

Molecules of elements could be:

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

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 ₃	Barium sulphate	Ba SO ₄
Sulfuric acid	H ₂ SO ₄	Ammonium chloride	NH ₄ Cl

Important notes:

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

Monovalent	Divalent	Trivalent
Hydroxide (OH) ⁻¹ Bicarbonate (HCO ₃) ⁻¹ Nitrite (NO ₂) ⁻¹ Nitrate (NO ₃) ⁻¹ Ammonium (NH ₄) ⁺¹	Carbonate (CO ₃) ⁻² Sulphate (SO ₄) ⁻² Sulphite (SO ₃) ⁻² Thiosulphate (S ₂ O ₃) ⁻²	Phosphate (PO ₄) ⁻³

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 PbBr_2 therefore:
Each **1 mole of lead bromide** PbBr_2 contains **1 mole of lead ion** Pb^{++} and **2 moles of bromide ions** 2Br^-

Example (2): The molecular formula of water is H_2O therefore:
Each **1 mole of H_2O** contains **2 moles of hydrogen atoms** and **1 mole of Oxygen atoms**

Example (3): How many moles in 53 gm. Sodium carbonate (Na_2CO_3) ?
($\text{Na} = 23 - \text{C} = 12 - \text{O} = 16$)

Solution: 1 mole of (Na_2CO_3) = $(23 \times 2) + (12) + (16 \times 3) = 106$ gm.

1mole of Na_2CO_3 \longrightarrow 106 gm

? mole of Na_2CO_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? ($\text{H}=1 - \text{O}=16$)

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

1mole of H_2O \longrightarrow 18 gm

0.1 mole of H_2O \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	$\text{C}_6\text{H}_{12}\text{O}_6$	CH_2O
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 ($\text{Mg} = 24, \text{O} = 16$)

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

	Mg	O
Masses	0.24	0.16
No. of moles	$0.24/24 = 0.1$	$0.16/16 = 0.1$
Molar ratio	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
Masses	0.12	0.02
No. of moles	$0.12/12 = 0.01$	$0.02/1 = 0.02$
Molar ratio	1	2

The empirical formula is CH₂

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 CH₂. 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 C₅H₁₀

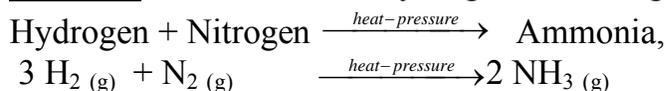
2- The chemical equation

"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.

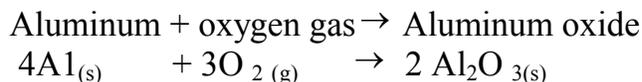


As shown in the above example the chemical equation must be balanced.

Balanced chemical equation:

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

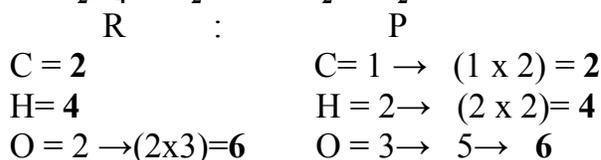
Example: Write the balanced equation representing the reaction between aluminum and oxygen to form aluminum oxide.



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 H_2O not H_2O_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

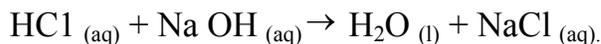
2-precipitation reaction

1-Neutralization reaction:

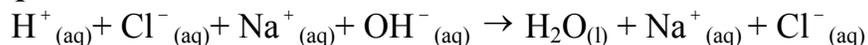
"It is the reaction between acid and base to form salt and water."

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:



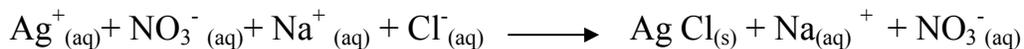
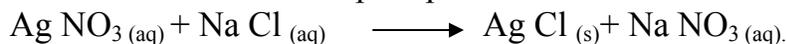
The reacted ions are:



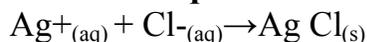
2-Precipitation reaction:

"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 = 6.02×10^{23})

Examples:

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

2- One mole of oxygen (O₂) = 6.02×10^{23} molecule of oxygen Or
 $2 \times 6.02 \times 10^{23}$ oxygen atoms

3- One mole of sodium sulphide (Na₂S) = 6.02×10^{23} sodium sulphide molecules
= 6.02×10^{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 : 6.02×10^{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 3.01×10^{22} carbon atoms? (C = 12)

Solution:

mole	:	gm	:	atoms
1	:	12	:	6.02×10^{23}
?	:	?	:	3.01×10^{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 5×10^{-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 (SO₂) = (32 x 1) + (16 x 2) = 64 gm

Mole	:	gm	:	molecules
1	:	64	:	6.02×10^{23}
?	:	32	:	?

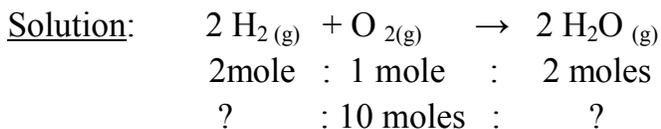
No. of moles = $32/64 = 0.5$ mole

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

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

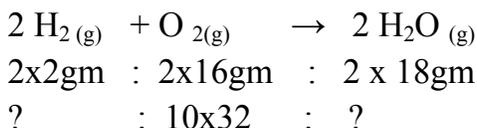
5- How many moles of H₂O are produced from the reaction of 10 moles of O₂ and excess of H₂, based on the following balanced equation:

2H_{2(g)} + O_{2(g)} → 2H₂O_(g). Calculate the mass of water produced and the mass of hydrogen needed.



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

The mass of 1 mole of H₂O = 16 + 2 x 1 = 18 gm.



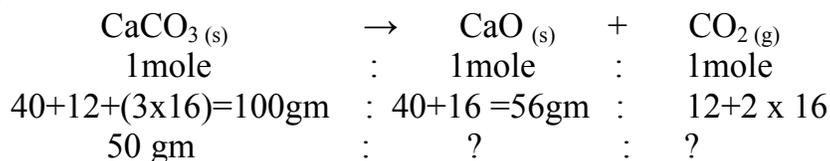
The mass of H₂O = 36 x 320/32 = 360 gm.

hydrogen moles = 20 mole → mass of H₂ = 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_{3(s)} → CaO + CO_{2(g)} [Ca=40, C= 12, O=16]

Solution:



Mass of CaO = 50x56/100=28gm