a well-defined volume, and it is expressed in g/mL, kg/L, kg/m^3.

$$\rho = \frac{m}{V}$$

Solutions are homogeneous mixtures comprising 2 or more simple or compound pure substances, called solutes and solvents..

In a binary solution (A, B), the component present in larger quantity is called the solvent, while the other is called the solute.

Example1:

- Pure liquid: water, Alcohol, benzene, chloroform

- Solution: ⟶ Solute solid: Water + NaCl (saline solution)

Water + Sugar (sugar solution)

⟶ Liquid solute: Water + Alcohol

Water + Acetone

⟶ Gas solute : water + NH_3 (Ammonia)

Example2: a mixture of 60 cm^3 of methanol CH_3OH and of 50 cm^3 of water H_2O, knowing that the density $\rho_{CH3OH} = 0{,}7 g/cm^3$.

To determine which one, methanol or water, plays the role of solvent, we need to calculate the number of moles in both cases

$$\rho = \frac{m}{V}$$

$$n_i = \frac{m_i}{M_i} = \frac{\text{mass of the compound (i)}}{\text{Molar Mass (i)}}$$

$$n_{CH_3OH} = \frac{\frac{60x0{,}7}{1}}{32} = 1{,}3 \text{ moles}$$

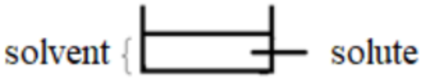
$$n_{H_2O} = \frac{50}{18} = 2{,}7 \text{ moles}$$

Since $n_{H_2O} > n_{CH_3OH}$ so the solvant is water.

III-1- Quantitative aspect of solutions:

The proportion of the solute in the solution can be expressed in various ways. In this regard, we mention units of concentration, such as molar concentration (molarity), mass concentration, normality, molality, etc.

Solution : solute + solvent.



So, each of the constituents is expressed by a quantity of matter.

For the solute:

- its mass.
- its number of moles.
- its Proportion in relation to a quantity of solvent.

For the solvent:

- its volume (generally in litre(liter)).
- its mass (Kg).
- its Proportion in relation to a quantity of solute.

III-1-1- Molarity or molar concentration C_m orM:

Represents the number of moles of solute per litre of solution, expressed in mole/L or M.

$c = \frac{n}{V}$ with n : number of moles

v: the volume of the solution

Example:

In a volume of 250 cm3 of solution, we dissolve m = 4gr de NaOH.

(M_{NaOH} =40gr/mol).

We calculate the number of moles .mole : $n = \frac{4}{40} = 0,1$ mole in 250 cm^3.

0,1mol → 250mL

→ 1000ml => M = 0,4mol/L.

III-1-2- Mass concentration or mass fraction Cg:

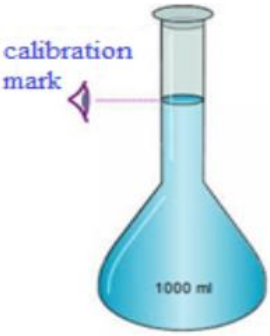
Definition: this is the mass of solute present in one litre of solution, expressed in g/L of solute contained in 1 litre of solution..

Ex : Preparation of a NaCl solution at 10 g/L

$\begin{cases} \text{Solute= NaCl} \\ \text{Solvent = Water} \end{cases}$ Volumetric flask of 1L

Weigh 10g of solute (NaCl).

There are 10g of solute/1L of solvent.



$c = \frac{m}{V}$ with m : mass of solute in g.

v : the volume of solution in l.

III-1-3-The Normality :

It expresses the number of gram-equivalents of solute present in one liter of solution. It also represents the number of moles of reactive species per liter (L) of solution.

The gram-equivalent corresponds to the quantity of a substance capable of exchanging one mole of active substance.

Example:

The equivalent mass of HCl is the molar mass $\frac{36.5}{1} = 36{,}5\text{g}$

The equivalent mass of H_2SO_4 is half its molar mass $\frac{98}{2} = 49\text{g}$

An active substance can be considered as the number of H+ or OH- protons exchanged in an 'acid' or 'base' solution, or the number of electrons exchanged in a redox (oxidation-reduction) solution. Normality is used for acid-base and redox solutions..

In the case of acids and bases:

- Acid: 1 eq. Gramme = $\frac{M}{nH^+}$HCl => 1 eq. Gramme = $\frac{M}{1}$
- Base: 1 eq. Gramme = $\frac{M}{nOH^-}$NaOH => 1 eq. Gramme = $\frac{M}{1}$

In the case of salts:

- $CuCl_2 \longrightarrow Cu^{2+}, 2Cl^-$ => 1eq. Gram(gramme) = $\frac{M}{2}$
- $Al_2(SO_4)_3 \longrightarrow 2Al^{3+}, 3SO^{2-}_4$ => 1eq. Gram(gramme) = $\frac{M}{6}$
- $CaO \longrightarrow Ca^{2+}, O^{2-}$ => 1eq. Gram(gramme) = $\frac{M}{2}$

In the case of oxidants and reducers (redox reaction), the gram equivalent is expressed by the number of e- exchanged: gained or lost.

- $MnO_4^- + 5e^- \longrightarrow Mn^{2+}$ => 1eq. gram(gramme) = $\frac{M}{5}$
- $FeSO_4 \longrightarrow Fe^{2+} + SO^{2-}_4$ => 1eq. gram(gramme) = $\frac{M}{1}$

Example:

Dissolve 73g of HCl in 250g of water. The density of the solution is 1.1g/mL. Determine the normality.

1 eq. Gram d’HCl => 36,5gr .

Lethe number of moles $n = \frac{73}{36,5}$ = 2 moles of solute = 2 eq. Gram.

The mass of the solution $m_{sol}=m_{HCl} + m_{H2O}$ = 73 + 250 = 323gr .

Density $\rho = \frac{m}{V}$ hence $v = \frac{323}{1,1}$= 294 mL.

The molarity will be: $C= \frac{2 \text{ x } 1000}{294}$ = 6,80 mol/L

So the normality N= 6,80 eq. Gram/L or HCl 6,80 N.

- The relationship between the molar concentration C_m and the mass concentration C_g :

$$c_m = \frac{Cg}{M} \quad \text{or} \quad C_g = C_m x M$$

- The relationship between molar concentration C_m and normality:

$$C_m = \frac{N}{n} \quad \text{or} \quad N = C_m \, xn$$

With n = the number of H^+or OH^- protons exchanged in an 'acid' or 'base' solution, or the number of electrons exchanged in a redox solution.

The relationship between mass concentration C_g and normality:

$$N = \frac{Cg}{Meq} \quad \text{or } Cg = N \text{ x } M_{eq}$$

Example:

We want to prepare a solution of NaCl at 10%

n = 10g of NaCl for 100g of solution.

The solution (water + NaCl) 10g of solute

$m_{sol}= m_{NaCl} + m_{H2O}$ so the mass m_{NaCl}= 10g the mass m_{H2O} = 90g

Example:

How many grams of NaCl solution at 5% by weight are needed to obtain 3.2 g of NaCl ?

Solution = solute + solvent.

Mass of solution = mass of solute + mass of solvent.

? 3,2 g +

5% by weight = 5 g of solute for 100 g of solution.

$\frac{100}{5}x3,2 = 64g$ of solution.

Example:

What is the molarity M of a solution containing 16g of CH_3OH in 200 cm^3 of solution (C = 12, O = 16, H = 1).

Solute = CH_3OH

Number of moles per 200 ml of solution:

$$n_i = \frac{m_i}{M_i} = \frac{16}{32} = 0,5\text{mole}$$

$\frac{1}{2}$mole $\xrightarrow{\hspace{2cm}}$ 200 mL

n $\xrightarrow{\hspace{2cm}}$ 1000 mL= 1L

$$n = \frac{1000}{200}x\frac{1}{2} = \frac{5}{2}\text{mole}$$

III-1-4- The molality M :

It expresses the number of moles of solute dissolved in 1 kg of solvent.

$\mathbf{M} = \frac{n}{msolv}$ expressed in mol/kg of solvent.

Example :

Dissolve 73g of HCl gas in 250g of water. Calculate the molality = ?

Number of moles d'HCl n $= \frac{m}{M} = \frac{73}{36,5} =$ 2moles in 250gr of water where the molality.

M $= \frac{2x1000}{250} =$ 8 moles/Kg of solvent.

III-1-5-Molar Fraction Xi :

It expresses the ratio of the number of moles of a component i to the total number of moles:

$$Xi = \frac{ni}{\sum ni}$$

With the sum of the mole fractions $\sum Xi = 1$

Consider a mixture of two constituents, A and B.

A (m_A, M_A, $n_A = \frac{m_A}{M_A}$) B(m_B, M_B, $n_B = \frac{m_B}{M_B}$)

$X_A = \frac{n_A}{n_A + n_B}$ and $X_B = \frac{n_B}{n_A + n_B}$ with $X_A + X_B = 1$

Example :

Determine the mole fraction of each of the constituents of a solution of HCl containing 73 g HCl gas in 220 g water.

$n_{HCl} = \frac{m}{36,5} = \frac{73}{36,5} = 2$ moles $n_{H2O} = \frac{220}{18}$ ($M_{H2O} = 18$)

hence, we determine X_{HCl} and X_{H2O}

$X_{HCl} = \frac{2}{2+\frac{220}{18}} = 0,1406$ $X_{H2O} = \frac{\frac{220}{18}}{2+\frac{220}{18}} = 0,8594$

$X_{HCl} + XH_{2O} = 1$ or $1 = 0,1406 + X_{H2O}$ so $X_{H2O} = 1 - 0,1406 = 0,8594$

III-2- Laws of diluted solutions :

If the liquid considered contains a solute in a small quantity (diluted solution), the values of Te, T_f and P_0 vary slightly.

- The vapour pressure P_0 (pression) at a givenT°.
- The boiling point T_e.
- Melting or freezing temperature T_f.

These variations ΔT_e, ΔT_f and ΔP_0 depend on the solute concentration. RAOULT's laws express that these variations are proportional to the molality, ΔT_e and ΔT_f or the molar fraction of the pure solute.

Raoult's law for dilute solutions of non-volatile compounds (which do not evaporate) that are not electrolytes (do not conduct current), the lowering of vapor pressure, (ΔP) (variation in vapor pressure) ΔP is proportional to the molar fraction of the solute or the molarity of the solution.

Characteristics of liquids:

- The boiling point: T_e
- melting or freezing temperature: T_f or T_c
- The vapour pressure : P_0

III-2-1- Raoult's Law :

a- Boiling :

Boiling point elevation (the technique being ebulliometry ΔTe):

$\Delta T_e = k_e . M$ with k_e = Ebullioscopic constant.

ΔTe = boiling point of the solution - boiling point of the pure solvent.

Temperature variation ($\Delta T = T_2 - T_1$) is proportional to the molality **M** (Quantity of solute added).

With k_e : Ebullioscopic constant.

With $\mathbf{M} = \frac{\text{number of moles of solute}}{\text{kg of solvent}}$

Example : We dissolve a mass m = 5,85 gr of NaCl in 200mL of water (200g)

M_{NaCl} = 23 + 35,5 = 58,5g/mol.

The number of moles is $n = \frac{m}{M} = \frac{5{,}85}{58{,}5}$ = 0,1mol

0,1mol → 200g of water

M 1000g of water →

The molality M = 0,5

mole/kgs $_{olv}$e $_{nt}$ ΔT_e= $k_e.M$ = 0,51 x

05 = 0,255°c

Some values of k_e:

Solvent	k_e	ΔT_e for a molality =0,5
Water	0,51	0,255
Benzene	0,53	1,265
Ethanol	1,22	0,610
Acetone	1,71	0,855

b-Cryometry

The freezing or melting temperature decreases by $\Delta T_f = \Delta T_c$ such that

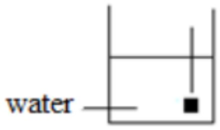
$\Delta T_f = k_f. M$ with k_f: freezing point depression constant or cryoscopic constant (molal depression constant).

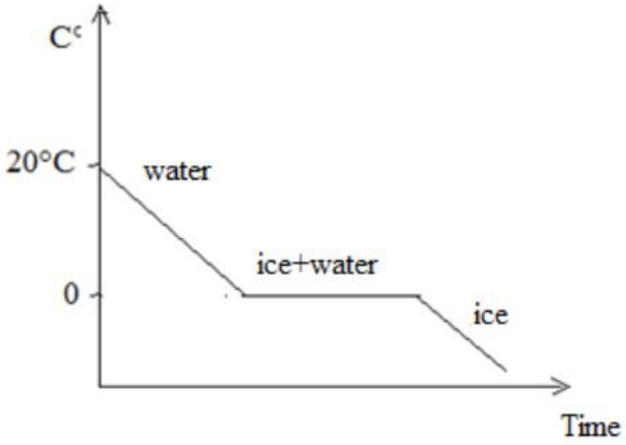
Some values of k_f:

Solvent	K_f	ΔT_f for a molality =0,5
Water	1,86	0,98
Benzene	5,12	2,56
Cetric acid	3,90	1,95

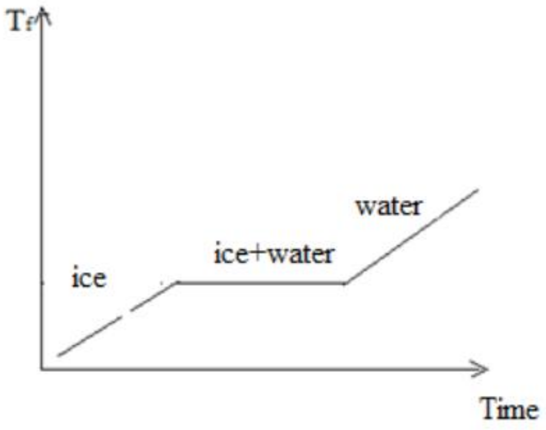
Example : freezing of water

$T_c = f(t)$.





The melting of ice:



c- Tonometry :

Liquids are characterized by their vapor pressure, which depends on the amount of solute present. The addition of a certain amount of solute to a solvent lead to a decrease in vapor pressure (ΔP) following the relation:

$$\Delta P = k_p . M$$

k_p: is a constant influencing pressures.

The vapor pressure above a solution = (is equal) to the vapor pressure of the pure solvent multiplied by x the mole fraction of the solvent.

For a number of solutions, the vapor pressure of the solvent is proportional to its mole fraction.

If P_0 initial pressure, and P is the vapor pressure of the solvent, then :

$P = P_0 . x_S$

Where, x_S: the mole fraction of the solvent.

The change in vapor pressure is given by the relation:

$\Delta P = P_0 - P$

$= P_0 - P_0 . x_S = P_0(1 - x_S) = P_0 . xs$ so $\Delta P = P_0 xs$

(xs: mole fraction of the solute) et $\Sigma x_i = 1 \Rightarrow x_S + xs = 1$

Example: If 1 mole of naphthalene is dissolved in 10 moles of benzene, and the vapor pressure P_0=75 mmHg at T=20°C.

calculate the change in pressure ΔP and the solvent pressure P.

We have: $\Delta P = P_0 . x_s$

Calculating the mole fraction of the solute $x = \frac{n_1}{n_T} = \frac{n_n}{n_n + n_b} = \frac{1}{1+10} = \frac{1}{11}$

Calculating the change $\Delta P = P_0 . x_s$

$= 75.1 \text{ x } \frac{1}{11} = 6{,}8$ mmHg

$\Delta P = P_0 - P \Rightarrow P = -\Delta P + P_0$

Therefore, the solvent pressure P can be deduced.

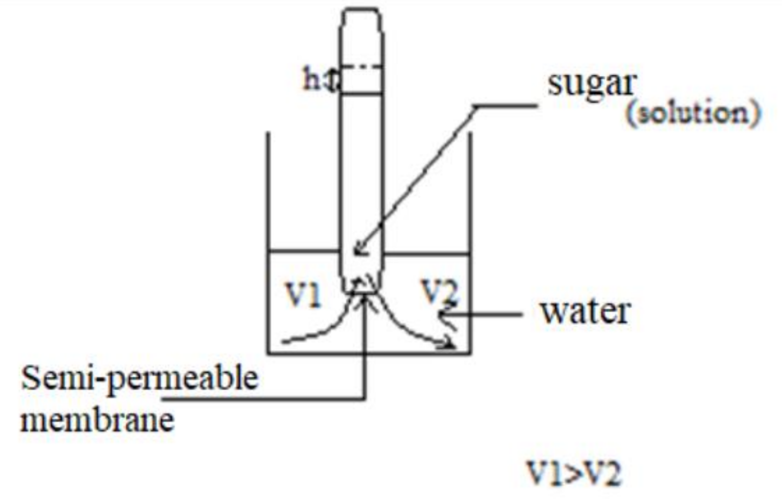
$\Rightarrow P = -6{,}8 + 75 \Rightarrow P = 68{,}2$ mmHg

III-2-2- Van't Hoff's law:

This law is related to osmotic pressure and the movement of particles from a concentrated medium to a less concentrated medium through a separating membrane .

Consider a solution of sucrose (sugar + water):

Solute→ (sugar) Solvent→ (water)



Semi-permeable membrane → It is permeable to solvent.

↘ It is impermeable to solute.

At the initial instant, the solvent and the solute exert the same P.

At time t, there is Equilibrium => $V_1 = V_2$.

=> On pressure called osmotic pressure π.

We apply the law of osmotic pressure (liquid).

$$\pi V = nRT$$

$$\pi = \frac{nRT}{V} = \frac{n}{V}RT = \frac{m}{MV}RT = \frac{m}{V}.\frac{RT}{M}$$

$\frac{m}{V}$: Weight concentration (gr/l).

$\pi = C.\frac{RT}{M}$ with $C = \frac{m}{V}$M: molar mass of solute.

IV- Binary Mixtures

Binary mixtures are systems composed of two different substances. They can be liquid-liquid, liquid-gas, solid-solid, etc.

IV-1- Types of Binary Mixtures

IV-1-1- Ideal Mixtures:

- The interactions between the molecules of the two components are identical to the interactions between the molecules of the same component.
- Obey Raoult's law.

IV-1-2- Non-Ideal Mixtures:

- The interactions between the molecules of the two components are different.
- They can show positive or negative deviations from Raoult's law.

IV-2- Properties of Binary Mixtures

IV-2-1- Thermodynamic Properties:

- Enthalpy of mixing
- Entropy of mixing
- Gibbs free energy of mixing

IV-2-2-Transport Properties:

- Viscosity
- Thermal conductivity
- Diffusivity

Applications

- **Petrochemical Industry:** Separation of components in petroleum mixtures.
- **Pharmaceuticals:** Formulation of medications where the solubility of active components is critical.
- **Food Industry:** Mixing ingredients for specific properties.

Examples of Binary Mixtures

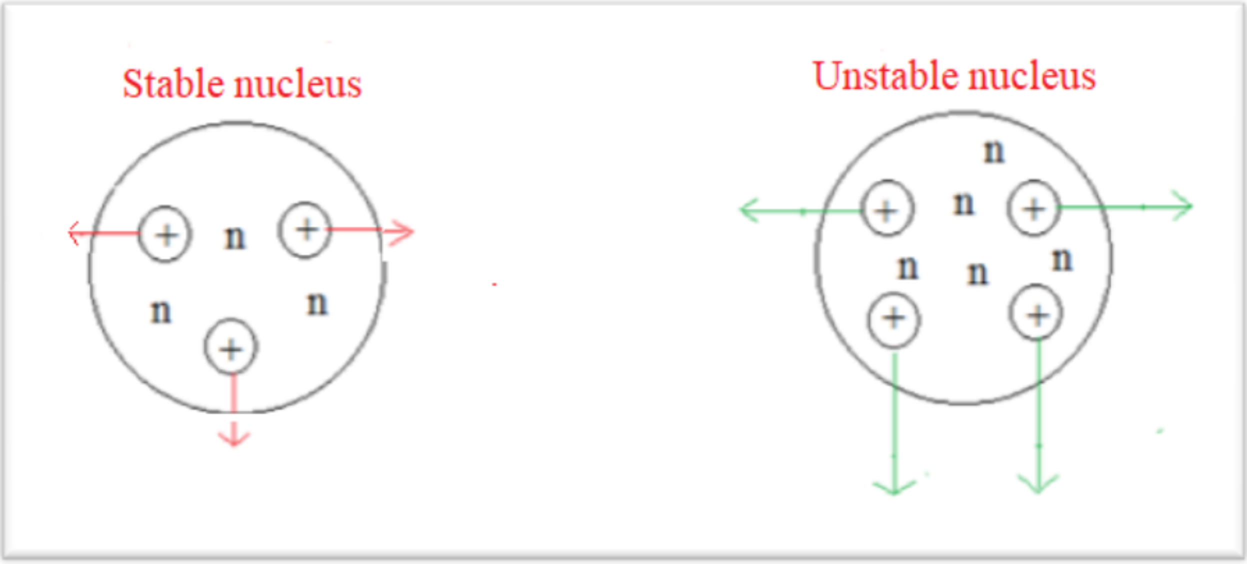
1. **Ethanol and Water:** A very common liquid-liquid mixture.
2. **Benzene and Toluene:** Used to illustrate the principles of ideal and non-ideal mixtures.
3. **Metal Alloys:** Such as bronze (copper and tin), which is a solid-solid mixture.

I- Stability of nuclei(Nuclear stability):

In nature, there are stable and unstable nuclei; a nucleus is said to be stable if the proton-proton repulsion forces are weak, whereas the binding energy is strong.

On the other hand, an unstable nucleus has a strong repulsion force and the binding energy is low(weak).

The origin of stability is explained by the presence of neutrons that neutralize the repulsive forces.



Quantitatively, we can determine if the nucleus is stable or not by calculating the ratio $\frac{A-Z}{Z}=\frac{N}{Z}$.

If $\frac{A-Z}{Z} \leq 1{,}5$ => The nucleus is stable.

If $\frac{A-Z}{Z} > 1{,}5$ =>The nucleus is unstable.

Example : ${}^{238}_{92}U$: uranium => $\frac{N}{Z}=\frac{146}{92}=1{,}58$ so U is instable.

Stable nuclei can be artificially transformed into unstable nuclei by bombarding the nucleus with neutrons.

Any unstable nucleus can become stable with emission of radiation: α , β , γ.

I-1-The radiation α:

It corresponds to the Helium nucleus $^{4}_{2}He$ and concerns heavy nuclei : It is a less energetic but more massive radiation, this type of radiation corresponds to a decrease of the mass number (A) of 4 units and a decrease of Z of 2 units and of the neutron number of 2 units.

The reaction is represented by:

$$^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$$

Example:

$$^{236}_{88}Ra \longrightarrow {}^{232}_{86}Rn + {}^{4}_{2}He$$

$A \longrightarrow A' = A - 4$

$Z \longrightarrow Z' = Z - 2$

$N = A - Z \longrightarrow N' = A' - Z' = (A-4) - (Z-2)$ so $N' = N - 2$

I-2-The radiation β:

Representing a charge, it is very powerful compared to α radiation. The 'β' radiation does not change the mass number, it is the number of charges and the number of neutrons that change by one unit, i.e. a decrease or increase of just one unit.

In the nucleus, two types of reactions occur:

$$^{1}_{1}P \longrightarrow {}^{1}_{0}n + {}^{0}_{+1}e$$

$$^{1}_{0}n \longrightarrow {}^{1}_{1}P + {}^{0}_{-1}e$$

It exists 2 types of β

Negaton $\beta^{-} = {}^{0}_{-1}e$ **$\beta^{+} = {}^{0}_{+1}e$ positron**

$$^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e \qquad {}^{A}_{Z}X \longrightarrow {}^{A}_{Z-1}Y + {}^{0}_{+1}e$$

A	A	A	A
Z	Z+1	Z	Z – 1
N	N-1	N	N+1

The β radiation is accompanied by the emission of particles that have neither charge nor mass, called 'neutrino' and 'antineutrino', so they can be neglected in the reaction.

β radiation concerns both heavy and light nuclei. It is more energetic but less massive.

$$\left.\begin{array}{l} {}^{A}_{Z}C \longrightarrow {}^{14}_{7}N + {}^{0}_{-1}e \\[2ex] {}^{A}_{Z}N \longrightarrow {}^{14}_{6}C + {}^{0}_{1}e \\[2ex] {}^{23}_{11}Na \longrightarrow {}^{23}_{12}Mg + {}^{0}_{-1}e \end{array}\right\}$$

I-3-The radiation γ:

It is an electromagnetic wave accompanying the two transformations (α, β), It represents the energy released by the resulting nucleus from both transformations to transition from an excited state to a stable state, according to the reaction:

$$\begin{tikzcd} {}^{236}_{88}Ra \arrow[r] \arrow[dr] & {}^{232}_{86}Rn^{*} + {}^{4}_{2}He \arrow[d] & \text{a very short intermediate stage.} \\ & {}^{232}_{86}Rn + \alpha + \gamma & \end{tikzcd}$$

II- Laws of radioactive decay:

To explain the variation of the number of nuclei with time and the kinetics of a nuclear reaction, we use the law of radioactive decay. Let's consider an unstable nucleus X that transforms into Y.

	nucleus X →	nucleus Y
$t = 0$	N_0	0
$t > 0$	N_t	N_t'

with :

N_0: The initial number of nuclei.

N_t: number of nuclei remaining at time X undecayed.

N_t': number of nuclei transformed from X or number of nuclei formed from Y.

One can study either the rate of disappearance of X or the rate of appearance of Y according to the relationship:

$$v = -\frac{dN_X}{dt} = \frac{dN_Y}{dt}$$

With λ: Decay coefficient or radioactive constant expressed in s-1.

$$v = -\frac{dN}{dt} = \lambda N$$

It is a first-order differential equation. To solve it, we must follow the following steps:

1/- We separate the variables N and t by multiplying the two members of the equation by:

$$\frac{dt}{N}x(-\frac{dN}{dt} = \lambda N) \Rightarrow -\frac{dt}{N} x \frac{dN}{dt} = \frac{dt}{N}\lambda N \Rightarrow \frac{dN}{N} = -\lambda dt$$

2/- We integrate:

$$\int_{N_0}^{N} \frac{dN}{N} = \int_0^t -\lambda dt = -\lambda \int_0^t dt \ln N \left|_{N_0}^{N}\right. = -\lambda t \left|_{0}^{t}\right.$$

So: $\ln N_t - \ln N_0 = -\lambda t \Rightarrow$ **$\ln \frac{N_t}{N_0} = -\lambda t$**

3/- We introduce the exponential function:

The number of undecayed nuclei N(t) at a time t is given by the exponential decay law:

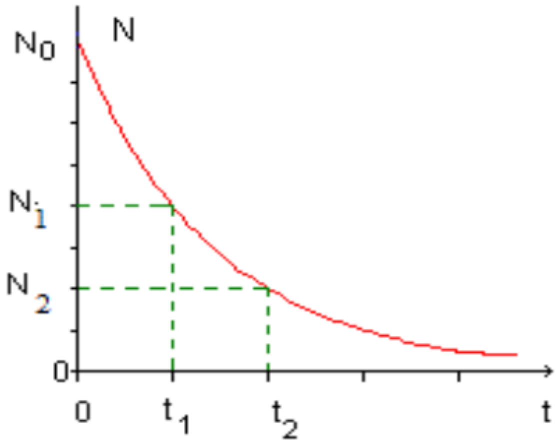
$N(t)=N_0e^{-\lambda t}$

where:

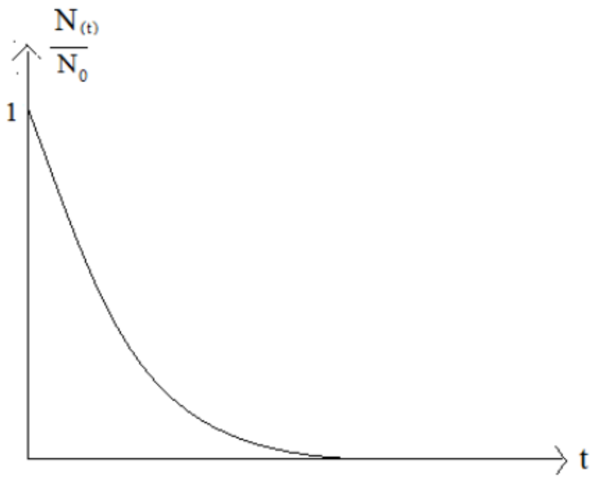
- N0 is the initial number of nuclei at t=0t = 0t=0.
- λ is the decay constant.
- e is the base of the natural logarithm.
- T is the time.

$e^{\ln\frac{N_t}{N}} = e^{-\lambda t}$ so $\frac{N_t}{N_0} = e^{-\lambda t}$, we obtain **$N_t = N_0 e^{-\lambda t}$**

The graphical representation $N_{(t)} = f(t)$ $N_{(t)} = N_0\, e^{-\lambda t}$



For the same equation, we can divide the two members of the equality by N_0 to obtain $\frac{N_t}{N_0} = e^{-\lambda t}$ its graphical representation is a decreasing exponential curve :



We can pass to the logarithmic form, which is represented by lines of the form

$y = ax + b$.

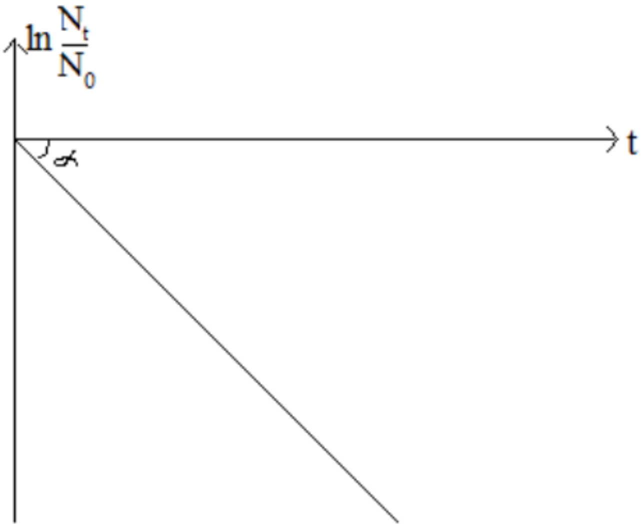
The value of λ is determined graphically by calculating the slope.

We introduce the Naperian logarithm into the equation $\frac{N_t}{N_0} = e^{-\lambda t}$, we will have

$\ln\frac{N_t}{N_0} = \ln e^{-\lambda t}$ and we obtain the following forms :

1

1st form : $\ln\frac{N_t}{N_0} = -\lambda t$

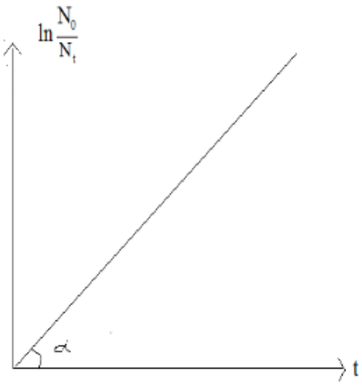


2nd form : $\ln\frac{N_0}{N_t} = \lambda t$

$\ln\frac{N_t}{N_0} = -\lambda t$ and $\ln\frac{N_t}{N_0} = -\ln\frac{N_0}{N_t}$

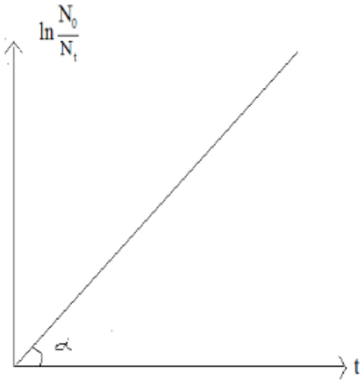
So: $-\ln\frac{N_0}{N_t} = -\lambda t$

Then:



3rd form :$-\ln \frac{N_t}{N_0} = \lambda t$. multiply both sides of the equation by -1

$-1 (\ln \frac{N_t}{N_0} = -\lambda t) \Rightarrow -\ln \frac{N_t}{N_0} = \lambda t$



4th form : $\ln N_t = -\lambda t + \ln N_0$

find the decay constant λ or to analyze the data, we can transform this equation into a linear form using natural logarithms.

1. Take the natural logarithm (ln) of both sides:

$\ln (N(t))=\ln (N_0e^{-\lambda t})$

Use the property of logarithms to separate the terms:

$\ln(N(t))=\ln(N_0)+\ln(e^{-\lambda t})$

2. Since $\ln(e^x)=x$:

$\ln(N(t))=\ln(N_0)-\lambda t$

This is a linear equation of the form y=ax+by, where:

- $y = \ln(N(t))$
- $a=-\lambda$ (the slope)
- $x = t$
- $b= \ln(N_0)$ (the y-intercept)

If $\ln \frac{N_t}{N_0} = -\lambda t \Rightarrow \ln N_t - \ln N_0 = -\lambda t$

So: $\ln N_t = \ln N_0 - \lambda t$ then : $\ln N_t = - \lambda t + \ln N_0$

III- Radioactive half-life:

Nuclear transformations are differentiated by their speed: (there are fast reactions and other slow reactions), for this reason, each nucleus is characterised by a period called the half-life time T or $t_{1/2}$ which does not depend on the number of nuclei, it can be defined as follows:

- The half-life time (T) is the time required for half of the initial number of nuclei to undergo transformation.

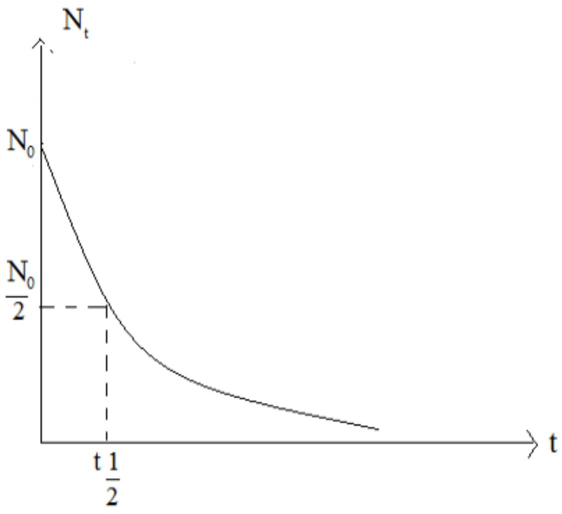
- T: represents the time at which the initial activity decreases by 50%. The half-life T is related to the radioactive constant λ

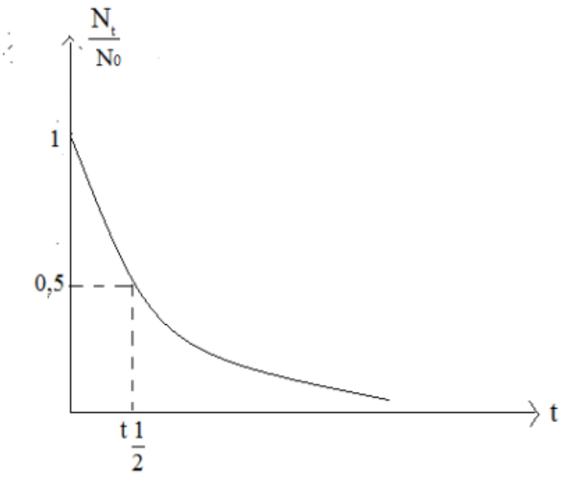
When $t = T$ we have $Nt = \frac{N_0}{2}$, we replace it in the equation $N_{(t)} = N_0\, e^{-\lambda t}$

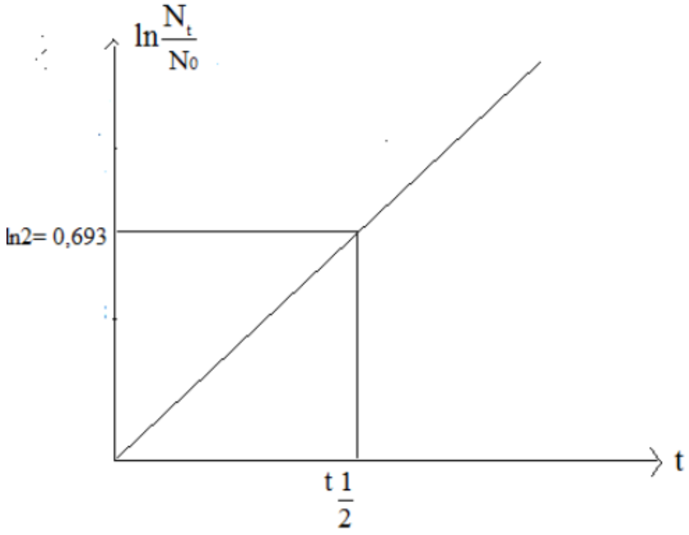
So: $\frac{N_0}{2} = N_0\, e^{-\lambda t} \Rightarrow \frac{1}{2} = e^{-\lambda t½}$ Then: $\ln \frac{1}{2} = -\lambda T$ So: $-\ln 2 = -\lambda T$

From this we deduce: $T = \frac{\ln 2}{\lambda}$ or $\lambda = \frac{\ln 2}{T}$

The period T can be determined using the graphical method:

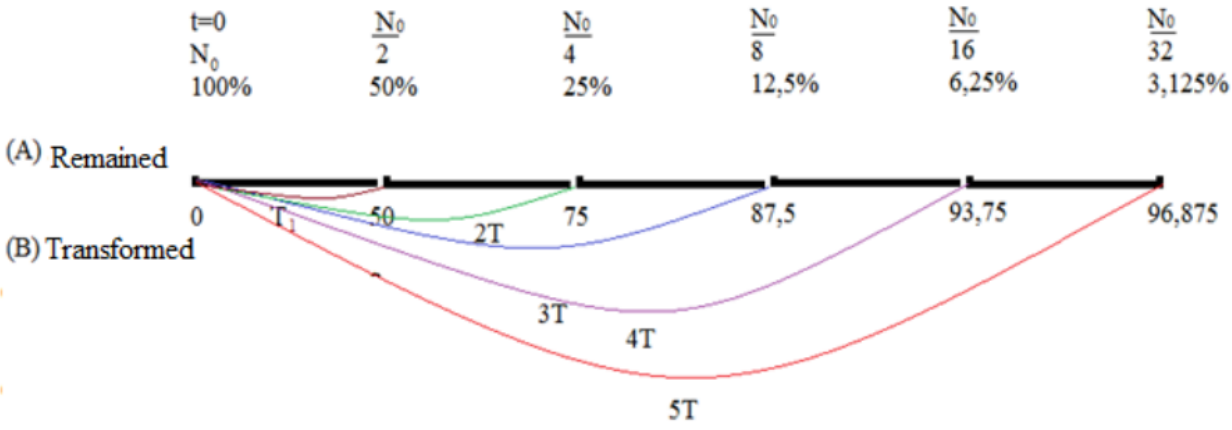






The number of remaining nuclei at the instant. t =nT or t= $nt_{1/2}$.

With n : Natural integer (number)multiple of T



It can be deduced that at time $t = nT$ we have $N_t = \frac{N_0}{2^n}$

$N_t = N_0\, e^{-\lambda t}$ substitute the values into this equation $t = nT$ and $\lambda = \frac{\ln 2}{T}$ and obtain

So: $N_t = N_0 e^{-n \ln 2}$

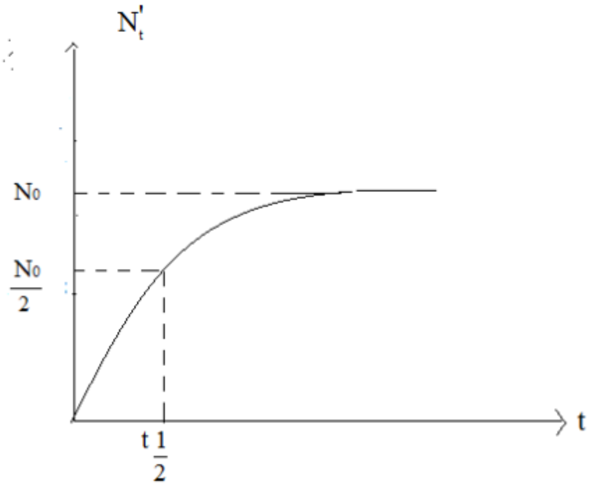
Then: $N_t = N_0 e^{\ln 2^{-n}}$ $N_t = \frac{N_0}{e^{\ln 2^n}}$ obtain $N_t = \frac{N_0}{2^n}$

The number of transformed or disintegrated nuclei can be deduced at each moment t .

If: $N_t = N_0\, e^{-\lambda t}$ we have: $N'_{t(\text{transformed})} = N_{0(\text{initial})} - N_{t(\text{remained})}$

So: $N'_t = N_0 - N_0\, e^{-\lambda t}$

Then: $N'_t = N_0\, (1 - e^{-\lambda t})$



IV-The time constant τ:

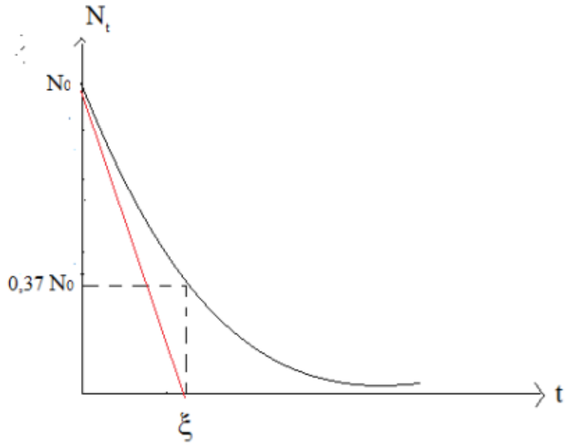
It represents the time at which 63% of the initial nuclei have transformed (leaving 37% remaining).

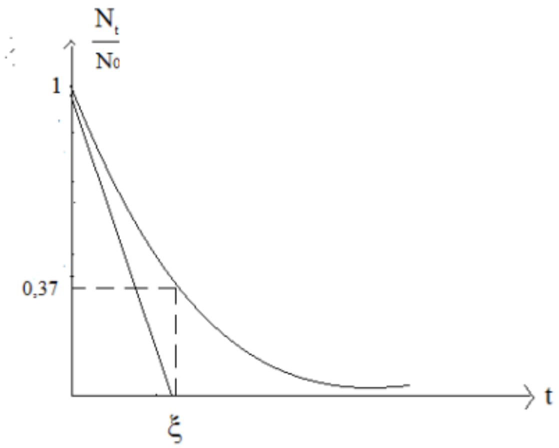
Two methods to determine the time constant:

a) By calculation $\tau = \frac{1}{\lambda} = \frac{t_{\frac{1}{2}}}{\ln 2} \Rightarrow t_{\frac{1}{2}} = \tau \ln 2$

b) By the Graphical Method :

This consists of multiplying the maximum value N_0 x 0.37 or plotting the tangent at the origin.





V- The radioactive activity A:

Activity is the number of disintegrations (number of nuclear decays) per unit of time (s) and represents the rate of disintegration (the rate of decay); it is expressed in Becquerels (Bq).

1Becquerel (Bq)=1dps : decay per second.

It is also expressed in "dpm" (disintegrations per minute).

One can also use Curies (Ci) as a unit:

$1ci = 3,7 \times 10^{10} dps = 3,7 \times 10^{10}$ Bq.

Activity is defined by the equation $A = -\frac{dN}{dt} = v$ (speed)

Let X be a nucleus that transforms into Y $X \longrightarrow Y$

We can measure either the rate of disappearance of X or the rate of appearance of Y

activity is proportional to the number of nucleiNt

At each moment, we have: $A_t = \lambda.N_t$

At the initial moment, we have $A_0 = \lambda.N_0$ Si: $N_0 > N_t$ so $A_0 > A_t$

It can be demonstrated that at any instant t $A_t = \lambda N_t$?

If: $A_t = -\frac{dN_t}{dt}$ with $N_t = N_0 e^{-\lambda t}$

$A = -\frac{d(N_0 e^{-\lambda t})}{dt} \Rightarrow A = -N_0 \frac{d(e^{-\lambda t})}{dt}$

$A_t = -N_0 (-\lambda)e^{-\lambda t} = \lambda N_0 e^{-\lambda t} = \lambda . N_t$.

The laws of decay can be expressed in terms of activity :

Start with : $N_t = N_0 e^{-\lambda t}$, if both sides of the equation are multiplied by λ.

$\lambda . N_t = \lambda . N_0 e^{-\lambda t}$, obtain: $A_t = A_0 e^{-\lambda t}$ and subsequently, we can have the following relation: $\frac{A_t}{A_0} = e^{-\lambda t}$. By introducing the Natural Logarithm, we have :

$\ln\frac{A_t}{A_0} = \ln e^{-\lambda t}$

and these equations can be represented in the same way as the equations for the number of nuclei.

VI- The relationship between experimental mass m and the number of nuclei N:

In practice, the mass m is used instead of the number of nuclei N, as the latter has no dimensions in the macroscopic system.

The mass m is related to the number of nuclei by the expression :

$N_t = \frac{m_t}{M} N_A$ so $m_t = \frac{N_t M}{N_A}$ and subsequently $N_t = n_t \times N_A$

Where N_A: Avogadro's number, M: molar mass g/mole, m_t: mass in g

Example : For a sample ^{226}Ra with an initial mass m_0 = 0,15 µg, how many nuclei are there in this mass?

$N_0 = \frac{m_0}{M} N_A = \frac{0{,}15 \times 10^{-6}}{226} \times 6{,}023 \times 10^{23}$ so $N_0 = 3{,}99 \times 10^{15}$ nuclei

The decay law can be expressed in terms of mass:

We have $N_t = N_0\, e^{-\lambda t}$ If: $N_t = \frac{m_t}{M} N_A$ $N_0 = \frac{m_0}{M} N_A$

$\frac{m_t}{\cancel{M}}\cancel{N_A} = \frac{m_0}{\cancel{M}}\cancel{N_A}\, e^{-ct}$ $m_t = m_0\, e^{-ct}$ and $n_t = n_0\, e^{-\lambda t}$

$\frac{m_t}{m_0} = e^{-\lambda t} \Rightarrow \ln \frac{m_t}{m_0} = -ct$

Same goes for the number of moles.

VII-The energetic aspect:

VII-1-The unit of universal atomic mass:

Since masses expressed in kg or g do not correspond to the dimensions of atoms and molecules, the unit of atomic mass (u.m.a) or universal mass unit (u.m.u) is used.

The u.m.a represents the $\frac{1^{st}}{12}$ of the mass of the carbon atom ^{12}C.

$1 \text{ u.m.a} = \frac{1}{12}\frac{12}{Na} = \frac{1}{Na} \Rightarrow 1 \text{ u.m.a} = 1{,}66 \times 10^{-27}$ kg

$1 \text{ u.m.a} = 1{,}66 \times 10^{-24}$ g

$1 \text{ u.m.a} = 1{,}66 \times 10^{-27}$ kg

$m_p = 1{,}672 \times 10^{-27}$ kg $= 1{,}00728$ u.m.a

$m_n = 1{,}674 \times 10^{-27}$ kg $= 1{,}00866$ u.m.a

VII-2-The mass defect Δm:

The mass defect represents the difference between the mass of the nucleus and the mass of its constituents (nucleons). It is given by the following relation:

$$\Delta m = (Z\, m_p + N\, m_n) - m\, {}^{A}_{Z}X$$

Example : For the uranium nucleus ${}^{235}_{92}U$, calculate the mass defect.

Given $m_p = 1{,}00728$ u.m.a, $m_n = 1{,}00866$ u.m.a, $m_U = 234.94784$ u.m.a

$\Delta m = 92(1.00728) + 143(1.00866) – 234.94784 = 1.9603$u.m.a

VII-3- Binding energy $\Delta E_L = E_L$:

Binding energy is the energy required to form a nucleus from its constituents (nucleons); it is the energy needed to separate a nucleus from its constituents.

It can be expressed in Joules or in eV or MeV.

$\Delta E_L = E_L = \Delta m x\ c^2$

Where : Δm (kg) $c = 3x10^8 m.s^{-1}$ (speed of light in vacuum)

Where : Δm (u.m.a) 931,5 represents the energy of one u.m.a

1eV = 1,6 10^{-19} Joule1 MeV = 10^6 eV 1 MeV = 1,6 10^{-13} Joule

Example:

For the nucleus of $^{222}_{86}$Rn, Calculate ΔE_L in MeV and in Joule.

Given : m_p = 1,00728 u.m.a

m_n = 1,00866 u.m.a

m_{Rn} = 221,9947 u.m.a

$\Delta E_L = E_L = \Delta m$ x 931,5

Δm = 86 (1,00728) + 136 (1,00866) – 221,9947

Δm = 1,80914 u.m.a

E_L = 1,80914 x 931,5

E_L = 1685,21 Mev

E_L = 2,696 x 10^{-13} Joule

VIII- Fission and Fusion reactions:

4.7.2. Fission reaction:

It involves bombarding a heavy nucleus with a neutron to produce two smaller nuclei that are more stable than the original heavy nucleus, along with the generation of a number of neutrons that will initiate the reaction again.

Example:

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{139}_{54}Xe + ^{94}_{38}Sr + 3\,^{1}_{0}n$$

VIII-1-Fusion Reaction:

It is the combination of two light nuclei to form a heavier nucleus, which is more stable than the starting nuclei.

$$^{2}_{1}H + ^{3}_{1}H \longrightarrow ^{4}_{2}He + ^{1}_{0}n$$

$$^{1}_{1}H + ^{3}_{1}H \longrightarrow ^{4}_{2}He$$

Fission and fusion reactions produce a type of energy called released energy, which manifests in two forms: Heat Energy and Kinetic Energy.

$\Delta E_{lib} = \Delta mc^2$ (joule) $\Delta E_{lib} = \Delta m\ 931{,}5$ (MeV)

$$\text{With } \Delta m = \sum m_{reactants} - \sum m_{products}$$

IX-Application exercise

Exercise N°01:

Tritium (^3H) has a half-life of 12.26 years. After how many years will a sample containing tritium see its radioactivity reduced to 25%, 10%, and 6.25% of its initial value?

Exercise N°02:

Calculate the age of three objects based on their ^{14}C content:

- Half of the initial content.

- A quarter of the initial content.
- A tenth of the initial content. Given that the half-life of the element is 5700 years. What is the time required for 85% of In atoms to decay, given T = 50000 years?

Exercise N°03:

The isotope $^{24}_{11}$Nais radioactive (beta emitter); its radioactive decay follows a first-order kinetics law:

- Give the decay equation of Na.
- Calculate the element's half-life in hours. A 10 ml solution containing initially 10^{-3} mol/l of Na is injected into a person's blood, distributed uniformly. Five hours later, 10 ml of blood is sampled, and 1.6 x 10^{-8} moles of Na are found in this volume. Calculate the blood volume of the individual.

ExerciseN°06 :

The specific activity of an object containing (^{614})C is 1.545 times less than it was initially. Determine the age of this object, given that the half-life of (^{614})C is 5,570 years.

ExerciseN°07:

Balance these reactions:

- (^{614})N + (^{24})He → (^{817})O + ( )
- (^{49})Be + (^{24})He → (^{612})C + ( )
- (^{49})Be + p → (^{64})C + ( )
- (^{1530})P → (^{1430})Si + ( )
- (^{13})H → (^{23})H + ( )
- (^{2043})Ca + ( ) → (^{2146})Se + ( )
- (^{11})H → (^{23})H + ( )

Exercise N°08:

Consider the nuclear reactions:

$(^{9424})$Pa + … → $(^{9424})$Pu + ( )

Complete these reactions. Americium $(^{9524})$Am is found in the residues of aromatic products; its radioactive constant is $9.4 \text{ x } 10^{-5}$ per year. To protect humans and food products, these residues must be isolated for a time corresponding to 20 half-lives. How many years are needed for the contamination risk from Am to disappear? Given the initial activity of americium is 120 d.p.s., what will its activity be after 20 half-lives? For a sample containing the isotope with a half-life of T, how much will remain after a time of 2T, 3T, 4T, ..., nT?

I- Introduction:

In the periodic table, chemical elements are classified in ascending order of atomic number (Z) from the left to right and the top to bottom.

It consists of 7 horizontal rows called periods and 18 vertical columns.

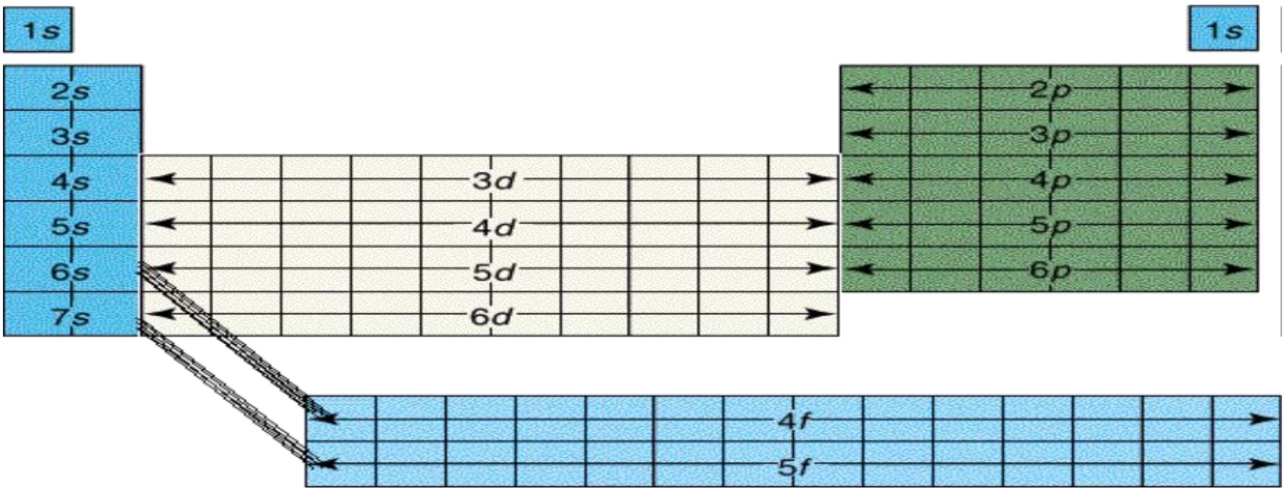
There are 4 essential blocks in the periodic table: s-block, d-block, p-block, and f-block.

S-block => 2 columns (red)

D-block => 10 columns (blue)

P-block => 6 columns (green)

F-block => 14 columns (yellow)



II- Description of the periodic table:

In the periodic table, elements in the same column have identical physicochemical properties. These properties depend on the nature of the element and its outer electron configuration. Among the existing families, we can distinguish:

II-1- Alkali metals:

- These are the elements in the first column of the periodic table, and their electron configurations end with ns^1 (except for Hydrogen - H: $1s^1$)
- The first alkali metal has the electron configuration: $\mathbf{1s^2\ 2s^1}$
- The second alkali metal has the electron configuration: $\mathbf{1s^2\ 2s^2\ 2p^6\ 3s^1}$

Example:

The electron configuration of the (4th) fourth alkali metal:

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6 4s^2\ 3d^{10}\ 4p^6\ 5s^1$

II-2- Alkaline earth metals:

These are the elements that belong to the 2nd column of the periodic table, and their electron configurations end with: $\mathbf{ns^2}$.

- The first alkaline earth metal has the electron configuration: $\mathbf{2s^2}$
- The second alkaline earth metal has the electron configuration: $\mathbf{3s^2}$
- The third alkaline earth metal has the electron configuration: $\mathbf{4s^2}$

Example:

The electron configuration of the 5th alkaline earth metal:

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10} 5p^6\ 6s^2$

II-3- Halogens:

These are the elements in the 17th column of the periodic table with electron configurations ending in: $\mathbf{np^5}$.

- The first halogen has the electron configuration $\mathbf{2p^5}$ F: $1s^2\ 2s^2\ 2p^5$
- The second halogen has the electron configuration $\mathbf{3p^5}$ Cl: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

- The third halogen has the electron configuration **$4p^5$** Br :$1s^2 2s^2 2p^6$ $3s^2$ $3p^6 4s^2 3d^{10} 4p^5$

Example:

The electron configuration of the 4th halogen:

$1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $4s^2$ $3d^{10}$ $4p^6$ $5s^2$ $4d^{10}$ $5p^5$

II-4- Noble gases (Inert gases) :

These are all the elements in the 18th column of the periodic table with electron configurations ending in **np^6**, except for Helium:(^4_2He which ends in$1s^2$.

- The first noble gas has the electron configuration**$1s^2$** He :$1s^2$.
- The second noble gas has the electron configuration **$2p^6$** Ne: $1s^2$ $2s^2$ $2p^6$.
- The third noble gas has the electron configuration **$3p^6$** Ar:$1s^2 2s^2 2p^6 3s^2$ $3p^6$.

II-5-Transition metals:

These are the elements in the 'd' block, with electron configurations ending in**ns^2 $(n\text{-}1)d^\alpha$**, with $\alpha = 1$ where α ranges from 1 to 9.

- The first transition metal ends with **$3d^1$**: $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $4s^2$ $3d^1$
- The second transition metal ends with **$3d^2$:**$1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $4s^2$ $3d^2$
- The third transition metal ends with **$3d^3$:**$1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $4s^2$ $3d^3$

III- Position of elements in the periodic table:

The elements in the periodic table are classified according to their charge number. Based on this periodic classification, one can determine the electronic structure of the elements, knowing their position, and vice versa.

To determine the position of an element in the periodic table, one needs to provide its electron configuration in order to find its row and column.

III-1- Row (period):

To identify the row, consider the coefficient of the last 's' subshell in the electron configuration.

III-2- Column:

Consider the exponent (power) of the last subshell in the electron configuration.

- If the electron configuration ends with $\mathbf{s^n}$ => n = 1, 2, then it corresponds to the nth column in the s-block, thus the nth column in the periodic table.
- If the electron configuration ends with $\mathbf{p^n}$ => n = 1…6, then it corresponds to the nth column in the p-block, thus the $\mathbf{(n + 12)^{th}}$ column in the periodic table.
- If the electron configuration ends with $\mathbf{d^n}$ => n = 1…10, then it corresponds to the nth column in the d-block, thus the $\mathbf{(n + 2)^{ième}}$ column in the periodic table

Example:

Indicate the position of the following elements in the periodic table:

$\mathbf{{}_6C, {}_{26}X, {}_4B}$

$\mathbf{{}_6C: 1s^2\ 2s^2\ 2p^2}$

(2nd row, 2nd column in p, thus the 14th column in the periodic table).

$\mathbf{{}_{26}X: 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^6}$

(4th row, 6th column in d, thus the 8th column in the periodic table).

$\mathbf{{}_4B: 1s^2\ 2s^2}$

(2nd row, 2nd column in s, thus the 2nd column in the periodic table).

From the periodic classification of elements, we can also determine the concept of groups and subgroups, which allows us to know the number of valence electrons. There are two subgroups: subgroup A and subgroup B.

The elements in the **s** and **p** blocks of the periodic table, those that end in their electronic configurations with **s** or **p**, belong to **subgroup A**.

The elements in the **d** block of the periodic table, those that end in their electronic configurations with **d**, belong to **subgroup B**.

Block **s**		Block **d**										Block **p**					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

I_A	II_A	III_B	IV_B	V_B	VI_B	VII_B	$VIII_B$	I_B	II_B	III_A	IV_A	V_A	VI_A	VII_A	0

Example:

$_3$Li : $1s^2\ 2s^1$; period 2, Group I_A

$_4$Be: $1s^2\ 2s^2$; period 2, Group II_A

$_7$N : $1s^2\ 2s^2\ 2p^3$; period 2, Group V_A

$_{11}$Na : $1s^2\ 2s^2\ 2p^6\ 3s^1$; period 3, Group I_A

$_{16}$S :$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$; period 3, Group VI_A

$_{20}$Ca : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$; period 4, Group II_A

$_{33}$As : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^3$; period 4, Group V_A

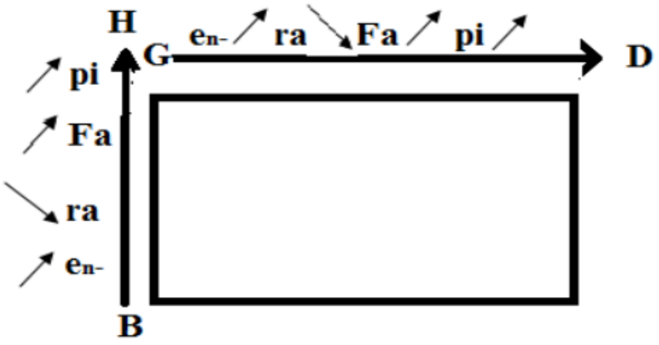
$_{52}$Te : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^4$; period 5, Group VI_A

IV- Physical and Chemical Parameters

Some physical and chemical parameters can be deduced from the periodic table, such as:

- Atomic radius (r_a).
- Electronegativity (e_n^-).
- Ionisation potential (E_i, P_i).
- Attraction force ($F_a = \frac{Ke^2}{r^2}$)
- Electron affinity

These parameters are classified in the periodic table and evolve in the row and column as follows:



IV-1-Atomic radius (r_a) :

Definition: The distance between the nucleus of an atom and the outer boundary of its electron cloud.

Trend in the periodic table:

- Across a period (left to right): The atomic radius decreases. The increasing number of protons attracts the electrons closer to the nucleus.
- Down a group (top to bottom): The atomic radius increases. Each additional period adds an electron shell, increasing the size of the atom.

In the same row or period, moving from left to right, the atomic number Z increases, which means the number of electrons increases, leading to a reduction in the atomic radius.

In the same column, moving from bottom to top, one gets closer to the nucleus, and therefore, the atomic radius decreases.

IV-2-Electronegativity (e_n^-) :

Definition: The ability of an atom to attract electrons in a chemical bond.

The Electronegativity represents the power of electron attraction through the σ bond between two atoms in a bond.

Trend in the periodic table:

- **Across a period (left to right):** Electronegativity increases. Elements on the right side of the table have a greater tendency to attract electrons.
- **Down a group (top to bottom):** Electronegativity decreases. Valence electrons are further from the nucleus and less strongly attracted.

Within the same period, electronegativity increases from left to right, which is explained by the increase in the number of electrons in the same shell, leading to increased electron density.

In the same column, electronegativity increases from bottom to top, which is explained by the electrons getting closer to the nucleus.

IV-3- Attraction force (F_a) :

The force of attraction between the nucleus and the electrons is influenced by two main factors: effective nuclear charge and the distance between the nucleus and the valence electrons. Generally, electrons are attracted to the nucleus (which contains positively charged protons) by the Coulombic attraction force.

Effective Nuclear Charge (Z_eff): This is the net charge felt by the valence electrons after accounting for the shielding effect of the inner electrons. It increases as you move from left to right across a period due to the increasing number of protons without a significant addition of inner electrons.

Distance from the Nucleus (atomic radius): The greater the distance between the nucleus and the valence electrons, the weaker the force of attraction.

Trend in the periodic table:

Across a period (left to right): The force of attraction between the nucleus and the valence electrons increases. This is due to the increase in effective nuclear charge without a significant increase in the distance between the nucleus and the valence electrons. In the same row (same shell), moving

attraction force also increases.

Down a group (top to bottom): The force of attraction between the nucleus and the valence electrons decreases. This is due to the increase in the distance between the nucleus and the valence electrons despite the increase

in the number of protons in the nucleus. In same the column, moving from bottom to top (closer to the nucleus), the attraction force increases.

IV-4- Ionisation Potential (E_i, P_i) :

Definition: The energy required to remove an electron from an atom in its gaseous state. It is the energy required to remove electrons, and it is proportional to the attraction force.

Trend in the periodic table:

- **Across a period (left to right):** Ionization energy increases. Electrons are more strongly attracted to the nucleus as the number of protons increases.
- **Down a group (top to bottom):** Ionization energy decreases. Electrons are further from the nucleus and less attracted to it due to the shielding effect of other electrons.

IV-5- Electron Affinity (A_f) :

Definition: The energy released when an atom in the gaseous state accepts an electron to form a negative ion. It is the energy required for stabilising an electron on a shell after being captured by an atom. It increases from left to right in a period and from bottom to top in a column.

Trend in the periodic table:

- **Across a period (left to right):** Electron affinity becomes more negative (more energy is released) up to the halogens, which have the highest electron affinities. However, noble gases have low or positive electron affinities.
- **Down a group (top to bottom):** Electron affinity becomes less negative (less energy is released). Added electrons are further from the nucleus and experience less attraction.

V- Application exercise

Exercise N° 01:

- Give the electron configuration, group, and period of nitrogen (N, Z=7).
- Find the atomic numbers (Z) of the three elements that follow nitrogen and are in the same group.

Exercise N° 02:

- What are the period and group of an atom X whose cation X^{2+}has the sa me electron configuration as krypton (Z=36)?

Exercise N° 03:

Which of the following atoms are in the same column of the periodic table? $_3$Li, $_4$Be, $_7$N, $_{11}$Na, $_{16}$S, $_{20}$Ca, $_{52}$Te, $_{33}$As.

- Knowing that polonium (Po) belongs to group VIA and the sixth period, determine its atomic number (Z).
- To which group and period does antimony (Sb) belong, knowing that its atomic number is Z=51?

Exercise N° 04:

Given a chemical element whose last electron is characterized by the following four quantum numbers: (4, 1, -1, +1/2).

- Give the electron configuration of this element.
- Find its atomic number (Z), group, and period.

Exercise N° 05:

The following elements are given: $_{13}$Al, $_{24}$Cr, $_{37}$Rb, $_{73}$Ta.

Give the electron configuration of these elements.

- Locate them in the periodic table.
- Give the values of the four quantum numbers for the 19th electron of chromium (Cr).

Exercise N° 06:

An element in the 4th period has one unpaired electron.

- Give the possible structures of this element.
- Deduce the atomic numbers and groups of these elements.
- Determine this element knowing that it belongs to the boron family (^{5}B).

Exercise N° 07:

Using their positions in the periodic table, indicate for each of the following pairs of atoms, which has the highest first ionization energy and which has the largest size:

a) Li and K b) B and N c) F and Cl

Exercise N° 08:

Given the following elements: 16S,37Rb,52Te,49In16 \text{S}, 37 \text{Rb}, 52 \text{Te}, 49 \text{In}16S,37Rb,52Te,49In.

1. Locate each element in the periodic table.
2. Arrange them in order of increasing first ionization energy.
3. Arrange them in order of increasing electronegativity.

Exercise N° 09:

Among the following elements: $_{55}$Cs, $_{38}$Sr, $_{21}$Sc, $_{9}$F, identify the element that:

1. Is the most electronegative.
2. Has the largest atomic radius.
3. Has the highest first ionization energy.

Solution

Solution N°01:

$_{7}$N: $1s^2\ 2s^2\ 2p^3 \longrightarrow$ Group V_A, période 2.

Eléments qui se trouvent dans le même groupe => $nS^2\ nP^3$ so:

X: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3 \longrightarrow$ X: (Z=15) which is phosphorus $_{15}$P.

Y: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^3 \longrightarrow$ Y: (Z=33) which is arsenic $_{33}$As.

Z: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^3 \longrightarrow$ Z: (Z=51) which is antimony $_{41}$Sb.

Solution N°02:

$X^{2+} \equiv\ _{36}$Kr: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6$

$X^{2+} + 2e^- \longrightarrow$ X so X: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2$; périod 5, Group II_A

Solution N°03:

$_{3}$Li: $1s^2\ 2s^{1;}$ périod 2, Group I_A

$_4$Be: $1s^2\ 2s^{2;}$ périod 2, Group II_A

$_7$N: $1s^2\ 2s^2\ 2p^3$; périod 2, Group V_A

$_{11}$Na: $1s^2\ 2s^2\ 2p^6\ 3s^{1;}$ périod 3, Group I_A

$_{16}$S: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$; périod 3, Group VI_A

$_{20}$Ca: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$; périod 4, Group II_A

$_{33}$As: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^3$; period 4, Group V_A

$_{52}$Te: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^4$; périod 5, Group VI_A

Same column same group => ($_3$Li and $_{11}$Na), ($_4$Be and $_{20}$Ca), ($_7$N and $_{33}$As), ($_{16}$S and $_{52}$Te).

Po: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^6\ 6s^2\ 4f^{14}\ 5d^{10}\ 4P^6$ so: Po: (Z=84).

Po: Groupe VI_A et période 6

$ns^2\ np^4$ n=6 => $6s^2\ 6p^4$

$_{51}$Sb: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^3$, périod 5, Group V_A

Solution N°04:

(4, 1, -1, +1/2)

4p $\boxed{\uparrow}\boxed{\ }\boxed{\ }$ so : $4p^1$

-1 0 1

X: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^1$, périod 4, Group III_A

X: (Z=31) ; $_{31}X \equiv {}_{31}Ga$

Solution N°05:

$_{13}$Al: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$ $\longrightarrow$ périod 3, Group III_A

$_{24}$Cr: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^4$ $\longrightarrow$ périod 4, Group VI_A

$_{37}$Rb: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^1$ $\longrightarrow$ périod 5, Group I_A

$_{73}$Ta: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^6\ 6s^2\ 4f^{14}\ 5d^3$ périod 6, Group V_A

$_{24}$Cr: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^4$

19th electron: (4, 0, 0, +½).

Solution N°06:

A: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$; Groupe I_A, (Z=19).

B: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^1$; Group III_B, (Z=21).

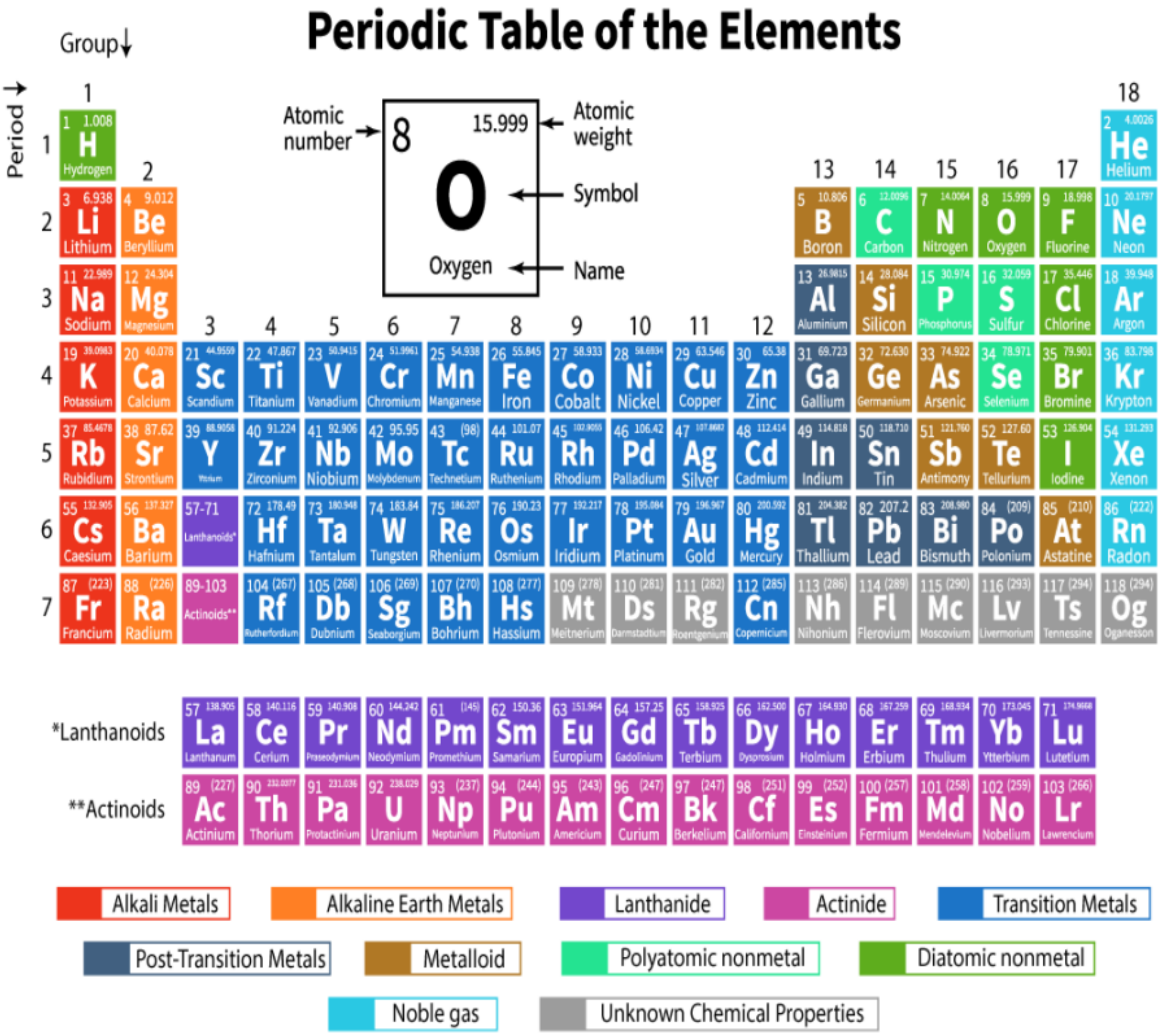
C: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}$; Group I_B, (Z=29).

D: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^1$; Group III_A, (Z=31).

E: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^5$; Group VII_A, (Z=35).

$_5B$:$1s^2\ 2s^2\ 2p^1$; Group III_A

So the element is: $_{31}D$, which is gallium ($_{31}Ga$).



Periodic Table of the Elements

Atomic number → 8 15.999 ← Atomic weight; O ← Symbol; Oxygen ← Name

Period → / Group ↓	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 1.008 H Hydrogen																	2 4.0026 He Helium
2	3 6.938 Li Lithium	4 9.012 Be Beryllium											5 10.806 B Boron	6 12.0096 C Carbon	7 14.0064 N Nitrogen	8 15.999 O Oxygen	9 18.998 F Fluorine	10 20.1797 Ne Neon
3	11 22.989 Na Sodium	12 24.304 Mg Magnesium											13 26.9815 Al Aluminium	14 28.084 Si Silicon	15 30.974 P Phosphorus	16 32.059 S Sulfur	17 35.446 Cl Chlorine	18 39.948 Ar Argon
4	19 39.0983 K Potassium	20 40.078 Ca Calcium	21 44.9559 Sc Scandium	22 47.867 Ti Titanium	23 50.9415 V Vanadium	24 51.9961 Cr Chromium	25 54.938 Mn Manganese	26 55.845 Fe Iron	27 58.933 Co Cobalt	28 58.6934 Ni Nickel	29 63.546 Cu Copper	30 65.38 Zn Zinc	31 69.723 Ga Gallium	32 72.630 Ge Germanium	33 74.922 As Arsenic	34 78.971 Se Selenium	35 79.901 Br Bromine	36 83.798 Kr Krypton
5	37 85.4678 Rb Rubidium	38 87.62 Sr Strontium	39 88.9058 Y Yttrium	40 91.224 Zr Zirconium	41 92.906 Nb Niobium	42 95.95 Mo Molybdenum	43 (98) Tc Technetium	44 101.07 Ru Ruthenium	45 102.9055 Rh Rhodium	46 106.42 Pd Palladium	47 107.8682 Ag Silver	48 112.414 Cd Cadmium	49 114.818 In Indium	50 118.710 Sn Tin	51 121.760 Sb Antimony	52 127.60 Te Tellurium	53 126.904 I Iodine	54 131.293 Xe Xenon
6	55 132.905 Cs Caesium	56 137.327 Ba Barium	57-71 Lanthanoids*	72 178.49 Hf Hafnium	73 180.948 Ta Tantalum	74 183.84 W Tungsten	75 186.207 Re Rhenium	76 190.23 Os Osmium	77 192.217 Ir Iridium	78 195.084 Pt Platinum	79 196.967 Au Gold	80 200.592 Hg Mercury	81 204.382 Tl Thallium	82 207.2 Pb Lead	83 208.980 Bi Bismuth	84 (209) Po Polonium	85 (210) At Astatine	86 (222) Rn Radon
7	87 (223) Fr Francium	88 (226) Ra Radium	89-103 Actinoids**	104 (267) Rf Rutherfordium	105 (268) Db Dubnium	106 (269) Sg Seaborgium	107 (270) Bh Bohrium	108 (277) Hs Hassium	109 (278) Mt Meitnerium	110 (281) Ds Darmstadtium	111 (282) Rg Roentgenium	112 (285) Cn Copernicium	113 (286) Nh Nihonium	114 (289) Fl Flerovium	115 (290) Mc Moscovium	116 (293) Lv Livermorium	117 (294) Ts Tennessine	118 (294) Og Oganesson

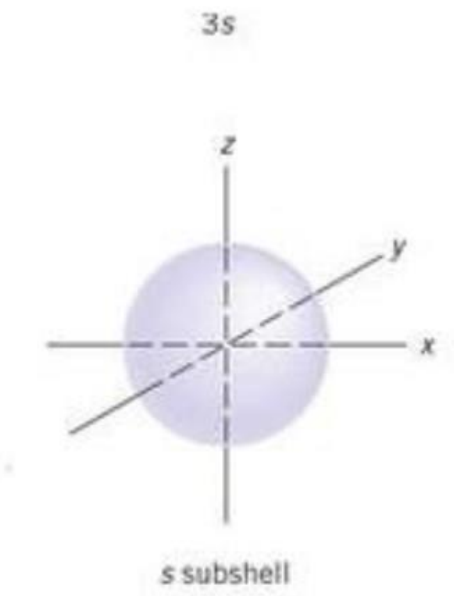
*Lanthanoids	57 138.905 La Lanthanum	58 140.116 Ce Cerium	59 140.908 Pr Praseodymium	60 144.242 Nd Neodymium	61 (145) Pm Promethium	62 150.36 Sm Samarium	63 151.964 Eu Europium	64 157.25 Gd Gadolinium	65 158.925 Tb Terbium	66 162.500 Dy Dysprosium	67 164.930 Ho Holmium	68 167.259 Er Erbium	69 168.934 Tm Thulium	70 173.045 Yb Ytterbium	71 174.9668 Lu Lutetium
**Actinoids	89 (227) Ac Actinium	90 232.0377 Th Thorium	91 231.036 Pa Protactinium	92 238.029 U Uranium	93 (237) Np Neptunium	94 (244) Pu Plutonium	95 (243) Am Americium	96 (247) Cm Curium	97 (247) Bk Berkelium	98 (251) Cf Californium	99 (252) Es Einsteinium	100 (257) Fm Fermium	101 (258) Md Mendelevium	102 (259) No Nobelium	103 (266) Lr Lawrencium

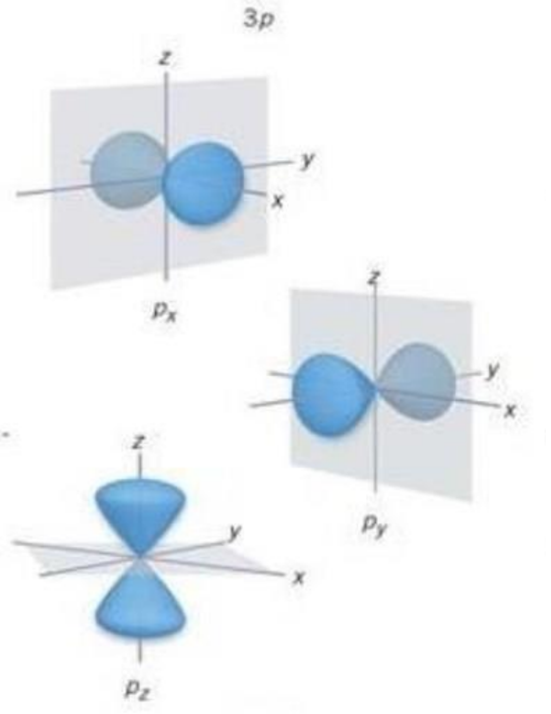
🟥 Alkali Metals
🟧 Alkaline Earth Metals
🟪 Lanthanide
🟪 Actinide
🟦 Transition Metals
⬛ Post-Transition Metals
🟫 Metalloid
🟩 Polyatomic nonmetal
🟩 Diatomic nonmetal
🟦 Noble gas
⬜ Unknown Chemical Properties

I- Définition :

Chemical bond represents a connection that forms between the electrons in the outer shell of atoms to create molecular orbitals from atomic orbitals. This bond results from either axial or lateral overlap.

S orbital : represented by a sphere. P orbital :





I-1- overlap type

⇨ ***Axial overlap:*** results from an interaction of electrons along the same axis, giving rise to a σ bond.

Example : H_2