

# Chemistry Lovers

By: Mr. Mohamed Taha

## Unit (1): Chemical equation & chemical calculation

### 1- Calculation of the chemical formulas

**Chemistry:** It is the branch of science that deals with the composition & structure of matter and the changes that matter undergoes.

**Matter could be:**

- 1) Element                                      2) Compound                                      3) Mixture

**Element:** is a pure substance that contains only one type of atoms.  
Elements are expressed chemically by simple symbols like:

| Element  | Symbol | Atomic no. | Electronic configuration | Valence        | Kind      |
|----------|--------|------------|--------------------------|----------------|-----------|
| Hydrogen | H      | 1          | 1                        | 1 <sup>+</sup> | Non metal |
| Sodium   | Na     | 11         | 2,8,1                    | 1 <sup>+</sup> | Metal     |
| Chlorine | Cl     | 17         | 2,8,7                    | 1 <sup>-</sup> | Non metal |
| Argon    | Ar     | 18         | 2,8,8                    | Zero           | Inert gas |
| Silicon  | Si     | 14         | 2,8,4                    | 4              | Metalloid |
| Sulfur   | S      | 16         | 2,8,6                    | 2 <sup>-</sup> | Non metal |
| Calcium  | Ca     | 20         | 2,8,8,2                  | 2 <sup>+</sup> | Metal     |

## Molecules of elements could be:

| Monatomic  |                                     |   | Diatomic  |
|--|-------------------------------------|---|---|
| All metals like:<br>Fe – Al – Na<br>Ca – Cu – Ag | Solid non metals like:<br>C – S – P | Inert gases like:<br>He – Ne – Ar<br>Kr – Xe – Rn | Liquid and gaseous non metals like:<br>H <sub>2</sub> – N <sub>2</sub> – O <sub>2</sub> – Cl <sub>2</sub> – F <sub>2</sub> – Br <sub>2</sub> – I <sub>2</sub> |

## Compound:

It is formed by the chemical combination of atoms or ions of two or more elements in a certain weight ratio.

## Compounds are expressed chemically by formulas like:

### 1- Molecular formula

### 2- Empirical formula

- 1- **Chemical (molecular) formula:** it is a simple symbolic formula that shows the number and the type of atoms or ions in the molecule of a compound.

| Compound         | Molecular formula              | Compound          | Molecular formula  |
|------------------|--------------------------------|-------------------|--------------------|
| Sodium hydroxide | Na OH                          | Magnesium oxide   | Mg O               |
| Copper carbonate | Cu CO <sub>3</sub>             | Barium sulphate   | Ba SO <sub>4</sub> |
| Sulfuric acid    | H <sub>2</sub> SO <sub>4</sub> | Ammonium chloride | NH <sub>4</sub> Cl |

## Important notes:

### A) Atomic groups (Radicals) or (Polyatomic ions):

| Monovalent   | Divalent  | Trivalent                                  |
|--|---|--|
| Hydroxide (OH) <sup>-1</sup><br>Bicarbonate (HCO <sub>3</sub> ) <sup>-1</sup><br>Nitrite (NO <sub>2</sub> ) <sup>-1</sup><br>Nitrate (NO <sub>3</sub> ) <sup>-1</sup><br>Ammonium (NH <sub>4</sub> ) <sup>+1</sup> | Carbonate (CO <sub>3</sub> ) <sup>-2</sup><br>Sulphate (SO <sub>4</sub> ) <sup>-2</sup><br>Sulphite (SO <sub>3</sub> ) <sup>-2</sup><br>Thiosulphate (S <sub>2</sub> O <sub>3</sub> ) <sup>-2</sup> | Phosphate (PO <sub>4</sub> ) <sup>-3</sup> |

B) **Mole:** it is the atomic mass of an element expressed in grams

**Or** it is the molecular mass of a compound expressed in grams

**Example (1):** The molecular formula of lead bromide is  $\text{PbBr}_2$  therefore:  
Each **1 mole of lead bromide**  $\text{PbBr}_2$  contains **1 mole of lead ion**  $\text{Pb}^{++}$  and **2 moles of bromide ions**  $2\text{Br}^-$

**Example (2):** The molecular formula of water is  $\text{H}_2\text{O}$  therefore:  
Each **1 mole of  $\text{H}_2\text{O}$**  contains **2 moles of hydrogen atoms** and **1 mole of Oxygen atoms**

**Example (3):** How many moles in 53 gm. Sodium carbonate ( $\text{Na}_2\text{CO}_3$ ) ?

(Na = 23 – C = 12 – O = 16)

Solution: 1 mole of ( $\text{Na}_2\text{CO}_3$ ) =  $(23 \times 2) + (12) + (16 \times 3) = 106$  gm.

1mole of  $\text{Na}_2\text{CO}_3$   $\longrightarrow$  106 gm

? mole of  $\text{Na}_2\text{CO}_3$   $\longrightarrow$  53 gm

No. of moles =  $53 \times 1 / 106 = 0.5$  moles

**Note:** no. of moles = mass/molar mass

**Example (4):** calculate the mass of 0.1 mole of water? (H=1 - O=16)

Solution: 1 mole of  $\text{H}_2\text{O}$  =  $2 + 16 = 18$  gm

1mole of  $\text{H}_2\text{O}$   $\longrightarrow$  18 gm

0.1 mole of  $\text{H}_2\text{O}$   $\longrightarrow$  ? gm

The mass of 0.1mole of  $\text{H}_2\text{O}$  =  $0.1 \times 18 / 1 = 1.8$  gm,

2- **Empirical formula:** it is a simple symbolic formula that shows the simplest ratio (percentage composition) of atoms of a compound.

**Examples:**

| Compound        | Molecular formula  | Empirical formula              |
|-----------------|--|--------------------------------|
| Magnesium oxide | Mg O   | Mg O                           |
| Glucose sugar   | $\text{C}_6\text{H}_{12}\text{O}_6$                                | $\text{CH}_2\text{O}$          |
| Sodium Chloride | Na Cl  | Na Cl                          |
| Ethyl Alcohol   | $\text{C}_2\text{H}_5\text{OH}$ ( $\text{C}_2\text{H}_6\text{O}$ ) | $\text{C}_2\text{H}_6\text{O}$ |

**Note:** The empirical formula is similar to the molecular formula in the ionic compounds.

**Problems:**

- 1- A magnesium ribbon is heated until complete combustion and a white ash of magnesium oxide is formed. If the mass of magnesium used = 0.24 gram, and the mass of magnesium oxide produced = 0.40 gm. Calculate the empirical formula of magnesium oxide (Mg = 24, O=16)

**Solution:** Magnesium + oxygen  $\rightarrow$  magnesium oxide.  
 The mass of reacting oxygen =  $0.40 - 0.24 = 0.16$  gram.

|                     | Mg              | O               |
|---------------------|-----------------|-----------------|
| <b>Masses</b>       | 0.24            | 0.16            |
| <b>No. of moles</b> | $0.24/24 = 0.1$ | $0.16/16 = 0.1$ |
| <b>Molar ratio</b>  | 1               | 1               |

The empirical formula is: Mg O

2- Calculate the empirical formula of an unknown hydrocarbon compound If the masses of carbon and hydrogen are 0.12 and 0.02gram, then calculate the molecular formula if you know that the molecular mass of the compound is 56 gm.  
 (C = 12, H=1).

**Solution:**

|                     | C                | H               |
|---------------------|------------------|-----------------|
| <b>Masses</b>       | 0.12             | 0.02            |
| <b>No. of moles</b> | $0.12/12 = 0.01$ | $0.02/1 = 0.02$ |
| <b>Molar ratio</b>  | 1                | 2               |

The empirical formula is CH<sub>2</sub>

Mass of the empirical formula =  $(12 \times 1) + (2 \times 1) = 14$

Number of units of the empirical formula =  $56/14 = 4$

the formula of the compound =  $4 \times \text{CH}_2 = \text{C}_4 \text{H}_8$

**Note:** The molecular formula = empirical formula x no. of units of the empirical formula

3- If the molecular mass of a hydrocarbon compound is 70 gm and its empirical formula is CH<sub>2</sub>. Find the molecular formula.

**Solution:**

The mass of the empirical formula =  $(12 \times 1) + (1 \times 2) = 14$

the number of units of the empirical formula =  $70/14 = 5$ .

The molecular formula is C<sub>5</sub>H<sub>10</sub>

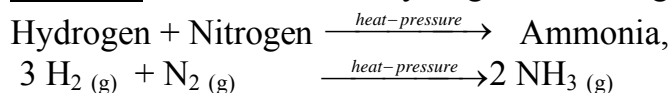
## 2- The chemical equation

"It is a simple and concise description of the changes happened in the chemical reaction"

### Chemical equation includes:

(Reactants – products – conditions of the reactions – physical state of both reactants and products)

**Example:** The reaction of hydrogen and nitrogen gases to produce ammonia gas.

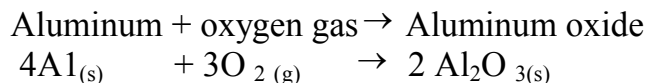


As shown in the above example the chemical equation must be balanced.

### Balanced chemical equation:

"It is the equation at which the number of atoms in the both sides of the equation is equal."

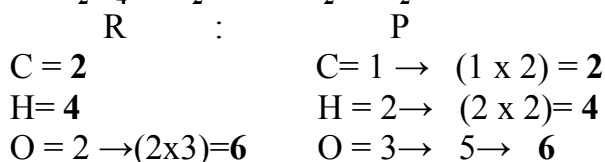
**Example:** Write the balanced equation representing the reaction between aluminum and oxygen to form aluminum oxide.



**Note:** the equation  $\text{H}_2 (\text{g}) + \text{O}_2 (\text{g}) \rightarrow \text{H}_2\text{O}_{2(\text{l})}$  is balanced wrongly because the produced compound is water and its formula is  $\text{H}_2\text{O}$  not  $\text{H}_2\text{O}_2$ .

**Balance the following equation:**  $\text{C}_2\text{H}_4 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$

Solution:



### Ionic equation:

"It is the equation that represents the chemical reaction taking place between ions in the aqueous solutions".

### Examples of ionic equations:

1-Neutralization reaction

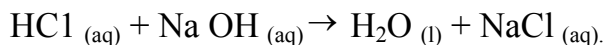
2-precipitation reaction

### 1-Neutralization reaction:

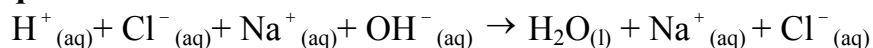
"It is the reaction between acid and base to form salt and water."

It is called neutralization reaction **because** the properties of both acid and base disappear after they react together.

**Example:** on adding aqueous solution of hydrochloric acid to aqueous solution of sodium hydroxide it produces water and sodium chloride. The balanced symbolic equation for this reaction is:



**The equation in the ionic form is:**



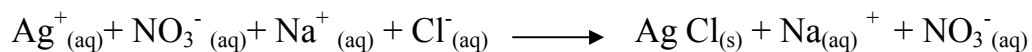
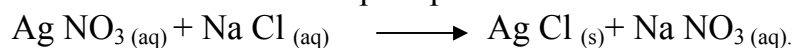
**The reacted ions are:**



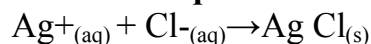
## **2-Precipitation reaction:**

"It is the reaction of ions in the aqueous solution which gives insoluble substance"

**Example:** Addition of silver nitrate solution to sodium chloride solution, gives a white insoluble silver chloride precipitate



**This ionic equation is :**



**The equation is balanced because the atoms and charges are the same on both sides.**

**Since** the sum of the charges on the left side equals to zero (+1 -1 = 0) and the same for the charges on the right side where AgCl compound is neutral.

### 3- Chemical calculation

**"It is the study of the quantitative relations in the chemical equation by the calculation of the amounts of both reactants and products"**

**Give reasons:**

1-The balanced chemical equation represents the base of the true chemical calculation.  
Because it expresses the true ratio of the atoms, ions or molecules which share in the chemical reaction

2-The mole is considered as the suitable unit which can be used in the chemical calculations.  
Because it is difficult to deal with limited atoms, ions or molecules due to their small masses and volumes

**Mole:** it is the atomic or molecular mass of a substance expressed in grams

**Number of moles = 1 mole of substance / molar mass**

**Avogadro's number:**

(It is the number of atoms or ions or molecules which are existed in one mole of a substance  
Avogadro's number =  $6.02 \times 10^{23}$ )

**Examples:**

1- One mole of helium (He) =  $6.02 \times 10^{23}$  molecule (or atom) of helium

2- One mole of oxygen (O<sub>2</sub>) =  $6.02 \times 10^{23}$  molecule of oxygen Or  
 $2 \times 6.02 \times 10^{23}$  oxygen atoms

3- One mole of sodium sulphide (Na<sub>2</sub>S) =  $6.02 \times 10^{23}$  sodium sulphide molecules  
=  $6.02 \times 10^{23}$  sulphide ions  
=  $2 \times 6.02 \times 10^{23}$  sodium ions

**Problems:**

1- How many moles are present in 90 gm of water?

Solution: 1 mole of water =  $(2 \times 1) + 16 = 18$  gm

No. of moles of water = mass of water / molar mass =  $90/18 = 5$  moles

2- How many moles of lead are present in 41.4 grams of lead? And how many atoms of lead are in this mass? (Pb = 207)

Solution: The mass of one mole of lead = 207 grams

mole: gm

1 : 207

? : 41.4

No. Of moles =  $41.4/207 = 0.2$  mole

Secondly:

mole: atoms

1 :  $6.02 \times 10^{23}$

0.2 : ?

No. of atoms =  $0.2 \times 6.02 \times 10^{23} = 1.204 \times 10^{23}$  atoms.

3- What is the mass of  $3.01 \times 10^{22}$  carbon atoms? (C = 12)

Solution:

|      |   |    |   |                       |
|------|---|----|---|-----------------------|
| mole | : | gm | : | atoms                 |
| 1    | : | 12 | : | $6.02 \times 10^{23}$ |
| ?    | : | ?  | : | $3.01 \times 10^{22}$ |

No. of moles =  $3.1 \times 10^{22} / 6.02 \times 10^{23} = 5 \times 10^{-2}$  moles

1 mole of carbon = 12 gm

The mass of  $5 \times 10^{-2}$  moles =  $5 \times 10^{-2} \times 12 = 0.6$  gm

4- How many molecules are present in 32 grams of sulphur dioxide? (S = 32, O = 16)

Solution:

1 mole of sulphur dioxide ( $\text{SO}_2$ ) =  $(32 \times 1) + (16 \times 2) = 64$  gm

|      |   |    |   |                       |
|------|---|----|---|-----------------------|
| Mole | : | gm | : | molecules             |
| 1    | : | 64 | : | $6.02 \times 10^{23}$ |
| ?    | : | 32 | : | ?                     |

No. of moles =  $32/64 = 0.5$  mole

No. of molecules =  $0.5 \times 6.02 \times 10^{23} = 3.01 \times 10^{23}$  molecules

**Or: directly no. Of molecules =  $32 \times 6.02 \times 10^{23} / 64 = 3.01 \times 10^{23}$**



5- How many moles of H<sub>2</sub>O are produced from the reaction of 10 moles of O<sub>2</sub> and excess of H<sub>2</sub>, based on the following balanced equation:

2H<sub>2(g)</sub> + O<sub>2(g)</sub> → 2H<sub>2</sub>O<sub>(g)</sub>. Calculate the mass of water produced and the mass of hydrogen needed.

Solution:

|                     |   |                   |   |                                   |
|---------------------|---|-------------------|---|-----------------------------------|
| 2 H <sub>2(g)</sub> | + | O <sub>2(g)</sub> | → | 2 H <sub>2</sub> O <sub>(g)</sub> |
| 2mole               | : | 1 mole            | : | 2 moles                           |
| ?                   | : | 10 moles          | : | ?                                 |

No. of water moles = 2 x 10 / 1 = 20 mole

The mass of 1 mole of H<sub>2</sub>O = 16 + 2 x 1 = 18 gm.

|                     |   |                   |   |                                   |
|---------------------|---|-------------------|---|-----------------------------------|
| 2 H <sub>2(g)</sub> | + | O <sub>2(g)</sub> | → | 2 H <sub>2</sub> O <sub>(g)</sub> |
| 2x2gm               | : | 2x16gm            | : | 2 x 18gm                          |
| ?                   | : | 10x32             | : | ?                                 |

The mass of H<sub>2</sub>O = 36 x 320/32 = 360 gm.

hydrogen moles = 20 mole → mass of H<sub>2</sub> = 320 x 4/32 = 40gm

6- Calculate the mass of calcium oxide produced from the thermal dissociation of 50 grams of calcium carbonate according to the following equation:

CaCO<sub>3(s)</sub> → CaO + CO<sub>2(g)</sub> [Ca=40, C= 12, O=16]

Solution:

|                      |   |                    |   |                    |
|----------------------|---|--------------------|---|--------------------|
| CaCO <sub>3(s)</sub> | → | CaO <sub>(s)</sub> | + | CO <sub>2(g)</sub> |
| 1mole                | : | 1mole              | : | 1mole              |
| 40+12+(3x16)=100gm   | : | 40+16 =56gm        | : | 12+2 x 16          |
| 50 gm                | : | ?                  | : | ?                  |

Mass of CaO = 50x56/100=28gm