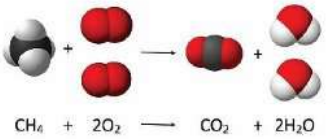
4 CHAPTER STOICHIOMETRY



Students Learning Outcomes

After studying this chapter, students will be able to:

- State the formulae of common elements and compounds.
- Define molecular formula of a compound as the number and type of different atoms in one molecule
- Define empirical formula of a compound as the simplest whole number ratio of different atoms in a Molecule.
- Deduce the formula and name of a binary ionic compounds from ions given relevant information
- Deduce the formula of a molecular substance from the given structure of molecules.
- Use the relationship amount of substance = mass/ molar mass to calculate number of moles, mass, molar mass, relative mass (atomic/molecular/formula) and number of particles.
- Define mole as amount of-substance containing Avogadro's number 6.02x 10^{23}) of particles
- Explain the relationship between a mole and Avogadro's constant.
- Construct chemical equations and ionic equations to show reactants forming products, including state symbols.
- Deduce the symbols equation with state symbols for a chemical reaction given relevant information.

INTRODUCTION

SHORT QUESTIONS

Q.1 Define stoichiometry. What is basis of stoichiometry? (RWP 2016)*(U.B+K.B)*

Ans:

STOICHIOMETRY

Definition

The branch of chemistry which deals with the calculations based on balanced chemical equation is called stoichiometry.

OR

Stoichiometry is an important concept in chemistry which helps us to calculate the amounts of reactants and products by using a balanced chemical equation.

Basis of Stoichiometry

It is based on the law of conservation of mass.

Law of conservation of mass

Matter can neither be created nor destroyed. Therefore, the total mass of all the reactants must be equal to the total mass of all the products.

Stoichiometry coefficient

The stoichiometric coefficient used to balance a chemical equation provides the mole ratio between reactants and products.

Role of Stoichiometry in industry

Stoichiometry is used in industry quite often to determine the amount of raw materials required to produce the desired amount of the products.

MULTIPLE CHOICE QUESTIONS

1. **Which is shown by stoichiometric co-efficients?**
   (A) Mass ratio (B) Mole ratio (C) Volume ratio (D) None of these
2. **Base of stoichiometry is:** ***(K.B)***
   (A) Law of definite proportion (B) Law of conservation of mass
   (C) Law of multiple proportion (D) Law of indefinite proportion

4.1 CHEMICAL FORMULA

Q.1 Define the chemical formula. What do you know about existence of elements and compounds and their chemical formula?

Ans:

CHEMICAL FORMULA

Definition:

*"**Representation of an element or a compound in terms of symbols** is called chemical formula".*

Examples:

- Chemical formula of aluminium sulphate: $Al_2(SO_4)_3$
- Chemical formula of calcium phosphate: $Ca_3(PO_4)_2$
- Chemical formula of chlorine: Cl_2
- Chemical formula of water: H_2O

EXISTENCE OF ELEMENTS

Elements exist in different forms in this world.

(a) In the form of aggregate of atoms

There are elements which exist in the form of aggregate of atoms. These elements are represented by their **symbols** alone,

Examples

- Na
- Ca
- C
- Fe etc.

(b) As discrete molecules

Some elements like O_2, N_2, H_2 exist as discrete molecules in which their atoms are chemically bonded to each other. In ozone, three atoms of oxygen are bonded to each other, so its **chemical formula** is O_3.

Example

- O_3
- O_2
- P_4
- S_8 etc.

EXISTENCE OF CHEMICAL COMPOUNDS

Similar to elements, chemical compounds also exist in different forms.

(a) As formula unit

Definition

Simplest ration between ions in ionic compound is called formula unit.

Example

Common salt i.e. sodium chloride exists in the form of ions which are bonded together in the form of a crystal. Since ratio between its ions is 1:1, sodium chloride is represented by a formula unit NaCl.

Similarly, the other ionic compounds are represented by their formula units which show the minimum ratio present between their ions.

Examples

- $CaCl_2$
- KBr
- $BaCl_2$ etc

(b) As discrete molecules

Covalent compounds generally exist in discrete molecules in which atoms are bonded together.

Examples

water exists as molecules which are represented by the chemical formula H_2O. It shows that in one molecule of water two atoms of hydrogen are bonded to one atom of oxygen. Similarly chemical compound, ammonia is represented by NH_3 and methane gas is represented by CH_4.

A chemical compound is thus, represented by a chemical formula which is called the molecular formula of that compound and which shows all the types of atoms bonded together in one molecule of that compound.

Examples

Covalent compounds are:

- HCI
- HF
- PH_3
- H_2O_2
- H_2SO_4
- CO_2
- CO
- C_6H_6 etc.

EXERCISE

Q. How would you differentiate between the chemical formula of an element and that of a compound? Give examples. Write down the names of ionic and covalent compounds whose formulas have been given in this article.

Ans: **DIFFERENTIATION**

The differences between chemical formula of element and that of compound is as follows:

Chemical Formula of Element	Chemical formula of Compound
Nature of Atoms	
Chemical formula of element consists of same type of atoms.	Chemical formula of compound consists of **different kinds** of atoms.
Representation	
It represents one molecule of an element.	It represents one molecule or formula unit of a molecular compound or ionic compound.
Examples	
Hydrogen (H_2), Oxygen (O_3) and sulphur (S_8)	CO_2, H_2O and NH_3

Names of Covalent and Ionic Compounds

i. **Covalent Compounds**

NaCl : sodium chloride
$CaC1_2$: calcium chloride
KBr : potassium bromide
$BaC1_2$: barium chloride

ii. **Ionic Compounds**

HCI : hydrochloric acid

HF : hydrofluoric acid
PH_3 : Phosphine
H_2O_2 : hydrogen peroxide
H_2SO_4 : sulphuric acid
CO_2 : carbon dioxide
CO : carbon monoxide
C_6H_6 : benzene

SHORT QUESTIONS

Q.1 Define the chemical formula.

Ans:

CHEMICAL FORMULA

Definition

*"**Representation of an element or a compound in terms of symbols** is called chemical formula".*

Examples

- Chemical formula of aluminium sulphate: $Al_2(SO_4)_3$
- Chemical formula of calcium phosphate: $Ca_3(PO_4)_2$

Q.2 Define formula unit.

Ans:

FORMULA UNIT

Definition

Simplest ration between ions in ionic compound is called formula unit.

Example

Common salt i.e. sodium chloride exists in the form of ions which are bonded together in the form of a crystal. Since ratio between its ions is 1:1, sodium chloride is represented by a formula unit NaCl.

MULTIPLE CHOICE QUESTIONS

1. $Al_2(SO_4)_3$ is the formula of: *(K.B)*

(A) Aluminium sulphate (B) Aluminium phosphate
(C) Calcium sulphate (D) Calcium phosphate

2. The valency of ion is written on: *(K.B)*

(A) Top left corner (B) Top right corner
(C) Bottom right corner (D) Bottom left corner

3. CaO is the chemical formula of: *(K.B)*

(A) Lime stone (B) Lime water (C) Caustic soda (D) Quick lime

4. Chemical formula of washing soda is: *(K.B)*

(A) $Na_2CO_3.H_2O$ (B) $Na_2CO_3.10H_2O$ (C) $Na_2CO_3.7H_2O$ (D) Na_2CO_3

4.1 EMPIRICAL FORMULA

LONG QUESTIONS

Q.1 Define empirical formula. Describe the empirical formula of ionic and covalent compounds.

Ans:

EMPIRICAL FORMULA

Definition

Empirical Formula of a compound shows the minimum ratio between atoms present in that compound.

All the ionic compounds are represented by their empirical formulas. These formulas show the simplest ratio present between their ions.

Example

The empirical formula of calcium fluoride is CaF_2 which shows the ratio present between calcium and fluoride ions in its crystal.

Empirical formula of covalent compounds

Definition

*"It is **simplest whole number ratio of atoms of each element present in a compound**"*

Examples:

(i) The covalent compound **silica (sand)** has simplest ratio of **1:2** of **silicon** and **oxygen,** respectively. Therefore, its empirical formula is **SiO_2**.

Silica or sand (silicon dioxide) = Si : O
1 : 2
Thus empirical formula of silica **SiO_2**

(ii) Glucose has simplest ratio **1:2:1** of **carbon, hydrogen** and **oxygen,** respectively. Hence its empirical formula is **CH_2O**.

Glucose = C : H : O
6 : 12: 6
1: 2 : 1
Thus empirical formula of glucose = **CH_2O**

(i) Empirical Formula of Ionic Compounds:

The ionic compounds exist in **three dimensional network** forms. Each ion is surrounded by oppositely charged ion in such a way to form **electrically neutral compound**. Therefore, the **simplest unit** taken as a **representative** of an ionic compound is called **formula unit**.

Formula Unit:

*"The **simplest whole number ratio of ions, as present in an ionic compound** is called formula unit."*

Example

- Formula unit of **common salt** consists of one Na^+ and one Cl^- ion and its empirical formula is **NaCl**.
- Formula unit of **potassium bromide** is **KBr** which is also its empirical formula.

A compound having different molecular or empirical formula

For covalent chemical compounds, which exist as molecules, the empirical formulas may be different from their molecular formulas.

Example

(i) Hydrogen peroxide is represented by its molecular formula H_2O_2 its empirical formula will be HO.

(ii) Similarly, a benzene molecule has C_6H_6 as its molecular formula; so its empirical formula will be CH.

Compound	Empirical Formula	Molecular Formula
Hydrogen peroxide	HO	H_2O_2

Benzene	CH	C_6H_6
Glucose	CH_2O	$C_6H_{12}O_6$

A compound having Same molecular or empirical formula

For water, the molecular formula and the empirical formula are both the same i.e. H_2O because there does not exist any minimum ratio between hydrogen and oxygen atoms.

Different compounds having same empirical formula

Since an empirical formula does not tell us the actual number of atoms present in that compound, rather it represents the simplest ratio between atoms, it is possible that some compounds may have the same empirical formula.

Example

Both benzene (C_6H_6) and acetylene (C_2H_2) have the same empirical formula CH.

EXERCISE

Q. Give two examples of a compound which have same empirical and molecular formulas.

Ans: **SAME EMPIRICAL AND MOLECULAR FORMULAS**

Water = H_2O

Carbon dioxide = CO_2

SHORT QUESTIONS

Q.1 Name the elements represented by the following symbols: *(K.B)*

Hg, Au, Fe, Ni, Co, W, Sn, Na, Ba, Br, Bi

Ans:

Symbol	Name	Symbol	Name
Hg	Mercury	Sn	Tin
Au	Gold	Na	Sodium
Fe	Iron	Ba	Barium
Ni	Nickel	Br	Bromine
Co	Cobalt	Bi	Bismuth
W	Tungsten		

Q.2 What elements do the following compounds contain? Sugar, common salt, lime water and chalk. *(K.B)*

Ans:

Compound	Elements	Formula
Sugar	Carbon (C), Hydrogen (H), Oxygen (O)	$C_6H_{12}O_6$
Common Salt	Sodium (Na), Chlorine (Cl)	NaCl
Lime water	Calcium (Ca), Oxygen (O), Hydrogen (H)	$Ca(OH)_2$
Chalk	Calcium (Ca), Carbon(C), Oxygen (O)	$CaCO_3$

MULTIPLE CHOICE QUESTIONS

1. $AlPO_4$ is the formula of: *(K.B)*

(A) Aluminium sulphate (B) Aluminium phosphate

(C) Calcium sulphate (D) Calcium phosphate

2. $Ca(OH)_2$ is the chemical formula of: *(K.B)*

(A) Lime stone (B) Slaked lime (C) Caustic soda (D) Quick lime

3. Which one of the following shows the simplest whole number ratio of atoms in a substance? *(U.B+K.B)*

(A) Molecular formula (B) Empirical formula

(C) Chemical formula (D) Covalent formula

4. **Chemical formula of soda ash is:** *(K.B)*
(A) $Na_2CO_3.H_2O$ (B) $Na_2CO_3.10H_2O$ (C) $Na_2CO_3.7H_2O$ (D) Na_2CO_3

5. **The empirical formula of glucose is:** **(LHR 2015)** *(K.B)*
(A) CH (B) CH_2O (C) OH (D) H_2O_2

6. **Which one of the following is empirical formula of benzene?**
(LHR 2016, (LHR 2016G-II, FSD 2017G-II) *(K.B)*
(A) $C_6H_6O_2$ (B) C_3H_3O (C) C_6H_6 (D)CH

7. **Silica is also known as:** *(K.B)*
(A) Silicate (B) Clay (C) Sand (D) Sulphate

8. **In silica the ratio of silicon and oxygen atoms is:** *(K.B)*
(A) 2:2 (B) 1:2 (C) 2:1 (D) 2:3

9. **The sum of atomic mass of all the atoms in one formula unit of a substance called:** *(K.B)*
(A) Atomic mass (B) Mass number
(C) Formula mass (D) Atomic mass unit

10. **The formula mass of an ionic compound expressed in gram is called:** *(K.B)*
(A) Gram formula mass (B) Gram molecular
(C) Mole (D) All of these

4.3 CHEMICAL FORMULA OF BINARY IONIC COMPOUNDS

LONG QUESTIONS

Q.1 Define empirical formula. Describe the empirical formula of ionic and covalent compounds.

Ans:

EMPIRICAL FORMULA

In order to write down the formula of an ionic compound,

(i) First identify the cations and anions

(ii) The number of charges present on them.

(iii) Finally combine the two ions together to form an electrically neutral compound.

Method to write chemical formula

(i) If you know the name of binary ionic compound, you can write its chemical formula.

(ii) Writing symbol of cation with its charge.

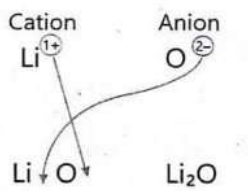
(iii) Then write the symbol of anion with its charge

(iv) Find out how many of these ions are needed to give an electrically neutral compound.

Example

1. Formula of lithium oxide

Write down the formula of lithium oxide.



(i) The symbol of lithium cation with its single positive charge is Li .

(ii) The symbol of anion is O_2

(iii) Let us now apply crisscross method to write the formula. In this method, the numerical value of each of the ion charges is crossed over to become the subscript of the other ion.

(iv) Signs of the charges are then dropped.

2. Formula of aluminium oxide

Write down the formula of Aluminium oxide.

3. Formula of magnesium nitrite

Write down the formula of Magnesium nitride.

INTERESTING INFORMATION

IMPORTANCE OF STOICHIOMETRY

The composition of all the chemical products we use in our lives, such as shampoos, perfumes, soaps and fertilizers are formed using stoichiometry calculation. Without stoichiometry the chemical industry does not exist.

Atoms and their Cations with charges		Atoms and their Anions and Cation with charges	
Atom	**Charge**	**Atom**	**Charge**
H	H^{1+}	O	O^{2-}
Na	Na^{1+}	N	N^{3-}
Li	Li^{1+}	Cl	Cl^{1-}
K	K^{1+}	Br	Br^{1-}
Mg	Mg^{2+}	I	I^{1-}
Ca	Ca^{2}	Cu	Cu^{1+}, Cu^{2+}
Ba	Ba^{2+}	Fe	Fe^{2+}, Fe^{3+}
Zn	Zn^{2+}	Sn	Sn^{2+}, Sn^{4+}
Al	Al^{3+}		

SHORT QUESTIONS

Q.1 Differentiate between empirical formula and formula unit? ***(U.B)***

Ans: The differences between empirical formula and formula units are given below:

Empirical Formula	Formula Unit
Definition	
• *Empirical formula is the simplest whole number ratio of atoms of different elements present in a compound.*	• *The simplest whole number ratio of ions as present in the ionic compound is called formula unit.*
Example	
• The empirical formula of glucose ($C_6H_{12}O_6$) is CH_2O.	• The formula unit of sodium chloride is NaCl.
Type of compound	
• Both covalent and ionic compound have empirical formula.	• Only ionic compounds have formula unit.

Q.2 How can you differentiate between molecular formula and empirical formula? ***(U.B)***

Ans: **DIFFERENTIATION**

The differences between empirical formula and molecular formula are as follows:

Empirical Formula	Molecular Formula
• *Empirical formula is the simplest whole number ratio of atoms of different elements present in a compound.*	• *The formula that shows actual number of atoms of each element present in a molecule of that compound is called molecular formula.*
• The Empirical formula of glucose ($C_6H_{12}O_6$) is CH_2O.	• The molecular formula of glucose is $C_6H_{12}O_6$.
• It is determined on the basis of percentage composition of a compound.	• It is derived from empirical formula by the following relationship. • Molecular formula = n × empirical formula.
• It can be written both for ionic and molecular compounds.	• It can only be written for molecular substances i.e. elements and compounds

Q.3 Identify the following formulae as formula unit or molecular formulae: ***(U.B)***

H_2O_2, CH_4, $C_6H_{12}O_6$, $C_{12}H_{22}O_{11}$, $BaCO_3$, KBr

Ans:

IDENTIFICATION OF FORMULAS

Molecular Formula	Formula Unit	Empirical Formula
H_2O_2	$BaCO_3$	$BaCO_3$
CH_4	KBr	KBr
$C_6H_{12}O_6$		CH_4
$C_{12}H_{22}O_{11}$		

Q.4 What is empirical formula of acetic acid (CH_3COOH)? Find out its molecular mass. ***(U.B+A.B)***

Ans:

EMPIRICAL FORMULA

Acetic acid ($C_2H_4O_2$) has simplest whole number ratio CH_2O. Thus empirical formula of acetic acid is CH_2O.

Molecular mass of acetic acid:

(CH_3COOH) = 1(12) + 3(1) +1(12) + 1(16) + 1(16) + 1(1)
= 12+3+12+16+16+1
= 60amu

MULTIPLE CHOICE QUESTIONS

1. **NaOH is the chemical formula of:** ***(K.B)***
(A) Lime stone (B) Lime water (C) Caustic soda (D) Quick lime

2. **Which one of the following shows the actual number ratio of atoms in a substance?** ***(U.B+K.B)***
(A) Molecular formula (B) Empirical formula
(C) Chemical formula (D) Covalent formula

3. **The empirical formula of ethyne is:** **(LHR 2015)** ***(K.B)***
(A) CH (B) CH_2O (C) OH (D) H_2O_2

4. **Which one of the following is molecular formula of benzene?**
(LHR 2016, (LHR 2016G-II, FSD 2017G-II) ***(K.B)***
(A) $C_6H_{12}O_6$ (B) C_3H_3O (C) C_6H_6 (D)CH

5. **Silica is also known as:** ***(K.B)***

(A) Silicate (B) Clay (C) Silicon dioxide (D) Sulphate

6. **In benzene the ratio of silicon and oxygen atoms is:** ***(K.B)***

(A) 2:2 (B) 1:2 (C) 1:1 (D) 2:3

4.4 CHEMICAL FORMULA OF COMPOUNDS

LONG QUESTION

Q.1 How we can determine the empirical formula and molecular formula of compounds?

Ans: **DETERMINATION OF MOLECULAR FORMULA**

Molecular formula of a compound can be found out if we know its empirical formula.

Steps

(i) Calculate the empirical formula of a compound

To calculate the empirical formula of a compound, you need to determine the simplest whole-number ratio of atoms in the compound. This can be done by using experimental data on the mass percent composition of the compound.

(ii) Molecular formula

Molecular formula is then calculated by the following relationship.

Molecular formula = n x (Empirical Formula)

Where n = 1, 2, 3, 4, 5 and so on.

n= Molecular mass/Empirical Formula mass

Compound having same empirical and molecular formula

If for a compound the value of n is one, then its molecular formula is the same as its empirical formula.

Example

For water, the molecular formula and the empirical formula are both the same i.e. H_2O because there does not exist any minimum ratio between hydrogen and oxygen atoms.

EXAMPLE

Q. Calculate molecular formula of hydrogen peroxide whose empirical formula HO and molar mass is 34

Solution

The empirical formula of hydrogen peroxide is HO. Its molar mass is 34. Its molecular formula will then be.

$$n = \frac{34}{17} = 2$$

$$\text{Molecular formula} = (HO)_2 = H_2O_2$$

EXERCISE

Q. Write down the names of three such compounds which have different empirical and molecular formulas.

Ans: **DIFFERENT EMPIRICAL AND MOLECULAR FORMULAE**

Compound	Empirical Formula	Molecular Formula

Hydrogen peroxide	HO	H_2O_2
Benzene	CH	C_6H_6
Glucose	CH_2O	$C_6H_{12}O_6$

SAMPLE PROBLEM

Q. Empirical formula of a compound is. CH. Its molecular mass 78 g mol^{-1}. Find out its molecular formula.

Solution:

Empirical Formula = CH Molecular mass = 78 $gmol^{-1}$

Molecular formula = n (Empirical formula)

n = molar mass/empirical formula mass

$= \frac{78}{13} = 6$

Molecular Formula = $(CH)_6 = C_6H_6$

EXERCISE

1. The empirical formula of a compound is CH_2O. Its molar mass is 180g mol^{-1}. Determine its molecular formula.

Ans: **NUMERICAL**

Molecular formula = n (Empirical formula)

n = molar mass/empirical formula mass

$= \frac{180}{30} = 6$

Molecular Formula = $(CH_2O)_6 = C_6H_{12}O_6$

2. The empirical formula of a compound is CH_2O. Its molar mass is 60g mol^{-1}. Determine its molecular formula.

Ans: **NUMERICAL**

Molecular formula = n (Empirical formula)

n = molar mass/empirical formula mass

$= \frac{60}{30} = 2$

Molecular Formula = $(CH_2O)_2 = C_2H_4O_2$

SHORT QUESTIONS

Q.1 How we can determine the molecular formula and molecular formula of compounds?

Ans: **DETERMINATION OF MOLECULAR FORMULA**

Molecular formula = n (Empirical formula)

n = molar mass/empirical formula mass

Its value is 1, 2, 3, 4 ……. Etc.

Q.2 What is empirical formula of benzene (C_6H_6)?

Ans: **EMPIRICAL FORMULA OF BENZENE**

The empirical formula of benzene is CH.

MULTIPLE CHOICE QUESTIONS

1. **$Ca_3(PO_4)_2$ is the formula of:** *(K.B)*

(A) Aluminium sulphate (B) Aluminium phosphate

(C) Calcium sulphate (D) Calcium phosphate

2. **The valency of sodium atom is written on:** *(K.B)*

(A) +1 (B) +2
(C) +4 (D) +3

3. **The molar mass of H_3PO_4 is:** **(GRW 2017G-II)*(U.B+K.B)***
(A) 58.5g (B) 98g (C) 40g (D) 98amu

4. **The formula mass of K_2SO_4 is:** ***(U.B+K.B)***
(A) 174amu (B) 174g (C) 170amu (D) 170g

5. **The sum of atomic mass of all the atoms in one formula unit of a substance called:** ***(K.B)***
(A) Atomic mass (B) Mass number (C) Formula mass (D) Atomic mass unit

4.5 DEDUCE THE MOLECULAR FORMULA FROM THE STRUCTURAL FORMULA

LONG QUESTIONS

Q.1 How we can deduce molecular formula from structural formula?

Ans:

STRUCTURAL FORMULA

Definition:

*"The formula which represents the **actual number of atoms** in one molecule of the organic compound is called the molecular formula".*

Example:

Molecular formula of butane is **C_4H_{10}.** It shows:

- **Butane** is made up of **carbon** and **hydrogen atoms**.
- Each molecule of butane consists of **4 carbon** atoms and 10 **hydrogen atoms.**

Structural Formula

*"Structural formula of a compound represents the **exact arrangement** of the **different atoms** of various elements present in a molecule of a substance".*

Representation of Bonds:

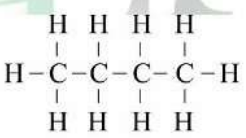
In a structural formula the bonds between bonded atoms are shown as follows:

- Single bond is represented by a single line (–)
- Double bond by two lines (=)
- Triple bond by three lines (≡)

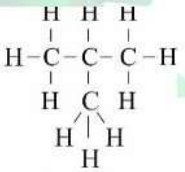
Organic compounds may have same molecular formulae but different structural formulae.

Example:

Structural formulae of butane (C_4H_{10}) are:



n-butane



isobutane

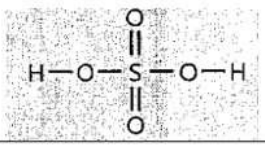
Determination of Structural formula

In order to deduce the molecular formula from the structural formula the following steps are taken.

(i) Write down the structural formula of the compound.
(ii) Count the number of atoms of each type in the structural formula.
(iii) Write the symbols of all the elements.
(iv) Write the total number of atoms of each kind as a subscript.
(v) Remove the subscript

SAMPLE PROBLEM

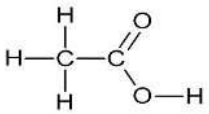
Q. Write down the molecular formula of sulphuric acid. Its structural formula is:



Ans: It has 2H, 1S, 4O atoms
Its molecular formula is H_2SO_4

SAMPLE PROBLEM

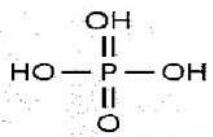
Q. Write down the molecular formula of acetic acid. Its structural formula is:



Ans: It has 2C, 4H, 2O atoms
Its molecular formula is $C_2H_4O_2$

EXERCISE

1. Find out the molecular formula of phosphoric acid, its structural formula is:



Ans:

Phosphoric acid has 1P, 3H, 4O atoms. Its molecular formula will be

C : H : O
3 : 8 : 1
H_3PO_4

2. Determine the molecular formula of n-propyl alcohol. Its structural formula is:

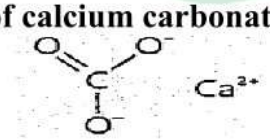
CH_3--CH_2--CH_2--OH

Ans:

n-propyl alcohol has 1O,3C, 8H atom. Its molecular formula will be:

C : H : O
3 : 8 : 1
$C_3H_8O_1$

3. Write down the formula of calcium carbonate. Its structural formula is:



Ans:

It has 1Ca, 1C, 3O atoms.
Its formula is $CaCO_3$

SHORT QUESTIONS

Q.1 What is the relationship between empirical formula and molecular formula?

(SWL 2017)*(U.B)*

Ans: The molecular formula is derived from empirical formula by the following relationship.
Molecular formula = n × (empirical formula)
Where n is 1, 2, 3, and so on.

Q.2 Differentiate between empirical formula and formula unit? ***(U.B)***

Ans: The differences between empirical formula and formula units are given below:

Empirical Formula	Formula Unit
Definition	
• Empirical formula is the simplest whole number ratio of atoms of different elements present in a compound.	• The simplest whole number ratio of ions as present in the ionic compound is called formula unit.
Example	
• The empirical formula of glucose ($C_6H_{12}O_6$) is CH_2O.	• The formula unit of sodium chloride is NaCl.
Type of compound	
• Both covalent and ionic compound have empirical formula.	• Only ionic compounds have formula unit.

Q.3 How can you differentiate between molecular formula and empirical formula? ***(U.B)***

Ans:

DIFFERENTIATION

The differences between empirical formula and molecular formula are as follows:

Empirical Formula	Molecular Formula
• Empirical formula is the simplest whole number ratio of atoms of different elements present in a compound.	• The formula that shows actual number of atoms of each element present in a molecule of that compound is called molecular formula.
• The Empirical formula of glucose ($C_6H_{12}O_6$) is CH_2O.	• The molecular formula of glucose is $C_6H_{12}O_6$.
• It is determined on the basis of percentage composition of a compound.	• It is derived from empirical formula by the following relationship. • Molecular formula = n × empirical formula.
• It can be written both for ionic and molecular compounds.	• It can only be written for molecular substances i.e. elements and compounds

Q.4 Identify the following formulae as formula unit or molecular formulae: ***(U.B)***

H_2O_2, CH_4, $C_6H_{12}O_6$, $C_{12}H_{22}O_{11}$, $BaCO_3$, KBr

Ans:

IDENTIFICATION OF FORMULAS

Molecular Formula	Formula Unit	Empirical Formula
H_2O_2	$BaCO_3$	$BaCO_3$
CH_4	KBr	KBr
$C_6H_{12}O_6$		CH_4
$C_{12}H_{22}O_{11}$		

Q.5 What is empirical formula of acetic acid (CH_3COOH)? Find out its molecular mass. ***(U.B+A.B)***

Ans:

EMPIRICAL FORMULA

Acetic acid ($C_2H_4O_2$) has simplest whole number ratio CH_2O. Thus empirical formula of acetic acid is CH_2O.

Molecular mass of acetic acid:

(CH_3COOH) = 1(12) + 3(1) +1(12) + 1(16) + 1(16) + 1(1)
= 12+3+12+16+16+1
= 60amu

Q.6 Calculate the formula masses of Na_2SO_4, $ZnSO_4$ and $CuCO_3$. ***(U.B+A.B)***

Ans:

FORMULA MASSES

Na_2SO_4 = 2(23) + 1(32) + 4(16)
= 46 + 32 + 64
= 142 amu

$ZnSO_4$ = 1(65) + 1(32) + 4(16)
= 65 + 32 + 64
= 161 amu

$CuCO_3$ = 1(63.5) + 1(12) + 3(16)
= 63.5 + 12 + 48
= 123.5 amu

MULTIPLE CHOICE QUESTIONS

1. The chemical formula of octane is: ***(K.B)***

(A) C_5H_{12} (B) C_3H_8
(C) C_2H_6 (D) C_8H_{18}

2. Formula which represents the actual number of atoms in one molecule of organic compound is: ***(U.B)***

(A) Structural formula (B) Condensed formula
(C) Dot and cross formula (D) Molecular formula

3. The molecular formula of pentane is: ***(K.B)***

(A) CH_4 (B) C_3H_3
(C) C_5H_{12} (D) C_4H_{10}

4.6 AVOGADRO'S NUMBER

LONG QUESTIONS

Q.1 Explain the Avogadro's number. **(RWP 2016)*(U.B+K.B)***

Ans:

AVOGADRO'S NUMBER

Introduction:

It is a huge number. It was suggested by an Italian scientist Amaedo Avogadro.

Definition:

*"The **number of particles in one mole of a substance** is called Avogadro's number."*

Representation and Numerical Value:

Avogadro's number is represented by symbol **'N_A'**. Its numerical value is **6.02×10^{23}**.

Significance

In a chemical reaction, large number of atoms or molecules of reactants react to give the products. We would very much like to know the weight ratio in which the reactants react. For this purpose, we would also like to express these weights of reactants in grams. To achieve this objective, we need to transform the concepts of chemical formula and atomic mass units into such concepts which may lead us to know the weights of reacting elements and compounds in grams. Avogadro, an Italian scientist, helped us to achieve this objective in the following way.

Relationship Between Avogadro's Number and Mole:

- Gram atomic mass of C = 12g = 1 mole of C = 6.02×10^{23} atoms of C
- Gram molecular mass of H_2O = 18g = 1 mole of H_2O = 6.02×10^{23} molecules of H_2O
- Gram formula mass of NaCl = 58.5g= 1mole of NaCl= 6.02×10^{23} formula units of NaCl

Explanation

Example: (Formation of CO and O_2)

Let us consider the following reaction in which two atoms of carbon react with a molecule of oxygen to produce two molecules of CO.

$$2C + O_2 \longrightarrow 2CO$$

Atom Molecule Molecules

Since it is not possible to account for the masses of individual atoms or molecules because these are very small particles, we increase the number of reacting species as written below.

$$O_2 \longrightarrow 2CO$$

2 x 100 atoms = 100 Molecules = 2 x 100 Molecules

2 x 10000 atoms = 10000 Molecules = 2 x 10000 Molecules

Increasing the number of reacting atoms or molecules will not change the ratio in which these are reacting or are being formed. .

Increasing the number of reacting species, however, has not solved the problem because this number is still very small. We should increase this number to such a value whereby it is convenient for us to calculate their masses.

$$2C + O_2 \longrightarrow 2CO$$

$2\times6.022\times10^{23}$ Atoms 6.022×10^{23} Molecules $2\times6.022\times10^{23}$ Molecules

$2 \times 6.022 \times 10^{23}$ is a huge number and we have selected this because

1 .00 g 6.022×10^{23} amu

AMOUNTS OF REACTANTS AND PRODUCTS

Now the amounts of reactants and products in the fore mentioned equation can be written as follows.

2400 g carbon atoms = $2 \times 6.022 \times 10^{23}$ (12.0 amu)

3200 g oxygen molecules = 6.022×10^{23} (16.0 amu)

2 x 28.00 g carbon monoxide molecules = $2 \times 6.022 \times 10^{23}$ (28 amu)

WEIGHT RATIO

The weight ratio between the reactants and those of products will then become

$$C + O_2 \longrightarrow 2CO$$

24g 32g 56g

You must have realized that starting from a simple equation we have developed such ratio of masses of the reacting species which can conveniently be used in the laboratory.

NUMBER OF PARTICLES

According to the above-mentioned equation,

24 g of carbon contains $2 \times 6.022 \times 10^{23}$ atoms of carbon

32 g of oxygen contains 6.02×10^{23} molecules of oxygen

56 g of carbon monoxide contains $2 \times 6.022 \times 10^{2}$ of its molecules.

CONCLUSION

- The number 6.022×10^{23} is called Avogadro's number after the name of Amaedo Avogadro who discovered it.
- This number is represented as N_A.

INTERESTING INFORMATION

IMPORTANCE OF MOLE

Mole is important because atoms and molecules are so small. The mole concept allow us to count atoms and molecules by weighing macroscopically small amounts of matter.

SHORT QUESTIONS

Q.1 Which term is used to represent the mass of 1 mole of molecules of a substance? ***(U.B)***

Ans: **ONE MOLE OF MOLECULE**

Gram molecular mass or gram molecule is used to represent the mass of 1 mole of molecules of a substance.

Example:

Mass of 1 mole of molecule of water is gram molecular mass i.e. 18 g.

Q.2 How many atoms are present in one gram atomic mass of a substance?

Ans: **NUMBER OF ATOMS**

One gram atomic mass of a substance is expressed in grams. It is equivalent to1 mole of an element. Thus it consists of Avogadro's number (6.02×10^{23}) of atoms.

MULTIPLE CHOICE QUESTIONS

1. The number of particles in one mole of a substance is called: ***(K.B+U.B)***

(A) Atomic number (B) Particle number (C) Avogadro's number(D) Mass number

2. **Total number of ions in one mole of NaCl is:** ***(U.B)***
(A) 12.04×10^{23} ions (B) 1.204×10^{23} ions (C) 6.04×10^{23} ions (D) 61.04×10^{23} ions

3. **The symbol of Avogadro's number is:** **(GRW 2017 G-I)*(K.B)***
(A) N_A (B) A_n (C) N_x (D) N_y

4.7 THE MOLE AND MOLAR MASS

LONG QUESTIONS

Q.1 **Define mole and what is the relationship between mole and substance?** ***(U.B+K.B)***

OR

Define and explain Mole as SI unit for the amount of a substance.

Ans:

MOLE (CHEMIST SECRET UNIT)

Definition:

The quantity of a substance containing Avogadro's number of particles (N_A) is called a Mole.

Quantitative Definition:

*"The **atomic mass, molecular mass, formula mass or ionic mass of a substance expressed in grams** is called a mole".*

Symbol:

It is abbreviated as **"mol"** when it is used as a unit.
Avogadro's number has an immense significance in Chemistry

Explanation

Mole is a number like a dozen or a gross. A dozen of oranges means 12 oranges. Similarly, a mole of a substance means its 6.022×10^{23} particles. When we use the term mole of a substance, we must also refer to what type of particles are present in this substance.

Example

- The following examples will help you to understand the concept clearly shows relationship Between Avogadro's Number and Mole.
- Gram atomic mass of C = 12g = 1 mole of C = 6.02×10^{23} atoms of C
- Gram molecular mass of O_2 = 32g = 1 mole of O_2 = 6.02×10^{23} molecules of O_2
- Gram formula mass of NaCl = 58.5g = 1mole of NaCl= 6.02×10^{23} formula units of NaCl.

MOLAR MASS

The mass of one mole of a substance is called Molar mass.

Example

The molar mass of hydrogen atoms refers to the mass of one mole of hydrogen atoms and its value is 1.008 g.

Similarly, the molar mass of hydrogen molecules will be 2.016 g.

Relationship Between Mole and Mass:

$$\text{Number of moles} = \frac{\text{Known mass of substance}}{\text{Molar mass of substance}}$$

Mass of substance (g) = Number of moles × molar mass

Relation between mole and Avagadro's number

The chemical equation discussed in the previous article will now be understood in the following way.

$$\text{Number of moles} = \frac{\text{Number of Particles of substance}}{\text{Avogadro's Number}}$$

$$\text{Number of Particles} = \text{Number of Mole} \times \text{Avogadro's Number}$$

$2C$	+	O_2	⟶	$2CO$
Two atoms		One molecule		Two molecules
Two moles of C		One mole of O_2		Two moles of CO
$2\times6.022\times10^{23}$ atoms		6.022×10^{23} molecules		$2\times6.022\times10^{23}$ molecules
Two moles		One mole		Two moles
24 g		32 g		56 g

EXERCISE

Q. Calculate the molar mass of the following compounds:
H_3PO_4, SiO_2, $C_{12}H_{22}O_{11}$, N_2O_4, $MgCO_3$
Ans:
Molar mass of H_2SO_4 = 2(1)+1(32)+4(16)
= 2 + 32 + 64
= 98 g/mol
Molar mass of SiO_2 = 1(28) 2(32)
= 28 + 64
= 92 g/mol
Molar mass of **$C_{12}H_{22}O_{11}$** = 12(12)+22(1)+16(11)
= 144 + 22 + 176
= 342g / mol
Molar mass of N_2O_4 = 2(14) + 4(16)
= 28 + 64
= 92 g/mol
Molar mass of $MgCO_3$ = (28)+(64)+(16×3)
= 24 + 12 + 48
= 84 g/mol
=84 g/mol

SAMPLE PROBLEM

Q. Determine molar masses of the following compounds in $gmol^{-1}$.
(a) H_2SO_4 (Sulphuric acid)
(b) $C_{10}H_8$ (Naphthalene)
Solution
(a) H_2SO_4
Atomic mass of H = 1
Atomic mass of S = 32
Atomic mass of O = 16
Add the contribution of each atom
(32) +4(16) = 98 g mol^{-1}
(b) $C_6H_{12}O_6$
Atomic mass of C= 12
Atomic mass of H = 1
Atomic mass of O = 16
Add the contribution of each atom
6(12) + 12(1) + 6(16) = 180 g mol^{-1}

SHORT QUESTIONS

Q.1 Explain the relationship between mass and mole of a substance. *(U.B)*

Ans:

RELATIONSHIP BETWEEN MASS AND MOLE OF A SUBSTANCE

$$\text{Number of moles} = \frac{\text{Given mass of a substance}}{\text{Molar mass of a substance}}$$

Mass of a substance = Number of moles x Molar mass of a substance

Q.2 Find out the mass of 3 moles of oxygen atoms: *(U.B+A.B)*

Ans:

NUMERICAL

Solution:

Given data:

Number of moles of O-atoms = 3mol

To Find:

Mass of 3 moles of O-atoms = ?

Calculations:

Mass of oxygen = Number of moles × molar mass of oxygen O-atom

$= 3 \text{ mole} \times 16\text{g mol}^{-1}$

$= 48\text{g}$

Result:

Thus mass of 3 moles of oxygen is 48 g.

Q.3 How many molecules of water will be present in half mole of water? *(U.B+A.B)*

Ans:

NUMERICAL

Solution:

Given Data:

Number of moles of water $= \frac{1}{2}$ mole

To Find:

Number of water molecules = ?

Calculations:

Number of water molecules = No of moles × N_A

$= \frac{1}{2} \text{ mole} \times 6.02\times10^{23}$

$= 3.01 \times 10^{23}$ molecules

Result:

3.01×10^{23} molecules are present in half mole of water.

MULTIPLE CHOICE QUESTIONS

1. The mass of one molecule of water is: **(LHR 2016, 17 G-I,II, DGK 2016 G-I, G-II)** *(K.B)*

(A) 18 amu (B) 18 g (C) 18 mg (D) 18 kg

2. The molar mass of H_2SO_4 is: **(LHR 2017 G-I, GRW 2016 G-I, MTN 2016 G-I)** *(U.B+K.B)*

(A) 98 g (B) 48 amu (C) 4.8 g (D) 98 amu

3. Molar mass is usually expressed in grams, which one of the following is molar mass of O_2 in

amu? *(U.B)*

(A) 32 amu (B) 53. 2 × 10^{-24} amu
(C) 1.92 ×10^{-25} amu (D) 192.64 × 10^{-25} amu

4. How many numbers of moles are equivalent to 8 grams of CO_2? **(BWP 2017 G-I, DGK 2016 G-I)** *(U.B)*

(A) 0.15 (B) 0.18 (C) 0.21 (D) 0.24

5. Which one of the following pairs has the same number of ions? **(LHR 2016 G-I)** *(U.B)*

(A) 1 mole of NaCl and 1 mole of $MgCl_2$
(B) 1/2 mole of NaCl and 1/2 mole of $MgCl_2$
(C) 1/2 mole of NaCl and 1/3 mole of $MgCl_2$
(D) 1/3 mole of NaCl and 1/2 mole of $MgCl_2$

6. Which one of the following pairs has the same mass? **(SWL 2017 G-I)** *(U.B)*

(A) 1 mole of CO and 1 mole of N_2 (B) 1 mole of CO and 1 mole of CO_2
(C) 1 mole of O_2 and 1 mole of N_2 (D) 1 mole of O_2 and 1 mole of CO_2

7. The mass of 1.2 moles of H_2SO_4 is: *(U.B)*

(A) 98g (B) 196g (C) 117.6g (D) 125g

8. There are 3.01×10^{23} molecules of CO_2 present in a container. What is the number of moles in it? *(U.B)*

(A) 22 mol (B) 0.5 mol
(C) 1.7 mol (D) 2.2 mol

9. 9 g of carbon has number of moles: *(U.B)*

(A) 0.75 mol (B) 9 mol
(C) 0.5 mol (D) 3 mol

4.8 CHEMICAL EQUATIONS AND CHEMICAL REACTIONS

LONG QUESTIONS

Q.1 Define chemical equation. Explain its significance and method to write the chemical equation. *(U.B)*

Ans:

CHEMICAL EQUATIONS

Definition

Representing a chemical change in term of symbol and formulas is called a chemical equation.

Example

$$2C + O_2 \longrightarrow 2CO$$

Need of Chemical Equation

To understand a chemical change and to study the different factors which control it, has always been a focal point in the efforts of chemists. To achieve these objectives, we should have an appropriate way of representing a chemical change.

Significance

- Fortunately, the chemists have developed a very suitable way of representing a chemical change in terms of symbols of elements and formulas of compounds.
- A chemical equation tells us the elements or compounds which are reacting and those which are being produced as a result of a chemical change.

Reactants

The reacting substances are called as reactants

Products

Those being produced are called products.

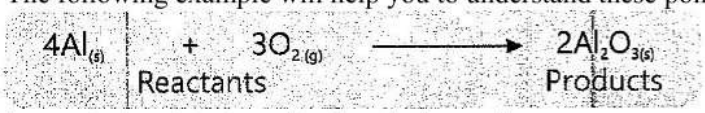
(A) Chemical equation for the irreversible reaction

Method

(i) It is customary to write the reactants on the left-hand side.
(ii) The products on the right-hand side.
(iii) An arrow head drawn from reactants to products separates the reactants and products.

Example

The following example will help you to understand these points clearly.



Important points to write chemical equation

The following points must be kept in mind while writing a chemical equation.

Law of conservation of mass

A chemical equation must obey the law of conservation of mass.

This means that no atom should be destroyed or produced during a chemical change. The total number and the type of atoms must remain the same during a chemical change.

1. **Formulas of elements and compounds**

The formulas of elements and compounds must be written correctly.

2. **Correct mole ratio among the reactants, the products**

A chemical equation must determine the correct mole ratio among the reactants, the products and between the reactants and the products.

3. **Direction**

A chemical equation must also point out the direction in which the change is proceeding.

4. **Physical states of reactants and products**

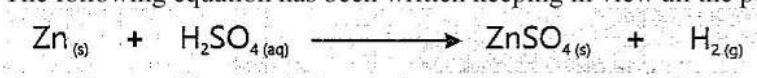
It is a usual practice to show the normal physical states of reactants and products. Solid, liquid and gas are symbolized as s, l and g respectively. Aqueous (aq) represents the solvated ion.

Why we become able to write a chemical reaction?

A chemical equation can, however, only be written if all the previous mentioned points are experimentally verified. For example, the nature of the products and their correct formulas must first be ascertained before writing a chemical equation. After the experimental verification of all the information about a chemical change, we should now be able to write a correct chemical equation.

Example: (Reaction of zinc with sulphuric acid to form zinc sulphate and hydrogen gas)

The following equation has been written keeping in view all the points mentioned above.



According to this chemical equation, zinc reacts with sulphuric acid to give zinc sulphate and hydrogen gas.

Information from chemical reaction

- This chemical equation further tells us the mole ratio not only between reactants or products but also between reactants and products.
- According to the equation, one mole of zinc reacts with one mole of sulphuric acid to produce one mole of zinc sulphate and one mole of hydrogen gas.

(B) Chemical equation for reversible reaction

Sometimes a chemical reaction moves both ways. In other words, the reactants react to give the products and the products, in turn, react to give the reactants back. Such reactions are called as reversible reactions

Representation

They are indicated by (⇌) sign, e.g.:

$$N_{2(s)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

(C) Chemical equation for reaction involving ions

Reaction involving ions may also be shown in the form of chemical equation. Both $AgNO_3$ and NaCl are ionic compounds and are soluble in water. When they are mixed in water, they react to form products.

$$AgNO_{3(aq)} + NaCl_{(aq)} \longrightarrow AgCl_{(s)} + Na^{+}_{(aq)} + NO_3^{-}_{(aq)}$$

AgCI being insoluble comes out of the aqueous solution.

SHORT QUESTIONS

Q.1 What are chemical reactions? *(Knowledge Base)*

Ans:

CHEMICAL REACTION

Definition:

"The process in which chemical change occurs in nature and composition of substances is called chemical reaction".

Examples:

- Rusting of iron
- $2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)}$

Q.2 Differentiate between reactants and products. *(Understanding Base)* (MTN 2016 G-I, FSD 2016 G-II)

Ans:

DIFFERENTIATION

The differences between reactants and products are as follows:

Reactants	Products
Definition	
• In a chemical reaction the substances that combine are called reactants.	• The new substances formed during a chemical reaction are called products.
Example	
• In a reaction $2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(l)}$ H_2 and O_2 are reactants.	• In a reaction $2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(l)}$ H_2O is product.

MULTIPE CHOICE QUESTIONS

1. In chemical reactions the substances that combine are called: *(K.B)* (FSD 2017 G-I)

(A) Products (B) Reaction intermediates
(C) Reactants (D) Both A and C

2. Name the reactants in the equation, $2H_{2(q)} + O_{2(g)} \xrightarrow[\text{Heat}]{\text{Pt}} 2H_2O_{(l)}$ *(K.B)*

(A) Water (B) Hydrogen and oxygen
(C) Oxygen (D) None of these

3. Name the products in the equation, $2H_{2(q)} + O_{2(g)} \xrightarrow[\text{Heat}]{\text{Pt}} 2H_2O_{(l)}$ *(K.B)*

(A) Water (B) Hydrogen and oxygen
(C) Oxygen (D) None of these

4.9 CALCULATIONS BASED ON CHEMICAL EQUATION

LONG QUESTION

Q.1 Describe the calculations based on chemical equation. *(U.B)*

Ans:

CALCULATIONS BASED ON CHEMICA EQUATION

Following calculations can be made, using chemical equation:

A complete and balanced chemical equation tells us the mole ratio or molar mass ratio between the reactants and the products.

i. Determination of Molar Mass of Products

With the help of this ratio, we can find out the molar masses of the products provided we know the molar masses of the reactants.

ii. Determination of Molar Mass of Reactants

Similarly the molar masses of the reactants can also be found out if we know the molar masses of the products.

Example

The following equation tells us that one mole (100 g) of calcium carbonate reacts with two moles (73 g) of hydrochloric acid to produce one mole (1 1 1 g) of CaClz, one mole (18 g) of water and one mole (44 g) of carbon dioxide.

oxide.

$$\underset{\text{1 mole}\ 100\ g}{CaCO_{3(s)}} + \underset{\text{2 moles}\ 73\ g}{2HCl_{(aq)}} \longrightarrow \underset{\text{1 mole}\ 111\ g}{CaCl_{2(aq)}} + \underset{\text{1 mole}\ 18\ g}{H_2O_{(l)}} + \underset{\text{1 mole}\ 44\ g}{CO_{2(g)}}$$

The total masses of the reactants are equal to the total masses of the products.

EXAMPLE 1

25g of limestone ($CaCO_3$) reacts with an excess of hydrochloric acid according to the above equation. How much calcium chloride ($CaCl_2$) will be produced?

Solution

mass of$CaCO_3$ = 100 g mol^{-1}

Mass of $CaCl_2$ product =?

Mass of$CaCO_3$ = 25

Molar mass of $CaCl_2$ = 111g mol^{-1}

According to the equation

100 g of limestone react to produce calcium chloride = 111 g

1g of limestone will react to produce calcium chloride $= \frac{111}{100}$ g

25 g of limestone react to produce calcium chloride $= \frac{111}{100}$ g $\times$ 25

$=$ 27.75g

EXAMPLE 2

1.80 moles of ethyl alcohol, when burnt in air completely will utilize how many moles of oxygen gas? Also calculate the number of moles of CO_2 produced.

Solution

No. of moles of ethyl alcohol = 1.80

No. of moles of oxygen needed =?

The balanced chemical equation for the reaction will be

$$C_2H_5OH_{(l)} + 3O_{2(g)} \longrightarrow 2CO_{2(g)} + 3H_2O_{(l)}$$

According to this equation

One mole of ethyl alcohol, when completely burnt, needs oxygen = 3 moles

1.8 moles of ethyl alcohol upon burning, will need oxygen $= \frac{3}{1} \times 1.8$

$= 5.4$ moles

1 mole of ethyl alcohol produces moles of $C0_2$	= 2.0
1.8 mot of ethyl alcohol will produce	$= \frac{3}{1} \times 1.8$
	= 36 mole

EXAMPLE 3

Q. Aluminium metal reacts with oxygen to produce aluminium oxide. How many grams of oxygen will be required to react completely with 0.3 moles of aluminium?

Solution

Moles of Al = 3.0

Grams of O_2 used =?

The balanced chemical equation for the reaction:

$$4Al_{(s)} + 3O_{2(g)} \longrightarrow 2Al_2O_{3(s)}$$

According to this equation

4 rnoles of aluminium need oxygen	= 3.0 moles
1.0 mole of aluminium will need oxygen	$= \frac{3}{4}$
0.3 moles of aluminium will need oxygen	$= \frac{3}{4}$ x 0.3
	= 0.225 moles
1 mole of oxygen (0_2) has molar mass	= 32g
0.225 mole of oxygen (02) will have molar mass	= 32 x 0.225
	= 7.2 g

EXAMPLE 4

Q. How many molecules of water will be produced if we react 5 g of hydrogen gas with excess of oxygen gas?

Solution

Mass of hydrogen gas = 5 g

To Find

Molecules of water produced = ?

The balanced chemical equation for the reaction:

$$H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(l)}$$

According to this equation

4 g of hydrogen produce $2H_2O_{(l)}$	= 36 g H_2O
5 g of hydrogen produce $2H_2O_{(l)}$	$= \frac{36}{4}$ x 5 = 45 g of H_2O
18 g (1 mole) of H_2O contains molecules	= 6.02×10^{23}
18 g (2 moles) of H_2O contains molecules	= $6.02 \times 10^{23} \times 2$
	= 12.04×10^{23}
45 g of H2O contains	$= \frac{45}{36} \times 12.04 \times 10^{23}$
	= 1.505×10^{23} molecules

SHORT QUESTIONS

Q.1 How many atoms of sodium are present in 3 moles of sodium and what is the mass of it? ***(U.B+A.B)***

NUMERICAL

Solution:

Given Data:

Number of moles of sodium = 3 mol

To Find:

(i) Number of atoms of sodium in 3 moles = ?

(ii) Mass of 3 moles of sodium = ?

Calculations:

(i) Number of atoms present in 1 mole of sodium $= 6.02\times10^{23}$ atoms

Number of atoms present in 3 moles of sodium $= 3\times6.02\times10^{23}$ atoms

$= 18.06\times10^{23}$ atoms

$= 1.806\times10^{24}$ atoms

(ii) Mass of substance = Number of moles of Na × molar mass of Na

$= 3\text{mol} \times 23\text{gmol}^{-1}$

$= 69$ g

Result:

1.806×10^{24} atoms are present in three moles of sodium and its mass is 69g.

Q.2 How many atoms are in 1 amu and 1 g of hydrogen (H)? *(U.B+A.B)*

NUMERICAL

Solution:

Given Data:

Atomic mass of hydrogen = 1 amu

Molar mass of hydrogen = 1g

To Find:

Number of atoms in 1 amu and 1 g of hydrogen =?

Calculations:

Atomic mass of hydrogen = Molar mass of hydrogen

Number of atoms in 1g of hydrogen $= \dfrac{\text{Given mass}}{\text{Molar mass}} \times N_A$

$= \dfrac{1\text{g}}{1\text{g}} \times 6.02\times10^{23}$

$= 6.02\times10^{23}$ atoms

Number of atoms in 1 amu of hydrogen = 6.02×10^{23} atoms

Result:

6.02×10^{23} atoms are present in 1 amu and 1g of hydrogen.

Q.3 How many atoms are present in 16 g of O and 8g of S? *(U.B+A.B)*

NUMERICAL

Solution:

Given Data:

Mass of Oxygen atom O = 16 g

Molar mass of Oxygen O = 16 g

Given mass of sulphur S = 8g

Molar mass of sulphur S = 32g

To Find:

Number of atoms in 16g of O = ?

Number of atoms in 8g of sulphur S = ?

Calculations:

$$\text{Number of atoms of Oxygen} = \frac{\text{Given mass}}{\text{Molar mass}} \times N_A$$

$$= \frac{16g}{16g} \times 6.02 \times 10^{23}$$

$$= 6.02 \times 10^{23} \text{ atoms}$$

Calculations:

$$\text{Number of atoms of sulphur, S} = \frac{\text{Given mass}}{\text{Molar mass}} \times N_A$$

$$= \frac{8g}{32gmol^{-1}} \times 6.02 \times 10^{23}$$

$$= 1.505 \times 10^{23} \text{ atoms}$$

Result:

6.02×10^{23} atoms are present in 16g of oxygen and 1.505×10^{23} atoms are present in 8g of sulphur.

Q.4 Is the mass of 1 mole of O and 1 mole of S same? *(U.B)*

Ans: As Mass of 1 mole of O = 16g
Mass of 1 mole of S = 32g
Hence, the mass of 1 mole of O and 1 mole of S is not the same.

Q.5 What do you mean by 1 atom of C and 1 gram atom of C? *(U.B)*

Ans:

ONE ATOM AND ONE GRAM ATOM OF C

1 atom of carbon means single smallest particle of carbon with mass 12 amu.
On the other hand, 1 gram atom means 12 g or 1 mole of carbon having 6.02×10^{23} carbon

Q.6 If 16g of oxygen contains 1 mole of oxygen atoms calculate the mass of one atom of oxygen in grams. *(U.B+A.B)*

NUMERICAL

Solution:
Given Data:
16 g of oxygen = 1 mole of oxygen atoms
To Find:
Mass of 1 atom of oxygen in grams = ?
Calculations:
16g of oxygen = 1 mole of oxygen = 6.02 □ 10^{23} atoms
Therefore, mass of 6.02×10^{23} atoms of oxygen = 16g

$$\text{Mass of 1 atom of oxygen} = \frac{16}{6.02\times10^{23}}$$

$$= 2.65\times10^{-23} \text{ g}$$

Q.7 How many times is 1 mole of oxygen atoms heavier than 1 mole of hydrogen atoms? *(U.B)*

Ans:

OXYGEN AND HYDROGEN

Mass of 1 mole of oxygen atoms = 16g
Mass of 1 mole of hydrogen atoms = 1g
Therefore, 1 mole of oxygen atoms is 16 times heavier than that of 1 mole of hydrogen atoms.

Q.8 Why does 10 g nitrogen gas contain the same number of molecules as 10 g of carbon monoxide? *(U.B+A.B)*

Ans: $\text{Number of moles of nitrogen gas} = \frac{\text{Given mass of substance}}{\text{Molar mass of substance}}$

$= \frac{10}{28}$

$= 0.35$ mol

Number of molecules of nitrogen gas (N_2) = number of mole □ N_A

$= 0.35$ □ 6.02 □ 10^{23}

$= 2.107 \times 10^{23}$ molecules

Number of moles of carbon monoxide = $\frac{\text{Given mass of substance}}{\text{Molar mass of substance}}$

$= \frac{10}{28}$

$= 0.35$ mol

Number of molecules of CO = number of mole □ N_A

$= 0.35$ □ 6.02 □ 10^{23}

$= 2.107$ □ 10^{23} molecules

Hence it is proved that 10g nitrogen gas contains the same number of molecules as 10g of carbon monoxide because both gases have same molar mass that is i.e. 28g.

MULTIPLE CHOICE QUESTION

1. **The mass of 1 moles of H_2SO_4 is:** ***(U.B)***

(A) 98g (B) 196g (C) 117.6g (D) 125g

2. **Which one of the following pairs has the same mass?** ***(U.B)***

(A) 1 mole of H_3PO_4 and 1 mole of H_2SO_4 (B) 1 mole of CO and 1 mole of CO_2

(C) 1 mole of O_2 and 1 mole of N_2 (D) 1 mole of O_2 and 1 mole if CO_2

3. **There are 6.02×10^{23} molecules of CO_2 present in a container. What is the number of moles in it?** ***(U.B)***

(A) 22 mol (B) 0.5 mol (C) 1 mol (D) 2.2 mol

4. **12 g of carbon has number of moles:** ***(U.B)***

(A) 0.75 mol (B) 9 mol (C) 0.5 mol (D) 1 mol

ANSWER KEY

MULTIPLE CHOICE QUESTIONS

INTRODUCTION

1	B	**2**	B

4.1 CHEMICAL FORMULA

1	B	**2**	B	**3**	D	**4**	B

4.2 EMPIRICAL FORMULA

1	B	**2**	B	**3**	B	4	D	5	B
6	D	**7**	C	**8**	B	9	C	10	A

4.3 CHEMICAL FORMULA OF BINARY IONIC COMPOUNDS

1	C	**2**	A	**3**	A	**4**	A	5	C	6	C

4.4. CHEMICAL FORMULA OF COMPOUNDS

1	D	2	A	3	B	4	B	5	C

4.5 DEDUCE THE MOLECULAR FORMULA FROM THE STRUCTURAL FORMULA

1	D	2	D	3	C		

4.6 AVOGADRO'S NUMBER

1	C	2	A	3	A

4.7 THE MOLE AND MOLAR MASS

1	A	2	A	3	A	4	B	5	C
6	A	7	C	8	B	9	A		

4.8 CHEMICAL EQUATIONS AND CHEMICAL REACTIONS

1	C	2	B	3	A

4.9 CALCULATIONS BASED ON CHEMICAL EQUATION

1	A	6	A	11	C	16	D

EXERCISE SOLUTION

MULTIPLE CHOICE

1. Tick the correct answer.

1. How many atoms are present in one gram of 1-120?

(A) 1.002×10^{23} atoms (B) 6.022×10^{23} atoms

(C) 0.334×10^{23} atoms (D) 2.004×10^{23} atoms

2. Which is the correct formula of calcium phosphide?

(A) CaP (B) CaP_2

(C) Ca_2P_3 (D) Ca_3P_2

3. How many atomic mass units (amu) are there in one gram?

(A) 1 amu (B) 10^{23} amu

(C) 6.022×10^{23} amu (D) 6.022×10^{22} amu

4. Structural formula of 2-hexene is $CH_3 — CH = CH — (CH_2)_2 - CH_3$. What will be

its empirical formula?

(A) C_2H_2 (B) CH

(C) C_6H_{12} (D) CH_2

5. How many moles are there in 25 g of H_2SO_4?

(A) 0.765 moles (B) 0.51 moles

(C) 0.255 moles (D) 0.4 moles

6. A necklace has 6g of diamonds in it. What are the number of carbon atoms in it?

(A) 6.02x 10 23 (B) 12.04 x 10 23

(C) 1.003 x 10 23 (D) 3.01 x 10 23

7. What is the mass of Al in 204g of aluminium oxide, Al_2O_3.

(A) 26g (B) 27g

(C) 54g (D) 108g

8. Which one of the following compounds will have the highest percentage of the mass

of nitrogen?

(A) $CO(NH_2)_2$ (B) N_2H_4

(C) NH_3 (D) NH_2OH

9. When one mole of each of the following compounds is reacted with oxygen which

will produce the maximum amount of CO_2?

(A)Carbon (B) Diamond

(C) Ethane (D) Methane

10. What mass of 95% $CaCO_3$ will be required to neutralize 50 cm^3 of 0.5M HCl

solution?

(A) 9.5g (B) 1.25g

(C) 1.32g (D) 1.45g

ANSWER KEY

1	A	**2**	D	**3**	C	**4**	D	**5**	C
6	D	**7**	D	**8**	B	**9**	C	10	C

QUESTIONS FOR SHORT ANSWERS

2. Questions for Short Answers

Q.1 Write down the chemical formula of barium nitride.

Ans: CHEMICAL FORMULA OF BARIUM NITRIDE

$Ba^{2+}\ N^{3-}$

$Ba_3\ N_2$

Q.2 Find out the molecular formula of a compound whose empirical formula is CH_2O and its molar mass is 180.

Ans: **NUMERICAL**

Given Data:
Empirical Formula of compound: CH_2O
Molar mass of compound : 180
To Find:
Molecular Formula = ?
Calculation:
Molecular formula = n (Empirical formula)
n = molar mass/empirical formula mass
$= \frac{180}{30} = 6$
Molecular Formula = $(CH_2O)_6 = C_6H_{12}O_6$
Result:
Thus, molecular formula of compound is $C_6H_{12}O_6$

Q.3 How many molecules are present in 1.5 g H_2O?

Ans:: **NUMERICAL**

Given Data:
Mass of H_2O = 1.5 g
To Find:?
Number of molecules = ?
Calculation:
Number of moles = $\frac{1.5}{18} = 0.0833$ moles
Number of molecules = Number of moles x N_A
$= 3 \times 0.0833 \times 6.02 \times 10^{23}$
$= 1.504398 \times 10^{23}$ molecules
Result:
Thus number of molecules of water is 1.504398×10^{23} molecules

Q.4 What is the difference between a mole and Avogadro's number?

Ans: **DIFFERENTIATION**

The differences between mole and **Avogadro's number** are as follows:

Mole	Avogadro's number
Definition	
The quantity of a substance containing Avogadro's number of particles (N_A) is called a Mole.	• The number of particles in one mole of a substance is called Avogadro's number.
Symbol	
• It is abbreviated as **"mol"** when it is used as a unit	• It is represented by N_A. yu • Its value is 6.02×10^{23}

Q.5 Write down the chemical equation of the following reaction.

Copper + Sulphuric acid ⟶ Copper sulphate + Sulphur dioxide + Water

Ans: **CHEMICAL EQUATION**

Copper + Sulphuric acid ⟶ Copper sulphate + Sulphur dioxide + Water

$$Cu + H_2SO_4 \longrightarrow CuSO_4 + H_2$$

CONSTRUCTED RESPONSE QUESTIONS

3. **Constructed Response Questions.**

Q.1 Different compounds will never have the same moleculer formula but they can have the same empirical formula. Explain

MOLECULER & EMPIRICAL FORMULA OF COMPOUNDS

Different compounds will never have the same moleculer formul because each compound has unique type of atoms in a fixed ratio by mass. They can have the same empirical formula because ratio between atoms of different compounds can be the same.

Q.2 Write down the chemical formulas of the following compounds.

Calcium phosphate, Aluminium nitride, Sodium acetate, Ammonium carbonate and Bismuth sulphate

Ans: **CHEMICAL FORMULAS OF COMPOUNDS**

Compound	Chemical Formula	Compound	Chemical Formula
Calcium phosphate	$Ca_3(PO_4)_2$	Ammonium carbonate	$(NH_4)_2CO_3$
Aluminium nitride	AlN	Bismuth sulphate	$BiSO_4$
Sodium acetate	CH_3COONa		

Q.3 Why does Avogadro's number have an immense importance in chemistry?

Ans: **IMPORTANCE OF AVOGADRO'S NUMBER**

In chemistry we deal with substances which are composed of atoms, molecules or formula units. The counting of these particles is not possible for the chemists. The concept of Avogadro's number facilitated the counting of particles contained in the given mass of a substance.

Q.4 When 8.657g of a compound were converted into elements, it gave 5.217g of carbon, 0.962g of hydrogen and 2.478g of oxygen. Calculate the percentage of each element present in this compound.

Ans: **NUMERICAL**

Given Data:

Mass of compound = 8.657 g
Mass of carbon = 5.127 g
Mass of hydrogen = 0.962 g
Mass of oxygen = 2.478 g

To Find:

Percentage of each element in the compound = ?

Calculation:

Percentage of carbon $= \frac{5.127}{8.657} \times 100 = 59.22\ \%$

Percentage of hydrogen $= \frac{0.962}{8.657} \times 100 = 11.11\ \%$

Percentage of oxygen $= \frac{2.478}{8.657} \times 100 = 28.62\ \%$

Result:

Thus percentage of carbon, hydrogen and oxygen is 59.22 %, 11.11 % and 28.62 %.

Q.5 How can you calculate the mass of the products formed in a reversible reaction?

Ans: **CALCULATION OF MASS OF PRODUCTS**

We can you calculate the mass of the products formed in a reversible reaction by multiplying the number of moles of products formed with the molar mass of the product.

DESCRIPTIVE QUESTIONS

4. Descriptive Questions

Q.1 Which conditions must be fulfilled before writing a chemical equation for a reaction?

Ans: Answer given on page #

Q.2 Explain the concepts of Avogadro's numbers and mole.

Ans: Answer given on page #

Q.3 How many grams of CO_2 will be produced when we react 10 g of CH_4 with excess of O_2 according to the following equation?

$$CH_4 + 2O_{2(g)} \longrightarrow CO_2 + 2H_2O$$

Ans: **NUMERICAL**

Given Data:

Mass of CH_4 = 10 g

To Find:

Mass of CO_2 = ? g

Calculation:

Number of moles of CH_4 produced = $\frac{Mass}{Molar\ mass} = \frac{10}{16}$ = 0.625 mole

According to the given equation:

1 mole of CH_4 produces moles of CO_2 = 1 mole

0.625 mole of CH_4 produces moles of CO_2 = 0.625 mole

Mass of CO_2 produced = Number of moles of CO_2 × Molar mass

= 0.625 × 44

= 27.5 g

Result:

Thus mass of CO_2 produced **is 27.5 g.**

Q.4 How many moles of coal are needed to produce 10 moles of CO according to the following equation?

$$3C(s) + O_{2(g)} + H_2O \longrightarrow H_2 + 3CO$$

Ans: **NUMERICAL**

Given Data:

Number of moles of CO = 10 moles

To Find:

Number of moles of coal (C) = ?

Calculation:

According to the given equation:

3 moles of CO needs number of moles of coal (C) = 3 moles

1 mole of CO needs number of moles of coal (C) = 1 mole

10 moles of CO needs number of moles of coal (C) = 10 moles

Result:

Thus 10 moles of CO needs number of moles of coal (C) = 10 moles

Q.5 How much SO_2 is needed in grams to produce 10 moles of sulphur?

$$2H_2S + SO_2 \longrightarrow 2H_2O_{(l)} + 3S_{(S)}$$

Ans: **NUMERICAL**

Given Data:
Number of moles of sulphur = 10 moles
To Find:
Mass of SO_2 = ? g
Calculation:
Number of moles of SO_2 produced = 10 moles
According to the given equation:
3 moles of S needs number of moles of SO_2 = 1 mole
1 mole of S needs number of moles of $SO_2 = \frac{1}{3}$ mole
10 moles of S needs number of moles of $SO_2 = \frac{1}{3} \times 10 = 3.33$ moles
Mass of SO_2 needed = Number of moles of SO_2 × Molar mass
$= 3.33 \times 64$
$= 213.12$ g
Result:
Thus mass of SO_2 needed **is 213.12 g.**

Q.6 How much ammonia is needed in grams to produce 1 kg of urea fertilizer?

$$2NH_3 + CO_2\,(aq) \longrightarrow CO(NH_2)_{2\,(aq)} + H_2O$$

Ans: **NUMERICAL**

Given Data:
Mass of urea to be produced = 1 Kg = 1000 g
To Find:
Mass of ammonia needed = ? g
Calculation:
Number of moles of urea to be produced $= \frac{Mass}{Molar\ mass} = \frac{1000}{60} = 16.66$ mole
According to the given equation:
1 mole of urea needs number of moles of NH_3 = 2 moles
16.66 moles of urea needs, number of moles of $NH_3 = 2 \times 16.66$ moles
$= 33.32$ moles
Mass of NH_3 needed = Number of moles of NH_3 × Molar mass
$= 33.32 \times 17$
$= 566.44$ g
Result:
Thus mass of NH_3 needed **is 566.44 g.**

Q.7 Calculate the number of atoms in the following.
(a) 3g of H_2
(b) 3.4 moles of N_2
(c) 10g of $C_6H_{12}O_6$

Ans: (a) **NUMERICAL**

Given Data:
Mass of H_2 = 3 g
To Find:
Number of atoms in 3 g of H_2 = ?
Calculation:

Number of atoms in 3 g of H_2 = $\frac{Mass}{Molar\ mass}$ × N_A × Number of atoms in 1 molecule of H_2

$= \frac{3}{2} \times 6.02 \times 10^{23} \times 2$

$= 1.5 \times 6.02 \times 10^{23} \times 2$

$= \mathbf{18.06} \times 10^{23}$ atoms

Result

Thus number of atoms in 3 g of H_2 **is 8.06** × 10^{23} atoms.

(b) **NUMERICAL**

Given Data:

Number of moles of N_2 = 3.4 moles

To Find:

Number of atoms of N_2 = ?

Calculation:

Number of atoms of N_2 = Number of moles × N_A × Number of atoms in 1 molecule of N_2

$= \mathbf{3.4} \times 6.02 \times 10^{23} \times 2$

$= \mathbf{40.936} \times 10^{23}$ atoms

Result

Thus number of atoms in 3.4 moles of N_2 **is 40.936** × 10^{23} atoms.

(c) **NUMERICAL**

Given Data:

Mass of **of $C_6H_{12}O_6$** = 10 g

To Find:

Number of atoms in 10 g of **$C_6H_{12}O_6$** = ?

Calculation:

Number of atoms = $\frac{Mass}{Molar\ mass}$ × N_A × Number of atoms in 1 molecule of **$C_6H_{12}O_6$**

$= \frac{10}{180} \times 6.02 \times 10^{23} \times 24$

$= 1.5 \times 6.02 \times 10^{23} \times 24$

$= \mathbf{216.72} \times 10^{23}$ atoms

Result

Thus number of atoms in 10 g of **$C_6H_{12}O_6$ is 216.72** × 10^{23} atoms.

INVESTIGATIVE QUESTIONS

5. Investigative Questions

Q.1 It is generally believed that drinking eight glasses of water every day is required to keep oneself hydrated especially in the summer. If a glass occupies 400 cm^3 of water on the average, how many moles of water are needed for a single adult?

Ans: **NUMERICAL**

Given Data:

Water needed by an adult every day = 8 glasses

Volume occupied by 1 glass = 400 cm^3 water

Volume occupied by 8 glasses = 400 × 8 = 3200 cm^3 water

To Find:

Number of moles of water needed by an adult daily = ?

Calculation:

Number of moles of water needed by an adult daily = $\frac{Volume}{Molar\ Volume}$

$$= \frac{3200}{24000} = 0.1333 \text{ mole}$$

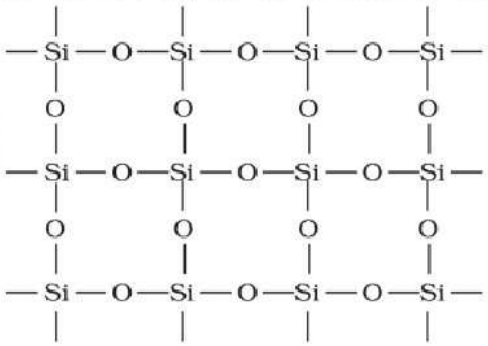
Result

Thus number of moles of water needed by an adult daily is 0.1333 mole.

Q.2 The chemical formula for sand is SiO_2 but the sand does not exist in the form of discrete molecules like H_2O. How has its formula been determined, keeping in view its structure?

Ans: **DETERMINATION OF FORMULA OF SiO_2**

Sand (SiO_2) is made up of silicon dioxide. Silicon dioxide has a tetrahedral structure in which each silicon atom (Si) is covalently bonded to four oxygen atoms (O), and each oxygen atom is bonded to two silicon atoms. In this way a three-dimensional network solid is obtained.



Its formula is determined by taking simplest ratio between Si and O atoms.

TERMS TO KNOW

Terms	Definitions
Molecular formula	Molecular formula of an element or a compound shows the actual number of atoms present in the molecule of the element or a compound
Empirical formula	The formula of a compound which gives the minimum ratio present between its atoms is called its Empirical formula. All the ionic compounds and some of the covalent compounds are represented by their empirical formulas.
Chemical Formula Writing	Chemical formula of a binary ionic compounds can be written if you know their names the charges present on the ions.
Molecular formula	Chemical formula of a compound is n times its empirical formula where n is the ratio molar mass to empirical formula mass.
Avogadro's number	Avogadro's number has been calculated to know the mass ratio of reactants and products in a chemical reaction. The value of this number is 6.022×10^{23}
Mole	The quantity of an element or a compound, which contains Avogadro's number of particles, is called a Mole and the mass of a substance present in it is called the Molar mass.
Chemical equation	A chemical equation tells the reacting and producing elements or compounds in a chemical reaction. It also tells the mole ratio between reactants or products and

	between reactants and products. A chemical equation must be balanced and should the correct formulas of all the participating elements and compounds.
Information from chemical equation	The mole ratio between reactants and products as shown by a chemical equation enables us to find out the mass ratio of these substances. A chemical equation is used calculate the masses of the reactants as well as the products, which take part in a chemical reaction.