



# Chapter # 4 Stoichiometry



## Student 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  $\text{amount of substance} = \text{mass}/\text{molar mass}$  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  $6.02 \times 10^{23}$  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 symbol equation with state symbols for a chemical reaction given relevant information.

## Subject Questions & Answers

**Q1. What is Stoichiometry? Give its importance.**

**Ans. Stoichiometry:**

The branch of chemistry which deals with the quantitative relationship between reactants and products in a balanced chemical equation is called Stoichiometry.

OR

The branch of chemistry which deals with the determination of unknown masses by using the known masses from a balanced chemical equation is called stoichiometry.

**Importance of stoichiometry:** It helps us to calculate the amounts of reactants and products by using a balanced chemical equation.

**Q2. Write down the name of law on which stoichiometry based.**

**Ans.** It is based on the Law of Conservation of Mass.

**Q3. Define the Law of Conservation of Mass.**

**Ans. Law of Conservation of Mass:**

This law states that "Matter can neither be created nor destroyed during a chemical reaction. The total mass of all the reactants must be equal to the total mass of products.

**Q4. How can you find the mole ratio between reactants and products?**

**Ans.** The stoichiometric coefficients used to balance a chemical equation provide the mole ratio between reactants and products.

**Q5. What is the importance of stoichiometry in industry?**

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

**Q6. What is meant by chemical formula? Give its importance.**

**Ans. Chemical formula:**

The representation of chemical compound of a substance interns of symbols and valencies is called chemical formula.

OR

A chemical formula is a shorthand notation of a compound.

**Example:** The chemical formula of calcium carbonate is  $\text{CaCO}_3$ .

**Importance of chemical formula:**

1. It shows the elements present in a compound.
2. It shows the number of atoms of each element present.

**Q7. Describe the types of chemical formula with examples.**

**Ans.** There are two types of chemical formulas:

1. Molecular formula
2. Empirical formula

**1. Molecular formula:** The formula which shows the actual number of atoms of each element present in the molecule of substance is called molecular formula.

**Examples:** The molecular formula of benzene is  $\text{C}_6\text{H}_6$  and molecular formula of hydrogen peroxide is  $\text{H}_2\text{O}_2$ .

**2. Empirical formula:** The formula which shows the minimum ratio between the atoms present in a compound is called empirical formula.

**Examples:** The empirical formula of benzene ( $\text{C}_6\text{H}_6$ ) is CH and empirical formula of hydrogen peroxide ( $\text{H}_2\text{O}_2$ ) is HO.

**Q8. How the ionic compounds are represented?**

**Ans.** 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  $\text{CaF}_2$  which shows the ratio present between calcium and fluoride ions in its crystal.

**Q9. Define formula unit with an example.**

**Ans. Formula unit:**

The simplest ratio of oppositely charged ions that gives an electrically neutral unit of an ionic compound is called formula unit.

**Example:** The formula unit of sodium chloride (common salt) consists of one  $\text{Na}^+$  ion and one  $\text{Cl}^-$  ion and its formula unit is  $\text{NaCl}$ . Similarly formula unit of potassium bromide is  $\text{KBr}$ .

**Q10. Is it possible that a compound has same empirical and molecular formula?**

**Ans.** Yes, it is possible that some molecules have same empirical and molecular formulas.

**Example:** Water has same empirical and molecular formula i.e.  $\text{H}_2\text{O}$ .

**Q11. Give two examples of the compounds which have same empirical and molecular formulas.**

**Ans.** Examples of molecules having same empirical and molecular formula :

(1) Methane  $\text{CH}_4$                       (2) Ammonia  $\text{NH}_3$

**Q12. Is it possible that two compounds have same empirical formula?**

**Ans.** Yes, it is possible that some compounds have same empirical formulas.

**Example:** Both benzene ( $\text{C}_6\text{H}_6$ ) and acetylene ( $\text{C}_2\text{H}_2$ ) have same empirical formula  $\text{CH}$ .

**Q13. Define binary ionic compounds.**

**Ans.** The ionic compounds consist of two ions (anion and cations).

**Examples:** Sodium chloride =  $\text{NaCl}$

Calcium oxide =  $\text{CaO}$

## Exercise

1. 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.** The chemical formula of an element consists of only one symbol representing that element.

The formula of a chemical compound consist of two or more different symbols of various elements present in a compound.

$\text{CaCl}_2$  represents calcium chloride which is made up of calcium and chlorines

| Formulas of ionic compounds |                   | Formula of covalent compounds |                          |
|-----------------------------|-------------------|-------------------------------|--------------------------|
| Sodium chloride             | = $\text{NaCl}$   | Hydrogen chloride             | = $\text{HCl}$           |
| Potassium bromide           | = $\text{KBr}$    | Carbon dioxide                | = $\text{CO}_2$          |
| Calcium chloride            | = $\text{CaCl}_2$ | Benzene                       | = $\text{C}_6\text{H}_6$ |
| Barium chloride             | = $\text{BaCl}_2$ | Ammonia                       | = $\text{NH}_3$          |

2. Give two examples of the compounds which have same empirical and molecular formula.

**Ans. Water:** Molecular formula of water =  $\text{H}_2\text{O}$

Empirical formula of water =  $\text{H}_2\text{O}$

**Ammonia:**

Molecular formula of ammonia =  $\text{NH}_3$

Empirical formula of ammonia =  $\text{NH}_3$

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

**Ans.** (i) Molecular formula,  $\text{CH}_3\text{COOH} = \text{C}_2\text{H}_4\text{O}_2$

Empirical formula = HO

(ii) Molecular formula of acetic acid is  $\text{CH}_3\text{COOH}$

Empirical formula of acetic acid is  $\text{CH}_2\text{O}$

(iii) Molecular formula of benzene is  $\text{C}_6\text{H}_6$ .

Empirical formula of benzene is CH.

4. The empirical formula of a compound is  $\text{CH}_2\text{O}$ . Its molar mass is 180 gmole<sup>-1</sup>. Determine its molecular formula.

Ans. Empirical formula =  $\text{CH}_2\text{O}$

Empirical formula mass of  $\text{CH}_2\text{O}$

$$= (12 \times 1) + (1 \times 2) + (16 \times 1)$$

$$= 12 + 2 + 16 = 30$$

Molar mass = 180 g/mol

As

$$n = \frac{\text{Molar mass}}{\text{Empirical Formula mass}} = \frac{180}{30} = 6$$

As

Molecular formula = 6 ( $\text{CH}_2\text{O}$ )



**Result:** Molecular formula =  $\text{C}_6\text{H}_{12}\text{O}_6$

**Q14. Explain the method to write the chemical formula of ionic compounds (Binary).**

Ans. 1. In order to write down the formula of an ionic compound, first identify the cations and anions and the number of charges present on them.

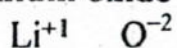
2. Write the symbols of two ions (anion and cation) side by side, the positive radical on the left and negative radical to the right.

3. Write the charge (valency) of each ion on it.

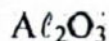
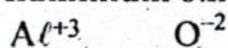
4. Cross the valencies (charges) to the lower right of each ion. If valencies (charges) are equal, do not cross.

**Examples:**

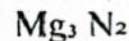
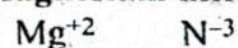
Lithium oxide



Aluminium oxide



Magnesium nitride



| Atoms and their Cations with charges |                  | Atoms and their Anions and Cations with charges |                                  |
|--------------------------------------|------------------|---|----------------------------------|
| Atom                                 | Charge           | Atom  | Charge                           |
| H                                    | $\text{H}^{1+}$  | O   | $\text{O}^{2-}$                  |
| Na                                   | $\text{Na}^{1+}$ | N   | $\text{N}^{3-}$                  |
| Li                                   | $\text{Li}^{1+}$ | Cl  | $\text{Cl}^{1-}$                 |
| K                                    | $\text{K}^{1+}$  | Br  | $\text{Br}^{1-}$                 |
| Mg                                   | $\text{Mg}^{2+}$ | I   | $\text{I}^{1-}$                  |
| Ca                                   | $\text{Ca}^{2+}$ | Cu  | $\text{Cu}^{1+}, \text{Cu}^{2+}$ |
| Ba                                   | $\text{Ba}^{2+}$ | Fe  | $\text{Fe}^{2+}, \text{Fe}^{3+}$ |

|    |                  |    |                                     |
|----|------------------|----|-------------------------------------|
| Zn | Zn <sup>2+</sup> | Sn | Sn <sup>2+</sup> , Sn <sup>4+</sup> |
| Al | Al <sup>3+</sup> | Ni | Ni <sup>2+</sup>                    |

**Q15. How can you calculate the molecular and empirical formula? Write down the relationship between molecular and empirical out formula.**

**Ans.** Molecular formula of a compound can be find out if we know its empirical formula.

To calculate the empirical formula, of a compound 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.

**Relation between molecular and empirical formula:**

Molecular formula = n (Empirical formula)

$$\text{where } n = \frac{\text{Molar Mass}}{\text{Empirical Formula mass}}$$

**Example:** Empirical formula of hydrogen peroxide is HO. Its molar mass is 34. Calculate its molecular formula.

**Sol:** Empirical formula of hydrogen peroxide = HO

$$\text{Empirical formula mass of HO} = (1 \times 1) + (16 \times 1) = 17$$

$$\text{Molar mass of hydrogen peroxide} = 34$$

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

$$\begin{aligned} \text{Molecular formula} &= 2(\text{HO}) \\ &= \text{H}_2\text{O}_2 \end{aligned}$$

**Q16. Empirical formula of a compound is CH. Its molecular mass is 78 gmole<sup>-1</sup>. Find out its molecular formula.**

**Sol.** Empirical Formula = CH

$$\text{Empirical formula mass of CH} = 13$$

$$\text{Molecular mass (molecular)} = 78$$

$$\text{As } n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}}$$

$$\therefore n = \frac{78}{13} = 6.$$

**As.** Molecular formula = n (Empirical formula)

$$\therefore \text{Molecular formula} = 6(\text{CH})$$

$$= \text{C}_6\text{H}_6$$

**Q17. Define molecular mass and formula mass.**

**Ans. Molecular mass:**

Sum of the atomic masses of all the atoms that are present in the molecular of a substance is called molecular mass.

**Examples:** Molecular mass of benzene C<sub>6</sub>H<sub>6</sub>

$$= (12 \times 6) + (1 \times 6) = 72 + 6 = 78 \text{ amu}$$

Molecular mass of hydrogen peroxide  $\text{H}_2\text{O}_2$

$$= (1 \times 2) + (16 \times 2) = 2 + 32 = 34 \text{ amu}$$

**Formula Mass:** The sum of the atomic masses of all the atoms that are present in one formula unit of a substance (ionic compound) is called formula mass.

**Examples:** Formula mass of  $\text{NaCl}$

$$\begin{aligned} &= (23 \times 1) + (35.5 \times 1) \\ &= 23 + 35.5 = 58.5 \text{ amu} \end{aligned}$$

Formula mass of  $\text{K}_2\text{SO}_4$

$$\begin{aligned} &= (39 \times 2) + (32 \times 1) + (16 \times 4) \\ &= 78 + 32 + 64 = 174 \text{ amu} \end{aligned}$$

**Q18.** The empirical formula of compound is  $\text{CH}_2\text{O}$ . Its molecular mass is  $180 \text{ g mole}^{-1}$ . Determine its molecular formula.

Sol. Empirical formula =  $\text{CH}_2\text{O}$   
Empirical formula mass of  $\text{CH}_2\text{O}$  =  $(12 \times 1) + (1 \times 2) + (16 \times 1)$   
=  $12 + 2 + 16 = 30$

Molar mass =  $180 \text{ g mole}^{-1}$

As Molecular formula =  $n$  (Empirical formula)  
=  $6 (\text{CH}_2\text{O})$   
=  $\text{C}_6\text{H}_{12}\text{O}_6$

Molecular formula =  $\text{C}_6\text{H}_{12}\text{O}_6$

**Q19.** The empirical formula of a compound is  $\text{CH}_2\text{O}$ . Its molar mass is  $60 \text{ g mole}^{-1}$ . Determine its molecular formula:

Sol. Empirical formula =  $\text{CH}_2\text{O}$   
Empirical formula mass of  $\text{CH}_2\text{O}$  =  $(12 \times 1) + (1 \times 2) + (16 \times 1)$   
Molar mass of compound =  $60$

As 
$$n = \frac{\text{Molar mass}}{\text{Empirical formula mass}}$$

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

As Molecular formula =  $n$  (Empirical formul)  
=  $2 (\text{CH}_2\text{O})$   
=  $\text{C}_2\text{H}_4\text{O}_2$   
Molecular formula =  $\text{C}_2\text{H}_4\text{O}_2$

**Q20.** What is meant by mole? Explain with examples.

**Ans. Mole:**

Atomic mass, molecular mass or formula mass of a substance expressed in grams is called mole.

OR

The quantity of a substance containing Avogadro's number of particles is called mole.

**Examples:** One mole of carbon atom = 12g  
 One mole of oxygen molecule  $O_2$  =  $16 \times 2 = 32g$   
 One mole of sodium chloride  $NaCl$  =  $(23 \times 1) + (35.5 \times 1) = 58.5 g$

**Q21. What do you know about Avogadro's number? Explain with examples.**

**Ans. Avogadro's number: ( $N_A$ )**

The number of particles (atoms, ions or molecules) present in one mole of a substance is called Avogadro's number. Its value is  $6.022 \times 10^{23}$ .

**Representation:** It is represented by  $N_A$ .

**Examples:** One mole of Carbon atom (12g) =  $6.022 \times 10^{23}$  atoms  
 One mole of water molecule,  $H_2O$  (18g) =  $6.022 \times 10^{23}$  Molecules  
 One mole of sodium ion,  $Na^+$  (23g) =  $6.022 \times 10^{23}$  ions

**Q22. Define molar mass with examples.**

**Ans. Molar mass:**

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

**Examples:** Molar mass of Carbon atom = 12g  
 Molar mass of water  $H_2O$  = 18g  
 Molar mass of  $CaCO_3$  =  $(40 \times 1) + (12 \times 1) + (16 \times 3)$   
 =  $40 + 12 + 48 = 100g$   
 Molar mass of sodium chloride,  $NaCl$  =  $(23 \times 1) + (35.5 \times 1) = 58.5 g$

**Sample problems**

**Q23. Determine the molar masses of following. (a) Sulphuric acid ( $H_2SO_4$ )  
 (b) Glucose ( $C_6H_{12}O_6$ ).**

**Sol.** Molar mass of sulphuric acid  $H_2SO_4$  =  $(1 \times 2) + (32 \times 1) + (16 \times 4)$   
 =  $2 + 32 + 64 = 98 \text{ gmole}^{-1}$ .  
 Molar mass of glucose  $C_6H_{12}O_6$  =  $(12 \times 6) + (1 \times 12) + (16 \times 6)$   
 =  $72 + 12 + 96 = 180 \text{ gmole}^{-1}$ .

**Q24. Determine the molar masses of following:**

- i. Naphthalene ( $C_{10}H_8$ )
- ii. Urea ( $(NH_2)_2 CO$ ).

**Sol.** (i) Molar mass of naphthalene,  $C_{10}H_8$  =  $(12 \times 10) + (1 \times 8) = 120 + 8 = 128 \text{ g/mole}$ .  
 (ii) Molar mass of urea,  $(NH_2)_2 CO$ :  
 =  $(14 \times 2) + (1 \times 4) + (12 \times 1) + (16 \times 1)$   
 =  $28 + 4 + 12 + 16 = 60 \text{ gmol}^{-1}$ .

**Q25. Calculate the molar mass of the following compounds  $H_3PO_4$ ,  $SiO_2$ ,  $C_{12}H_{22}O_{11}$ ,  
 $N_2O_4$ ,  $MgCO_3$ .**

**Sol.** Molar mass of  $H_3PO_4$  =  $(1 \times 3) + (31 \times 1) + (4 \times 16) = 3 + 31 + 64 = 98 \text{ gmole}^{-1}$   
 Molar mass of  $SiO_2$  =  $(28 \times 1) + (16 \times 2) = 28 + 32 = 60 \text{ gmole}^{-1}$   
 Molar mass of  $C_{12}H_{22}O_{11}$  =  $(12 \times 12) + (1 \times 22) + (16 \times 11) = 144 + 22 + 176 = 342 \text{ gmole}^{-1}$

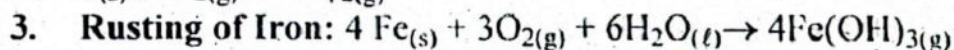
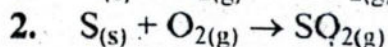
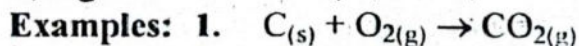
$$\text{Molar mass of } \text{N}_2\text{O}_4 = (14 \times 2) + (16 \times 4) = 28 + 64 = 92 \text{ gmol}^{-1}$$

$$\text{Molar mass of } \text{MgCO}_3 = (24 \times 1) + (12 \times 1) + (16 \times 3) = 24 + 12 + 48 = 84 \text{ gmol}^{-1}$$

**Q26. What is meant by chemical change? Give one example.**

**Ans. Chemical change:**

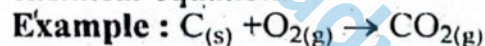
When two or more substances combine in such a way, that a new substance is formed which has entire different properties from its constituents is called chemical change.



**Q27.(a) What is meant by chemical equation?**

**Ans. Chemical equation:**

Representing a chemical change in terms of symbols and formulas is called chemical equation.



**(a) Information obtained from chemical equations:**

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.

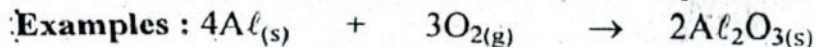
**Reactants:** The substances which react together are called reactants. "C" and  $\text{O}_2$  are reactants. In above equation ( $\text{C} + \text{O}_2 \rightarrow \text{CO}_2$ )

**Products:** The substances which are produced as a result of a chemical change are called products.

In above equation ( $\text{C} + \text{O}_2 \rightarrow \text{CO}_2$ ), the  $\text{CO}_2$  is product.

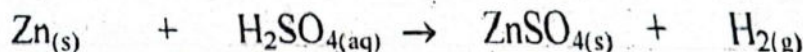
**(b) How to write a chemical equation?**

1. A chemical equation must obey the law of conservation of mass. This means that number atoms are neither created nor destroyed during a chemical reaction. The total number and the type of atoms must remain the same during a chemical change.
2. The formulas of elements and compounds must be written correctly.
3. A chemical equation must determine the correct mole ratio among the reactants and the products.
4. A chemical equation must also point out the direction in which the change is proceeding.
5. 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 solved ions.
6. It is customary to write the reactants on the left hand side and products on right hand side.
7. An arrow head drawn from reactant to product, which separates the two.



Reactants

Products

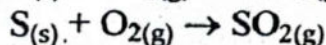


**Q28. What is meant by balancing of a chemical equation?**

**Ans. Balancing a chemical equation:**

The process of writing the equal number of atoms of each element on the both sides of chemical equation is called balancing of chemical equation.

**Examples:**  $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$



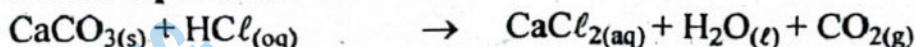
Both are balanced chemical equations.

**Q29. Balance the following chemical equations.**

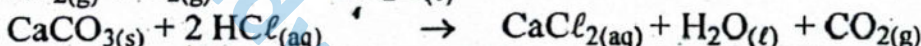
**Ans. (i)**  $CaCO_{3(g)} + HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$

**(ii)**  $H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)}$

**Unbalanced equation:**



**Balanced chemical equation**



### Exercise

**1. The Empirical formula of a compound is  $CH_2O$ . Its molar mass is  $60 \text{ gmole}^{-1}$ . Determine its molecular formula.**

**Ans.** Empirical formula =  $CH_2O$

$$\begin{aligned} \text{Empirical formula mass of } CH_2O &= (12 \times 1) + (1 \times 2) + (16 \times 1) \\ &= 12 + 2 + 16 = 30 \end{aligned}$$

As Molar mass = 60

$$n = \frac{\text{Molar mass}}{\text{Empirical Formula mass}}$$

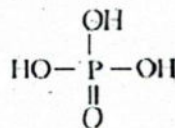
$$n = \frac{60}{30} = 2$$

Molecular formula =  $n(\text{Empirical formula})$

$$\begin{aligned} \text{Molecular formula} &= 2(CH_2O) \\ &= C_2H_4O_2 \end{aligned}$$

**Result:** Molecular formula =  $C_2H_4O_2$

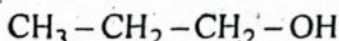
**2. Find out the molecule of phosphoric acid. Its structural formula is:**



**Ans.** Structural formula =  $\begin{array}{c} \text{OH} \\ | \\ \text{HO}-\text{P}-\text{OH} \\ || \\ \text{O} \end{array}$

Molecular formula =  $H_3PO_4$

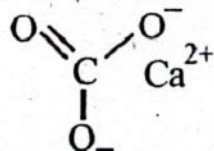
**3. Determine the molecular formula of n - propyl alcohol. Its structural formula is:**



**Ans.** Structural formula =  $CH_3 - CH_2 - CH_2 - OH$

Molecular formula =  $C_3H_8O$

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



Ans. Formula =  $CaCO_3$

5. Calculate the molar masses of the following compounds,  $H_3PO_4$ ,  $SiO_2$ ,  $C_{12}H_{22}O_{11}$ ,  $N_2O_4$ ,  $MgCO_3$

Ans. Molar mass of  $H_3PO_4$ :

$$\begin{aligned} &= (1 \times 3) + (31 \times 1) + (16 \times 4) \\ &= 3 + 31 + 64 = 98 \text{ g} \end{aligned}$$

Molar mass of  $SiO_2$ :

$$\begin{aligned} &= (1 \times 28) + (2 \times 16) \\ &= 28 + 32 = 60 \text{ g} \end{aligned}$$

Molar mass of  $C_{12}H_{22}O_{11}$ :

$$\begin{aligned} &= (12 \times 12) + (1 \times 22) + (11 \times 16) \\ &= 144 + 22 + 176 = 342 \text{ g} \end{aligned}$$

Molar mass of  $N_2O_4$ :

$$\begin{aligned} &= (1 \times 14) + (4 \times 16) \\ &= 14 + 64 = 78 \text{ g} \end{aligned}$$

Molar mass of  $MgCO_3$ :

$$\begin{aligned} &= (1 \times 24) + (1 \times 12) + (3 \times 16) \\ &= 24 + 12 + 48 = 84 \text{ g} \end{aligned}$$

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**Q30. What is meant by reversible reaction? Give one example.**

**Ans. Reversible reaction:**

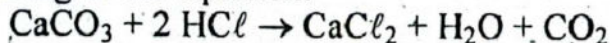
The reactions which can proceed in forward as well as in backward directions are called reversible reactions.

**Representation:** Reversible reactions are represented by a double arrow  $\rightleftharpoons$ .

**Example :**  $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

**Calculation Based on Chemical Equation:**

**Example 1:** 25g of Limestone ( $CaCO_3$ ) reacts with an excess of hydrochloric acid according to the equation:



**How much calcium chloride  $CaCl_2$  will be produced?**

**Solution:** Mass of  $CaCO_3 = 25\text{g}$

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

Mass of  $CaCl_2$  product

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

**According to the equation**

$$100\text{g of limestone reacts to produce calcium chloride} = 111\text{g}$$

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

$$25\text{g of limestone will react to produce calcium chloride} = \frac{111}{100} \times 25 = 27.75\text{g}$$

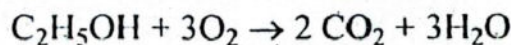
**Example 2 :**

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 moles

No. of moles of oxygen needed = ?

The balanced chemical equation for the reaction will be



**According to this equation:**

1 mole of ethyl alcohol needed oxygen = 3 moles

1.8 mole of ethyl alcohol needed oxygen =  $\frac{3}{1} \times 1.8$   
= 5.4 moles

1 mole of ethyl alcohol produces moles of  $\text{CO}_2$  = 2 moles

1.8 mole of ethyl alcohol will produce  $\text{CO}_2$  =  $2 \times 1.8$   
= 3.6 moles

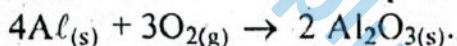
### Example 3

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 = 0.3

Grams of  $\text{O}_2$  used = ?

The balanced chemical equation for the reaction:



**According to this equation:**

4 moles of aluminium will need oxygen = 3.0 moles

1.0 mole of aluminium will need oxygen =  $\frac{3}{4}$

0.3 moles of aluminium will need oxygen =  $\frac{3}{4} \times 0.3 = 0.225$  moles

1 mole of oxygen (O) has molar mass = 32g

0.225 mole of oxygen ( $\text{O}_2$ ) will have molar mass =  $32 \times 0.225 = 7.2\text{g}$

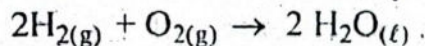
### Example 4

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

**Solution:** Mass of  $\text{H}_2$  used = 5g

Molecules of water produced = ?

The balanced chemical equation for the reaction:



2 moles    1 mole    2 moles

4g            32g            36g

**According to this equation**

4g of hydrogen produce  $\text{H}_2\text{O}$  = 36 g of  $\text{H}_2\text{O}$

5g of hydrogen will produce  $\text{H}_2\text{O}$  =  $\frac{36}{4} \times 5 = 45\text{g}$  of water

18g (1 mole) of  $\text{H}_2\text{O}$  contain molecules =  $6.02 \times 10^{23}$

36g of  $\text{H}_2\text{O}$  contain molecules =  $6.02 \times 10^{23} \times 2 = 12.04 \times 10^{23}$

45g of  $\text{H}_2\text{O}$  contain =  $\frac{45}{36} \times 12.04 \times 10^{23} = 1.505 \times 10^{24}$  molecules

## Conceptual Long Questions

1. Calculate the percentage of nitrogen in following:

- (i)  $\text{CO}(\text{NH}_2)_2$  (ii)  $\text{N}_2\text{H}_4$  (iii)  $\text{NH}_2\text{OH}$  (iv)  $\text{NH}_3$

Ans. (i)  $\text{CO}(\text{NH}_2)_2$

$$\text{Molar mass of } \text{CO}(\text{NH}_2)_2 = (12 \times 1) + (16 \times 1) + (14 \times 2) + (1 \times 4) = 12 + 16 + 28 + 4 = 60 \text{ g/mol}$$

$$= \frac{\text{Mass of Nitrogen}}{\text{Molar Mass of Urea}} \times 100$$

$$\text{Nitrogen} = \frac{28}{60} \times 100 = 46.67\%$$

$$\% \text{ age of Nitrogen in } \text{CO}(\text{NH}_2)_2 = 46.66 \%$$

(ii)  $\text{N}_2\text{H}_4$

$$\begin{aligned} \text{Molar mass of } \text{N}_2\text{H}_4 &= (14 \times 2) + (1 \times 4) \\ &= 28 + 4 = 32 \text{ g} \end{aligned}$$

$$\text{Nitrogen} = \frac{28}{32} \times 100 = 87.5\%$$

$$\% \text{ age of Nitrogen in } \text{N}_2\text{H}_4 = 87.5\%$$

(iii)  $\text{NH}_2\text{OH}$

$$\text{Molar mass of } \text{NH}_2\text{OH} = (14 \times 1) + (1 \times 3) + (16 \times 1) = 14 + 3 + 16 = 33 \text{ g}$$

$$\text{Nitrogen} = \frac{14}{33} \times 100 = 42.42 \%$$

$$\% \text{ age of Nitrogen in } \text{NH}_2\text{OH} = 42.42\%$$

(iv)  $\text{NH}_3$

$$\begin{aligned} \text{Molar mass of } \text{NH}_3 &= (14 \times 1) + (1 \times 3) \\ &= 14 + 3 = 17 \end{aligned}$$

$$\text{Nitrogen} = \frac{14}{17} \times 100 = 82.35\%$$

$$\% \text{ age of Nitrogen in } \text{NH}_3 = 82.35\%$$

2. Calculate the number of atoms in 6g of carbon (diamond)

Ans. Mass of carbon in grams = 6g

$$\text{Molar mass of carbon} = 12 \text{ g}$$

$$\text{As} \quad \text{No. of moles} = \frac{\text{Mass in grams}}{\text{Molar mass}}$$

$$\therefore \quad \text{No. of moles} = \frac{6}{12} = 0.5 \text{ moles}$$

$$\begin{aligned} \text{As} \quad \text{No. of atoms} &= \text{No. of moles} \times \text{Avogadro's number} \\ &= 0.5 \times 6.022 \times 10^{23} \text{ atoms} \\ &= 3.011 \times 10^{23} \text{ atoms} \end{aligned}$$

$$\begin{aligned} \text{Result} \quad \text{No. of atoms in 6g of diamond (carbon)} \\ &= 3.011 \times 10^{23} \text{ atoms} \end{aligned}$$

3. Aluminium is a light metal. It is used to make milk tanks. Calculate the mass of aluminium (Al) in 204g of aluminum oxide, (Al<sub>2</sub>O<sub>3</sub>).

Ans. Molar mass of aluminum oxide Al<sub>2</sub>O<sub>3</sub>:

$$\begin{aligned} &= (27 \times 2) + (16 \times 3) \\ &= 54 + 48 = 102 \text{g/mol} \end{aligned}$$

102g Al<sub>2</sub>O<sub>3</sub> contains, aluminum, Al = 54g

1g of Al<sub>2</sub>O<sub>3</sub> contains, aluminum, Al =  $\frac{54}{102}$ g

204g Al<sub>2</sub>O<sub>3</sub> contains, aluminum, Al =  $\frac{54}{102} \times 204 = 108$ g

**Result:** Mass of aluminum in 204 of Al<sub>2</sub>O<sub>3</sub> = 108g

4. Calculate the amount of carbon dioxide, which is produced by complete combustion of 30g of methane gas (CH<sub>4</sub>).

Ans. Balanced chemical equation:



$$(12 \times 1) + (1 \times 4) \rightarrow (12 \times 1) + (16 \times 2)$$

$$16 \text{g/mol} \rightarrow 44 \text{g/mol}$$

16g of methane (CH<sub>4</sub>) produces CO<sub>2</sub> = 44g

1g of methane (CH<sub>4</sub>) produces CO<sub>2</sub> =  $\frac{44}{16}$ g

36g of methane (CH<sub>4</sub>) produces CO<sub>2</sub> =  $\frac{44}{16} \times 30 \text{g} = 82.5$ g

**Result:** Amount of CO<sub>2</sub> = 82.5g

5. Air is a homogeneous mixture of various gases. It contains 78% by volume of nitrogen. Calculate the number of atoms in 3.5g of nitrogen (N<sub>2</sub>).

Ans. Molar mass of N<sub>2</sub> = 14 × 2 = 28g

Mass in grams of N<sub>2</sub> = 3.5g

As No. of moles of Nitrogen =  $\frac{\text{Mass in grams}}{\text{Molar mass}}$

$$= \frac{3.5}{28} = 0.125 \text{ moles}$$

As No. of molecules = No. of moles × Avogadro's number  
= 0.125 × 6.022 × 10<sup>23</sup>

No. of molecules = 0.752 × 10<sup>23</sup> molecules

One molecule of N<sub>2</sub> contains atom = 2 atoms

0.752 × 10<sup>23</sup> molecules contains atom = 2 × 0.75 × 10<sup>23</sup> atom = 1.505 × 10<sup>23</sup> atom

**Result:** No. of atoms in 3.5g of N<sub>2</sub> = 1.505 × 10<sup>23</sup> atoms

# Additional MCQs

## 4.1 Chemical formula

## 4.2 Empirical formula

- The chemical formula of ozone is:  
(a)  $O_2$  (b)  $O_4$  (c)  $O_3$  (d)  $O$
- The formula which shows the smallest whole number ratio between the atoms of various elements in a compound is called:  
(a) Empirical formula (b) Molecular formula  
(c) Structural formula (d) Condensed formula
- The chemical formula of common salt is:  
(a)  $CaCl_2$  (b)  $NaCl$  (c)  $NaBr$  (d)  $Na_2CO_3$
- The empirical formula of hydrogen peroxide is:  
(a)  $H_2O_2$  (b)  $H_2O$  (c)  $HO_2$  (d)  $HO$
- The symbol of iron is:  
(a)  $Fe$  (b)  $Ir$  (c)  $In$  (d)  $Fl$
- The molecular formula of benzene is:  
(a)  $CH$  (b)  $C_6H_6$  (c)  $C_2H_2$  (d)  $C_5H_5$
- The formula which shows the actual number of atoms of each element present in a compound is called:  
(a) Molecular formula (b) Empirical formula  
(c) Structural formula (d) Simple formula
- The chemical formula of sulphuric acid is :  
(a)  $HNO_3$  (b)  $HCl$  (c)  $H_2SO_4$  (d)  $SO_4$
- The chemical formula of acetylene is:  
(a)  $C_2H_2$  (b)  $CH$  (c)  $C_6H_6$  (d)  $C_3H_3$
- " $CH$ " is the empirical formula of :  
(a) Water (b) Benzene  
(c) Hydrogen peroxide (d) Chlorine

## 4.3 Chemical formulas of binary ionic compounds

## 4.4 Chemical formulas of compounds

- The negatively charged ions are called:  
(a) Anions (b) Cations (c) Both a and b (d) None of these

12. The positively charged ions are called:  
 (a) Anions (b) Cations (c) Both a and d (d) None of these
13. The formula of Aluminum nitride is:  
 (a)  $AlN$  (b)  $Al_2N_3$  (c)  $Al_3N_2$  (d)  $Al_4N_2$
14. The formula of Aluminum oxide is:  
 (a)  $AlO$  (b)  $Al_2O_3$  (c)  $Al_3O_2$  (d)  $Al_2O_2$
15. The molecular formula of glucose is:  
 (a)  $CH_2O$  (b)  $C_2H_4O_2$  (c)  $C_6H_{12}O_6$  (d)  $C_{12}H_{22}O_{11}$
16. The formula of Magnesium nitride is:  
 (a)  $Mg_2N_3$  (b)  $Mg_3N_2$  (c)  $MgN$  (d)  $MgN_2$

#### 4.5 Deduce the molecular formula from the structural formula

#### 4.6 Avogadro's Number ( $N_A$ )

17. The Avogadro's number was introduced by:  
 (a) Italian scientist (b) American scientist  
 (c) British chemist (d) Pakistani chemist
18. The Avogadro's number is represented by:  
 (a)  $A_N$  (b)  $N_A$  (c)  $A_V$  (d)  $A_N$
19. The number  $6.022 \times 10^{23}$  is called:  
 (a) Avogadro's number (b) Constant number  
 (c) Empirical number (d) None of these
20. Who discovered the Avogadro's number?  
 (a) Bohr (b) Rutherford  
 (c) Amaedo Avogadro (d) Jabir Bin Hyan

#### 4.7 The Mole and Molar mass

#### 4.8 Chemical Equations and Chemical Reactions

#### 4.9 Calculations Based on Chemical Equation

21. The atomic mass, molecular mass or formula mass of a substance expressed in grams is called:  
 (a) Avogadro's number (b) Mole  
 (c) Empirical formula (d) Molecular formula
22. The mass of one mole of a substance is called:  
 (a) Avogadro's number (b) Mole  
 (c) Molar mass (d) None of these
23. A mole of oxygen molecule contains:  
 (a)  $6.022 \times 10^{23}$  atom (b)  $6.022 \times 10^{23}$  molecules  
 (c)  $6.022 \times 10^{23}$  ions (d) 6.022 molecules
24. One mole of oxygen molecule contains:  
 (a) 32g (b) 16g (c) 48g (d) 8g

25. The way of representing a chemical change in terms of symbols and formulas is called:
- (a) Chemical equation (b) Chemical calculation  
(c) Product (d) reactant
26. The substances which react to give a chemical change are called:
- (a) Ractants (b) Products (c) Substitute (d) None of these
27. The substances which are produced as a result of chemical change are called:
- (a) Reactants (b) Products (c) Both a and b (d) None of these
28. One mole of calcium carbonate  $\text{CaCO}_3$  is equal to:
- (a) 100 g (b) 10 g (c) 110 g (d) 80 g

### ANSWERS:

1. (c) 2. (a) 3. (b) 4. (d) 5. (a) 6. (b) 7. (a)  
8. (c) 9. (a) 10. (b) 11. (a) 12. (b) 13. (a) 14. (b)  
15. (c) 16. (b) 17. (a) 18. (b) 19. (a) 20. (c) 21. (b)  
22. (c) 23. (b) 24. (a) 25. (a) 26. (a) 27. (b) 28. (a)

### Conceptual MCQs

1. The ionic compounds are represented by their:
- (a) Molecular formula (b) Empirical formula  
(c) Structural formula (d) Both (a) and (b)
2. The stoichiometry is based upon the:
- (a) Law of conservation of mass (b) Law of mass action  
(c) Distributive law (d) Scientific law
3. The molecular formula of glucose is:
- (a)  $\text{C}_6\text{H}_6$  (b)  $\text{CH}_2\text{O}$  (c)  $\text{C}_6\text{H}_{12}\text{O}_6$  (d) CH
4. The molecular formula of calcium oxide is:
- (a)  $\text{CO}_2$  (b)  $\text{CaCO}_3$  (c) CaO (d)  $\text{Ca}_2\text{O}$
5. The structural formula of a compound is  $\text{H}-\overset{\text{H}}{\underset{\text{H}}{\text{C}}}-\overset{\text{H}}{\underset{\text{H}}{\text{C}}}-\text{H}$ , What is its molecular formula?
- (a)  $\text{C}_2\text{H}_4$  (b)  $\text{C}_3\text{H}_6$  (c)  $\text{C}_2\text{H}_6$  (d)  $\text{C}_2\text{H}_5$
6. The number  $6.022 \times 10^{23}$  is called:
- (a) Avogadro's number (b) Bohr's number  
(c) Rutherford number (d) Lewis number
7. The molar mass of benzene ( $\text{C}_6\text{H}_6$ ) is:
- (a) 100g/mol (b) 78g/mol (c) 80g/mol (d) 13g/mol
8. The amount of a substance which contains Avogadro's number of particles is called:
- (a) Mole (b) Empirical formula  
(c) Molecular formula (d) Both (b) and (c)

9. A compound has structural formula,  $\text{CH}_3 - \text{CH}_2 - \text{CH}_3$ . What will be the empirical formula?  
 (a)  $\text{C}_3\text{H}_8$  (b)  $\text{C}_4\text{H}_{10}$  (c)  $\text{C}_2\text{H}_5$  (d)  $\text{C}_2\text{H}_6$
10. How many atoms are presented in 2g of  $\text{CH}_4$ ?  
 (a)  $3.763 \times 10^{23}$  (b)  $7.52 \times 10^{26}$  (c)  $0.75 \times 10^{24}$  (d)  $37.63 \times 10^{25}$

**ANSWERS:**

1. (b) 2. (a) 3. (c) 4. (c) 5. (c) 6. (a) 7. (b)  
 8. (a) 9. (c) 10. (a)

## Additional Short Questions

**4.1 + 4.2** Chemical formula + Empirical formula

**4.3** Chemical formulas of binary ionic compounds

**4.4** Chemical formulas of compound

1. Define the law of conservation of mass.

Ans. The matter can neither be created nor destroyed during a chemical reaction.

2. What do you know about empirical formula?

Ans. Empirical formula: The formula which shows the smallest whole number ratio between the atoms of various elements in a compound is called empirical formula

3. Write down the relationship between empirical and molecular formulas.

Ans. Relationship: Molecular formula = n (Empirical formula)

Where 
$$n = \frac{\text{Molar mass}}{\text{Empirical formula mass}}$$

4. What do you know about molecular formula? Give two examples.

Ans. Molecular formula: The formula which shows the actual number of atoms of each element present in a compound is called molecular formula.

Examples: Molecular formula of sulphuric acid =  $\text{H}_2\text{SO}_4$

Molecular formula of glucose =  $\text{C}_6\text{H}_{12}\text{O}_6$

5. Write down the chemical formula of following compounds.

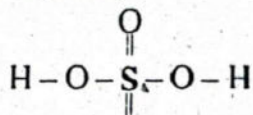
(i) Barium chloride (ii) Zinc oxide

Ans. (i) Barium chloride:  $\text{BaCl}_2$  (ii) Zinc oxide:  $\text{ZnO}$

**4.5** Deduce the molecular formula from the Structural Formula

**4.6** Avogadro's Number ( $N_A$ )

6. Write down the molecular formula of sulphuric acid from its structural formula.



- Ans. No. of H - atom = 2  
 No. of S - atom = 1  
 No. of O - atom = 4

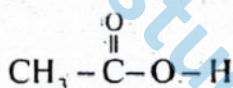
Molecular formula of sulphuric acid =  $\text{H}_2\text{SO}_4$

7. What is meant by Avogadro's number? Give one example.

Ans. The number of particles (atoms, ions or molecules) present in one mole of a substance is called Avogadro's number. It is represented by  $N_A$ . Its value is  $6.022 \times 10^{23}$ .

Example: One mole of water (18g) =  $6.022 \times 10^{23}$  molecules.

8. Deduce the molecular formula of acetic acid from its structural formula.



- Ans. No. of carbon atoms = 2  
 No. of H - atoms = 4  
 No. of O - atoms = 2

Molecular formula of acetic acid =  $\text{C}_2\text{H}_4\text{O}_2$

9. The empirical formula hydrogen peroxide is HO its molar mass is 34. Find its molecular formula.

Ans. Empirical formula of hydrogen peroxide  $\text{HO} = 1 + 16 = 17$

Molar mass of hydrogen peroxide = 34

Empirical formula of  $\text{HO} = 17$

$$n = \frac{\text{Molar mass}}{\text{Empirical formula mass}}$$

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

Molecular formula = n (Empirical formula)  
 = 2 (H O)  
 =  $\text{H}_2\text{O}_2$

Result: Molecular formula of hydrogen peroxide =  $\text{H}_2\text{O}_2$

4.7

The Mole and Molar Mass

4.8

Chemical Equations and Chemical Reactions

4.9

Calculations Based on Chemical Equation

10. Define mole with one example.

Ans. Mole: The atomic mass, molecular mass or formula mass expressed in grams is called mole.

**Example:** One mole of oxygen molecule ( $O_2$ ) =  $16 \times 2 = 32g$

11. **What is molecular mass?**

**Ans. Molecular mass:** The mass of one mole of a substance is called molar mass.

**Example:** The molar mass of water  $H_2O = (1 \times 2) + 16 \times 1 = 18g$

12. **Calculate the molar mass of  $SiO_2$ .**

**Ans.** Molar mass of  $SiO_2 = (28 \times 1) + (16 \times 2)$   
 $= 28 + 32 = 60g$

13. **Define chemical equation with one example.**

**Ans. Chemical equation:** The way of representing a chemical change in terms of symbols and formulas is called chemical equation.

**Examples:**  $Zn_{(s)} + H_2SO_{4(aq)} \rightarrow ZnSO_{4(g)} + H_2$

14. **Calculate mass of 2 moles of water.**

**Ans.** Mass of one mole of water,  $H_2O = (1 \times 2) + (16 \times 1) = 18g$

Mass of 2 moles of water =  $2 \times 18 = 36g$

**Result:** The mass of 2 moles of water =  $36g$

## Conceptual Short Questions

1. **What do you know about stoichiometry which law provide the basis of it?**

**Ans.** The branch of chemistry which helps us to calculate the amounts of reactants and products by using a balanced chemical equation.

**Basis of Law:** It is based on the law of conservation of mass.

2. **How stoichiometry is helpful in the industry?**

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

3. **How the empirical formula helps us to calculate the molecular formula?**

**Ans.** The molecular formula of a compound can be calculated by using empirical formula, if we know the value of "n" with the help of relation.

Molecular formula = n (Empirical formula)

4. **Determine the molecular formula of n-propyl alcohol, its structural formula is  $CH_3-CH_2-CH_2-OH$ .**

**Ans.** No. of Carbon atoms = 3

No. of Hydrogen atoms = 8

No. of Oxygen atoms = 1

Molecular formula =  $C_3H_8O$

5. **Balance the following chemical equation  $Al + O_2 \rightarrow Al_2O_3$ .**

**Ans.** Unbalance equation  $Al + O_2 \rightarrow Al_2O_3$

Balanced chemical equation  $4Al + 3O_2 \rightarrow 2Al_2O_3$

6. **Calculate the molar mass of ethyl alcohol,  $C_2H_5OH$ .**

**Ans.** Molar mass of  $C_2H_5OH$

$= 12 \times 2 + 5 \times 1 + 16 \times 1 + 1 \times 1$

$$= 24 + 5 + 16 + 1 = 46$$

7. How many atoms are present in one gram of  $\text{H}_2\text{O}$ ?

Ans. Mass of water in grams = 1g

Molar mass of water  $\text{H}_2\text{O}$  =  $(1 \times 2) + (16 \times 1) = 18\text{g}$

As.

$$\text{No. of moles of water} = \frac{\text{Mass in grams}}{\text{Molar mass}}$$

As.

$$\text{No. of moles} = \frac{1}{18} = 0.055 \text{ moles}$$

$$\begin{aligned} \text{No. of molecules} &= \text{No. of moles} \times \text{Avogadro's No.} \\ &= 0.055 \times 6.022 \times 10^{23} \text{ molecules} \\ &= 0.3345 \times 10^{23} \text{ molecules} \end{aligned}$$

One molecule of water contains atoms = 3 atoms

$$\begin{aligned} 0.3345 \times 10^{23} \text{ molecules} &= 3 \times 0.3345 \times 10^{23} \text{ atoms} \\ &= 1.0036 \times 10^{23} \text{ atoms} \end{aligned}$$

8. Calculate the number of moles in 25 g of  $\text{H}_2\text{SO}_4$ .

Ans. Mass in grams of  $\text{H}_2\text{SO}_4$  = 25g

As Molar mass  $\text{H}_2\text{SO}_4$  =  $(1 \times 2) + (32 \times 4) + (16 \times 4) = 98\text{g}$

$$\begin{aligned} \text{No. of moles} &= \frac{\text{Mass in gram}}{\text{Molar mass}} \\ &= \frac{25}{98} = 0.255 \text{ moles} \end{aligned}$$

**Result:** No. of moles in 25g of  $\text{H}_2\text{SO}_4$  = 0.255 moles

## Key Points

1. Molecular formula of an element or a compound shows the actual number of atoms present in the molecule of the element or a compound.
2. 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.
3. Chemical formula of a binary ionic compounds can be written if you know their names and the charges present on the ions.
4. Chemical formula of a compound is n times its empirical formula where n is the ratio of molar mass to empirical formula mass.
5. 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  $6.022 \times 10^{23}$ .
6. 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.
7. 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

- show the correct formulas of all the participating elements and compounds.
8. 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 to calculate the masses of the reactants as well as the products, which take part in a chemical reaction.

## Exercise Questions

### 1 Tick (✓) the correct answer.

- (i) How many atoms are present in one gram of  $H_2O$ ?  
(a)  $1002 \times 10^{23}$  atoms (b)  $6.022 \times 10^{23}$  atoms  
(c)  $0.334 \times 10^{23}$  atoms (d)  $2.004 \times 10^{23}$  atoms
- (ii) Which is the correct formula of calcium phosphide?  
(a)  $CaP$  (b)  $CaP_2$  (c)  $Ca_2P_3$  (d)  $Ca_3P_2$
- (iii) How many atomic mass units (amu) are there in one gram?  
(a) 1 amu (b)  $10^{23}$  amu  
(c)  $6.022 \times 10^{23}$  amu (d)  $6.022 \times 10^{22}$  amu
- (iv) 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)  $CH_2$
- (v) 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
- (vi) A necklace has 6g of diamonds in it. What are the number of carbon atoms in it?  
(a)  $6.02 \times 10^{23}$  (b)  $12.04 \times 10^{23}$  (c)  $1.003 \times 10^{23}$  (d)  $3.01 \times 10^{23}$
- (vii) What is the mass of Al in 204g of aluminium oxide,  $Al_2O_3$ ?  
(a) 26g (b) 27g (c) 54g (d) 108g
- (viii) 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)  $NH_2OH$
- (ix) 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 ( $C_2H_6$ ) (d) Methane ( $CH_4$ )
- (x) What mass of 95%  $CaCO_3$  will be required to neutralize 50 cm<sup>3</sup> of 0.5M HCl solution?  
(a) 9.5 g (b) 1.25g (c) 1.32g (d) 1.45g

### ANSWERS:

- i. (a) ii. (c) iii. (c) iv. (d) v. (c) vi. (d) vii. (d)  
viii. (b) ix. (c) x. (d)

## 2 Questions for Short Answers

i. Write down the chemical formula of barium nitride.

Ans. The chemical formula of barium nitride is  $B_3N_2$ .

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

Sols Empirical formula =  $CH_2O$

Empirical formula mass of  $CH_2O = (1 \times 1) + (1 \times 2) + (16 \times 1) = 12 + 2 + 16 = 30$

Molar mass of compound = 180

As

$$n = \frac{\text{Molar mass}}{\text{Empirical formula mass}}$$

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

As

Molecular formula =  $n$  (Empirical formula)

=  $6(CH_2O)$

=  $C_6H_{12}O_6$

iii. How many molecules are present in 1.5g  $H_2O$ ?

Sol. Mass in gram of  $H_2O = 1.5g$

Molar mass of  $H_2O = (1 \times 2) + (16 \times 1) = 2 + 16 = 18g$

As No. of moles =  $\frac{\text{Molar mass}}{\text{Empirical formula mass}}$

$$\therefore \text{No. of moles} = \frac{1.5}{18} = 0.0833 \text{ moles}$$

As No. of moles = No. of moles  $\times$  Avogadro's Number

$$= 0.0833 \times 6.022 \times 10^{23}$$

$$= 0.501 \times 10^{23} \text{ molecules}$$

$$= 5.01 \times 10^{24} \text{ molecules}$$

Result:

No. of molecules in 1.5g of water =  $5.01 \times 10^{24}$  molecules.

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

Ans.

| Mole  | Avogadro's Number   |
|---|---|
| The atomic mass, molecular mass or formula mass of a substance expressed in grams is called mole.<br>It is a unit of measurement. | The number of particles (atoms, ions and molecules) present in one mole of a substance is called Avogadro's number.<br>It is the number of particles in a mole. |

v. Write down the chemical equation of the following reaction.

Ans.  $Cu_{(l)} + H_2SO_{4(aq)} \rightarrow CuSO_{4(g)} + SO_{2(g)} + H_2O_{(l)}$

### 3 Constructed Response Questions

i. Different compounds will never have the same molecular formula but they can have the same empirical formula. Explain.

Ans. Different compounds will never have the same molecular formula because different compounds have different elements combined in a fixed ratio.

Empirical formula does not show tell us the actual number of atom present in that compound, rather it represents the simplest ratio between atoms.

It is possible that some compound may have same empirical formula.

**Example:** Both benzene ( $C_6H_6$ ) and acetylene ( $C_2H_2$ ) have same empirical formula, CH.

ii. Write down the chemical formulas of the following compounds.

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

Ans. Calcium phosphate =  $Ca_3(PO_4)_2$   
Aluminum nitride =  $AlN$   
Sodium acetate =  $CH_3COONa$   
Ammonium carbonate =  $(NH_4)_2CO_3$   
Bismuth sulphate =  $Bi_2(SO_4)_3$

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

Ans. Avogadro's number is important because it connects the microscopic world of atoms and molecules to the macroscopic world we experience every day.

Avogadro's number allows the scientists to calculate the number of particles in a given substance.

iv. 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.

Sol.

|                                     |   |                                  |
|-------------------------------------|---|----------------------------------|
| Mass of compound                    | = | 8.657 g                          |
| Mass of carbon                      | = | 5.217 g                          |
| Mass of hydrogen                    | = | 0.962 g                          |
| Mass of oxygen                      | = | 2.478 g                          |
| <b>% age of carbon</b>              |   |                                  |
| 8.657 g of compound contains carbon | = | 5.217 g                          |
| 1 g of compound contains carbon     | = | $\frac{5.217g}{8.657g}$          |
| 100 g of compound contains carbon   | = | $\frac{5.217}{8.657} \times 100$ |
| 100 g of compound contains carbon   | = | 60.26 %                          |
| <b>% age of carbon</b>              | = | 60.26%                           |

**% age of hydrogen**

$$\begin{aligned}
 8.657 \text{ g of Compound contains hydrogen} &= 5.217 \text{ g} \\
 1 \text{ g of Compound contains hydrogen} &= \frac{0.962}{8.657} \\
 100 \text{ g of Compound contains hydrogen} &= \frac{0.962}{8.657} \times 100 \\
 \text{\% age of hydrogen} &= 11.11 \%
 \end{aligned}$$

**% age of oxygen**

$$\begin{aligned}
 8.657 \text{ g compound contains oxygen} &= 2.478 \% \\
 1 \text{ g compound contains oxygen} &= \frac{2.478}{8.657} \text{ g} \\
 100 \text{ g compound contains oxygen} &= \frac{2.478}{8.657} \times 100 \\
 \text{\% age of oxygen} &= 28.62 \%
 \end{aligned}$$

**v. How can you calculate the masses of the products formed in a reversible reaction?**

**Ans.** To calculate the masses of products formed in a reversible reaction, first write a balanced chemical equation, then convert the given mass of reactants into moles, use the mole ratio from the balanced equation to find the moles of product formed, and finally convert those moles back to mass by multiplying by the molar mass of the product.

**4 Descriptive Questions**

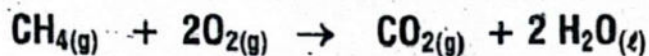
i. Which conditions must be fulfilled before writing a chemical equation for a reaction?

**Ans.** For answer See Q. 27 (b).

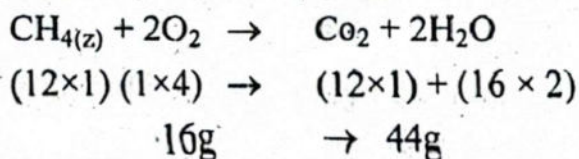
ii. Explain the concepts of Avogadro's number and mole.

**Ans.** For answer See Q. 21

iii. How many grams of  $\text{CO}_2$  will be produced when we react 10 g of  $\text{CH}_4$  with excess of  $\text{O}_2$  according to the following equation?



**Sol.** Balanced chemical equation



16 g of  $\text{CH}_4$  produces  $\text{CO}_2 = 44\text{g}$

$$1 \text{ g of CH}_4 \text{ produces CO}_2 = \frac{44}{16} \text{ g}$$

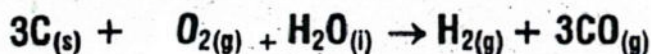
$$16 \text{ g of CH}_4 \text{ produces CO}_2 = \frac{44}{16} \times 10 \text{ g}$$

$$= 27.5 \text{ g}$$

**Result**

$$\text{The amount of CO}_2 = 27.5 \text{ g}$$

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



**Ans. Balanced chemical equation**



**From balanced chemical equation.**

$$3 \text{ moles of CO required moles of coal} = 3 \text{ moles}$$

$$1 \text{ moles of CO required moles of coal} = \frac{3}{3} \text{ mole}$$

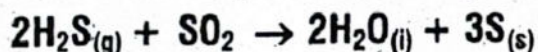
$$10 \text{ moles of CO required moles of coal} = \frac{3}{3} \times 10 = \frac{30}{3}$$

$$= 10 \text{ moles}$$

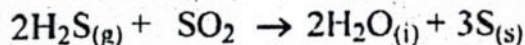
**Result:**

$$\text{Moles of coal} = 10 \text{ moles}$$

v. **How much SO<sub>2</sub> is needed in grams to produce 10 moles of sulphur?**



**Ans. Balanced chemical equation**



**From balanced chemical equation.**

$$3 \text{ moles of sulphur required SO}_2 = 1 \text{ mole}$$

$$1 \text{ moles of sulphur required SO}_2 = \frac{1}{3} \text{ mole}$$

$$10 \text{ moles of sulphur required SO}_2 = \frac{1}{3} \times 10 = \frac{30}{3}$$

$$= 3.33 \text{ moles}$$

$$\text{Moles of SO}_2 = 3.33 \text{ moles}$$

$$\text{Molar mass of SO}_2 = (32 \times 1) + (16 \times 2)$$

$$= 32 + 32 = 64 \text{ g}$$

$$\text{Mass in gram}$$

$$\text{No. of moles} = \frac{\text{Mass in gram}}{\text{Molar mass}}$$

**OR**

$$\text{Mass in grams} = \text{No. molar} \times \text{Molar mass}$$

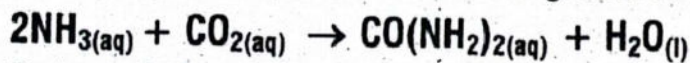
$$= 3.33 \times 64$$

$$= 213.12 \text{ g}$$

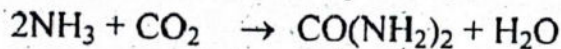
Result:

$$\text{No. of grams of SO}_2 = 213.12 \text{ g}$$

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



Sol. Balanced chemical equation



$$(14 \times 2) + (1 \times 6) \rightarrow (12 \times 1) + (16 \times 1) + (14 \times 2) + (1 \times 4)$$

$$34 \text{ kg} \rightarrow 60 \text{ kg}$$

$$60 \text{ Kg urea fertilizer required ammonia} = 34 \text{ kg}$$

$$1 \text{ Kg urea fertilizer required ammonia} = \frac{34}{60} \text{ kg}$$

$$= 0.566 \text{ kg}$$

$$\text{Amount of ammonia in kg} = 0.566 \text{ kg}$$

$$\text{Amount of ammonia in grams} = 0.566 \times 1000 \text{ g}$$

$$= 566 \text{ g}$$

$$\text{Result: Amount of ammonia in grams} = 566 \text{ g}$$

vii. Calculate the number of atoms in the following.

(a) 3g of H<sub>2</sub>

(b) 3.4 moles of N<sub>2</sub>

(c) 10g of C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>.

Ans. (a) 3g of H<sub>2</sub>

$$\text{Mole in grams} = 3 \text{ gm}$$

$$\text{Molar mass of H}_2 = 1 \times 2 = 2 \text{ g}$$

$$\text{No. of moles of H}_2 = \frac{3}{2} = 1.5 \text{ moles}$$

As.

$$\text{No. of particles (molecules)} = \text{No. of moles} \times \text{Avogadro's number}$$

$$= 1.5 \times 6.022 \times 10^{23} \text{ molecules}$$

$$= 9.033 \times 10 \text{ Avogadro's molecules}$$

$$1 \text{ molecule of hydrogen contain atoms} = 2 \text{ atoms}$$

$$9.033 \times 10^{23} \text{ molecules of hydrogen contain atoms}$$

$$= 2 \times 9.033 \times 10^{23} \text{ atoms}$$

$$= 1.8066 \times 10^{22} \text{ atoms}$$

Result:

$$\text{No. of atoms in 3g of hydrogen (H}_1) = 1.8066 \times 10^{22} \text{ atoms}$$

(b) 3.4 moles of N<sub>2</sub>

$$\text{Number of moles of N}_2 = 3.4 \text{ moles}$$

$$\text{As. No. of molecules of N}_2 = \text{No. of moles} \times \text{Avogadro's number}$$

$$= 3.4 \times 6.022 \times 10^{23} \text{ molecules}$$

$$= 20.4748 \times 10^{23} \text{ molecules}$$

As.

One mole of  $N_2$  contains atoms = 2 atoms

$$20.4748 \times 10^{23} \text{ molecule} = 2 \times 20.47 \times 10^{23} \text{ atoms}$$

$$\begin{aligned} \text{mole of } N_2 \text{ molecule contains atoms} &= 40.949 \times 10^{23} \text{ atoms} \\ &= 4.0949 \times 10^{22} \text{ atoms} \end{aligned}$$

**Result:**

$$3.4 \text{ moles of } N \text{ contains atoms} = 4.0949 \times 10^{22} \text{ atoms}$$

**(c) 10g of  $C_6H_{12}O_6$ .**

$$\begin{aligned} \text{Mass in grams of } C_6H_{12}O_6 &= (12 \times 6) + (1 \times 12) + (16 \times 6) \\ &= 180\text{g} \end{aligned}$$

$$\begin{aligned} \text{Molar mass of } C_6H_{12}O_6 &= (12 \times 6) + (1 \times 12) + (16 \times 6) \\ &= 180\text{g} \end{aligned}$$

As

$$\text{Number of moles} = \frac{\text{Mass in grams}}{\text{Molar mass}}$$

$$\text{Numbers. of moles} = \frac{10}{180} = 0.055 \text{ moles}$$

As

$$\begin{aligned} \text{No. of molecules} &= \text{No. of moles} \times \text{Avogadro's number} \\ &= 0.0555 \times 6.022 \times 10^{23} \end{aligned}$$

$$\text{No. of molecules} = 0.334 \times 10^{23} \text{ molecules}$$

$$1 \text{ molecules of } C_6H_{12}O_6 \text{ contains atoms} = 24 \text{ atoms.}$$

$$\begin{aligned} 0.334 \times 10^{23} \text{ molecules contains atoms} &= 24 \times 0.334 \times 10^{23} \text{ atoms} \\ &= 8.02 \times 10^{23} \text{ atoms} \end{aligned}$$

**Result**

$$\text{No. of atoms in 10g of } C_6H_{12}O_6 = 8.02 \times 10^{23} \text{ atoms}$$

### 5 Investigative Questions

- i. 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  $400 \text{ cm}^3$  of water on the average, how many moles of water are needed for a single adult?

$$\text{Ans. No. of glass of water required every day} = 8 \text{ glass}$$

$$\text{Volume of water occupied by one glass} = 400 \text{ cm}^3$$

$$\text{Volume occupied by 8 glass of water} = 8 \times 400$$

$$= 3200 \text{ cm}^3$$

As:

$$18 \text{ cm}^3 \text{ of water} = 1 \text{ mole}$$

$$1 \text{ cm}^3 \text{ of water} = \frac{1}{18} \text{ mole}$$

$$3200 \text{ cm}^3 \text{ of water} = \frac{1}{18} \times 3200$$

$$= 177.77 \text{ moles}$$

**Result:**

Water need by a single adult = 177.77 moles

- ii. **The chemical formula for sand is  $\text{SiO}_2$  but the sand does not exist in the form of discrete molecules like  $\text{H}_2\text{O}$ . How has its formula been determined keeping in view its structure?**

**Ans.** Some covalent compounds, like ionic compounds, do not exist in the form of molecules, rather they exist as network arrangement of atoms. Such covalent compounds are also given empirical formulas. For example,  $\text{SiO}_2$  is a covalent compound but it does not exist as individual molecules, rather silicon and oxygen atoms are arranged in such away that there exists a simple ratio of 1:2 between them. Therefore sand is represented by an empirical formula  $\text{SiO}_2$ .

