

Chapter	4 Stoichiometry	Class	1 st Year	Subject	Chemistry
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Give Short Answers of the Following Questions

1. Define Avogadro's number and molar volume.

Ans. Avogadro's number: "The number of particles (atoms, molecules, formula units or ions) which are present in one mole of a chemical substance is called Avogadro's number".

Equal volume of all the ideal gases at same temperature and pressure contain equal number of molecules.

- It is represented by N_A • Its unit is mol^{-1} • Its value is 6.022×10^{23}

Example:

$16\text{g CH}_4 = 1 \text{ mole of CH}_4 = 22.414 \text{ dm}^3 \text{ of CH}_4 = 6.02 \times 10^{23} \text{ molecules of CH}_4$.

Molar Volume:

"The volume occupied by one mole of an ideal gas at standard temperature and pressure (STP) i.e. 0°C and 1 atm is called molar volume".

Value: Its value is 22.414 dm^3 (0.022414 m^3 or 22414 cm^3)

Examples:

- (i) $2\text{g of H}_2 = 1 \text{ mole of H}_2 = 22.414 \text{ dm}^3$
- (ii) $16\text{g of CH}_4 = 1 \text{ mole of CH}_4 = 22.414 \text{ dm}^3$
- (iii) $44\text{g of CO}_2 = 1 \text{ mole of CO}_2 = 22.414 \text{ dm}^3$

From above examples it is clear that 1 mole of different gases e.g., 2g H_2 , 16g CH_4 , 44g CO_2 have same number of molecules and same volume (22.414 dm^3) at STP but different masses.

2. Define mole with two examples.

Ans. Mole: "The amount of a substance which contains Avogadro's number of particles (atoms, molecules, formula units, or ions) is called mole".

Examples:

- 1 mole of Na = 23 g
- 1 mole of H_2O = 18 g
- 1 mole of NaCl = 58.5 g
- 1 mole of HCO_3^- = 61 g

Formula: $\text{Mole} = \frac{\text{Given mass of the substance}}{\text{Molar mass}}$

3. Why 180 g of glucose and 342 g of sucrose have same number of molecules but different number of atoms?

Ans. Molar mass of glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) = 180 mol^{-1}

Molar mass of sucrose ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$) = 342 mol^{-1}

Both glucose and sucrose are molecular species. Therefore one mole contains same number of molecules i.e., Avogadro's number (6.02×10^{23}).

$180 \text{ g of glucose} = 1 \text{ mole} = 6.02 \times 10^{23} \text{ Molecules of glucose}$

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342 g of sucrose = 1 mole = 6.02×10^{23} Molecules of sucrose
 One molecule of glucose has differ number of atoms than one molecule of sucrose so one mole of each molecule contains different number of atoms in them.

As 1 molecule of glucose (contains) = 24 atoms

So, 1 mole glucose molecules (contains) = $24 \times 6.02 \times 10^{23}$ atoms

Similarly,

As 1 molecule of sucrose (contains) = 45 atoms

So, 1 mole of sucrose molecules (contains) = $45 \times 6.02 \times 10^{23}$ atoms

4. Calculate the number of oxygen atoms in 10.037g of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (Atomic mass of Cu = 63, H 1, O = 16).

Ans. Given Data: Mass of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ = 10.037 g

Required: Number of O atoms = ?

Solution:

$$\text{Number of moles of } \text{CuSO}_4 \cdot 5\text{H}_2\text{O} = \frac{\text{Mass of } \text{CuSO}_4 \cdot 5\text{H}_2\text{O}}{\text{Molar mass of } \text{CuSO}_4 \cdot 5\text{H}_2\text{O}}$$

$$\text{Molar Mass of } \text{CuSO}_4 \cdot 5\text{H}_2\text{O} = 63.5 + 32 + (4 \times 16) + (5 \times 18) = 249.5 \text{ g mol}^{-1}$$

$$\text{Number of moles of } \text{CuSO}_4 \cdot 5\text{H}_2\text{O} = \frac{10.037}{249.5} = 0.04 \text{ moles}$$

$$1 \text{ mole of } \text{CuSO}_4 \cdot 5\text{H}_2\text{O} \text{ have moles of O} = 9 \text{ moles}$$

$$0.04 \text{ moles of } \text{CuSO}_4 \cdot 5\text{H}_2\text{O} \text{ have moles of O} = 9 \times 0.04 = 0.36 \text{ moles}$$

$$\text{Number of oxygen atoms} = \text{Number of moles of oxygen atoms} \times N_A$$

$$= 0.36 \times 6.02 \times 10^{23}$$

$$\text{Number of oxygen atoms} = 2.167 \times 10^{23} \text{ atoms}$$

5. Calculate mass in Kg of 2.6×10^{20} molecules of SO_2 .

Ans. Given Data: Number of SO_2 molecules = 2.6×10^{20} molecules

Required: Mass in kg of SO_2 molecules = ?

$$\text{Solution: Number of } \text{SO}_2 \text{ molecules} = \frac{\text{Mass of } \text{SO}_2 \text{ molecules}}{\text{Molar mass of } \text{SO}_2} \times N_A$$

$$\text{Molar Mass of } \text{SO}_2 = 32 + (16 \times 2) = 64 \text{ g mol}^{-1}$$

$$2.6 \times 10^{20} = \frac{\text{Mass of } \text{SO}_2 \text{ molecules}}{64} \times 6.02 \times 10^{23}$$

$$\frac{2.6 \times 10^{20} \times 64}{6.02 \times 10^{23}} = \text{Mass of } \text{SO}_2 \text{ molecules}$$

$$27.641 \times 10^{-3} \text{ g} = \frac{27.641 \times 10^{-3}}{1000}$$

$$= 2.764 \times 10^{-5} \text{ kg} = \text{Mass of } \text{SO}_2 \text{ molecules}$$

6. Calculate the number of water molecules in 10 g of ice.

Ans. Given Data: Mass of ice (water) = 10.0gm

Molar mass of water = 18 g mol^{-1}

To Find: Number of molecules of water = ?

Solution:

$$\text{Number of molecules of water} = \frac{\text{Mass of water in gm}}{\text{Molar mass of water in } \text{g mol}^{-1}} \times \text{Avogadro's number}$$

$$= \frac{10}{18 \text{ g mol}^{-1}} \times 6.02 \times 10^{23}$$

$$= 0.55 \times 6.02 \times 10^{23} = 3.31 \times 10^{23}$$

7. Write down only steps to determine limiting reactant.

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Ans. Limiting Reactant:

“A reactant which is used or consumed earlier due to its lesser amount and controls the amount of product formed in a chemical reaction is called limiting reactant”.

A limiting reactant is that which

- | | |
|---|--|
| (i) Controls the amount of product formed | (ii) is taken in lesser amount |
| (iii) is consumed earlier | (iv) produces least amount of product. |

Identification of Limiting Reactant:

The following three steps should be followed to find out the limiting reactant:

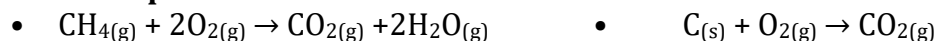
- Calculate the number of moles from the given amount of reactant.
- Find out the number of moles of product with the help of a balanced chemical equation.
- Identify the reactant which produces the least amount of product as limiting reactant.

8. Many reactions taking place in our surrounding involve limiting reactant. Justify with examples.

Ans. “The reactant which is consumed earlier and controls the amount of product in a chemical reaction is called a limiting reactant”.

Mostly combustion reactions taking place in our surrounding involve the limiting reactant.

For example:



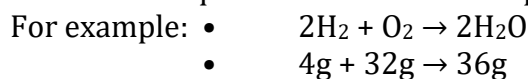
In above examples, O_2 gas is present in excess while CH_4 and C are the reactants which are consumed earlier so they are limiting reactants.

9. Law of conservation of mass has to be obeyed during stoichiometric calculations. Justify it.

Ans. According to law of conservation of mass.

“**Mass** can neither be created nor destroyed during a chemical reaction but it changes its form from one form to another”.

In stoichiometric calculations, we use balanced chemical equation where total mass of reactants is equal to the total mass of products.



So while doing stoichiometric calculations law of conservation of mass has to be obeyed.

10. What is stoichiometric? Which laws are obeyed during stoichiometric calculation?

Ans. Stoichiometry:

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

Assumptions:

When stoichiometric calculations are performed, we have to assume the following conditions:

- All the reactants are completely converted into products.
- No side reaction occurs.

During stoichiometric calculations, law of conservation of mass and law of definite proportions are obeyed.

11. Why theoretical yield of a chemical reaction is greater than the actual yield?

Ans. Actual yield of a chemical reaction is usually lesser than theoretical yield due to many reasons. They are:

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- (i) **Practically inexperienced** worker has many shortcomings and cannot get expected yield.
- (ii) **Mechanical loss** during experimentation e.g., filtration, separation by distillation or by a separating funnel, washing, drying and crystallization if not properly carried out, decrease the yield.
- (iii) Some of the reactants might take part in a competing side reaction.
- (iv) The reactants might be reversible.
- (v) The reactants might be impure.
- (vi) Sometimes the reaction conditions are not suitably maintained.

12. Differentiate between Theoretical and Experimental yield.

Ans.

Theoretical yield	Actual yield
1) The amount of product calculated from a balanced chemical equation is called theoretical yield.	1) The amount of product obtained while performing a chemical reaction is called actual yield.
2) It is also called expected yield or calculated yield.	2) It is also called experimental yield.
Theoretical yield is always greater than actual yield.	3) Actual yield is always lesser than theoretical yield.
No need to perform experiment. Just to calculate from balanced chemical equation.	In order to get actual yield experiment has to be performed.

13. How many moles of CO₂ can be produced from burning one mole of octane (mass of octane is 114)?

Ans. $2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$

Number of moles of octane = 2 moles

Number of moles of CO₂ = ?

2 moles of octane gives CO₂ = 16 moles

1 moles of octane gives CO₂ = 8 moles

14. How is the concept of mole derived from Avogadro's number?

Ans. Amedeo Avogadro proposed that:

"Equal volumes of gases, at the same temperature and pressure, contain equal numbers of molecules."

$$N_A = 6.02214076 \times 10^{23} \text{ particles per mole}$$

The mole (mol) was then defined as:

"The amount of substance containing exactly N_A elementary entities (atoms, molecules, ions etc)."

This means:

$$1 \text{ mol} = N_A \text{ particles} = 6.022 \times 10^{23} \text{ particles}$$

Derivation of molar mass

- The atomic mass unit (u) is defined based on ¹²C (12 u = mass of one ¹²C atom).
- Since N_A atoms of ¹²C weigh 12 grams, the molar mass (mass per mole) is numerically

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equal to the atomic/molecular mass in u:

Molar mass of ^{12}C = 12g/mol

We can calculate the number of moles by dividing the number of particles by Avogadro's number.

15. Define the following terms with one example in each case.

(a) Molar Mass

(b) Molar volume

(c) Molar concentration

Ans. (a) Molar Mass

The mass of one mole of a substance expressed in grams is called molar mass.

Molar mass of CCl_4 = Molar mass of one C + Molar mass of C $\times$ 4

Molar mass of CCl_4 = $12.0 \times 1 + 35.5 \times 4$

Molar mass of CCl_4 = $12.0 + 142.0 = 154.0 \text{ g}$

(b) Molar VOLUME

The volume of one mole of an ideal gas at STP (Standard temperature and pressure) is called molar volume. Its value is equal to 22.414 dm^3 . The value of molar volume is commonly rounded to 22.4 dm^3 . It is denoted by V_m . By using molar volume relationship, mass or mole of a gas at STP can be converted into volume, and vice versa.

(c) Molar Concentration

Molar concentration of solutions is given as mol/dm^3 , which is the number of moles of a substance (reactant or product) dissolved per volume of a solution in dm^3 . The relationship between number of moles and molar concentration is given by

$$n = C \times V$$

$$C = \frac{n}{V}$$

where C is the molar concentration and V is the volume of the solution.

Molar Concentration (C) = $\frac{\text{Number of moles (n)}}{\text{Volume in dm}^3 (V)}$

16. What do you mean by molar volume of a gas? How Avogadro's number is related with molar volume?

Ans. Molar Volume of a Gas:

The molar volume of a gas is the volume occupied by one mole of any ideal gas at standard temperature and pressure (STP).

- At STP (0°C or 273.15 K and 1 atm pressure),
- 1 mole of any ideal gas occupies 22.414 dm^3 (or liters).

Relation with Avogadro's Number:

Avogadro's number (6.022×10^{23} particles/mol) tells us that 1 mole of gas contains this many molecules. Therefore, 22.414 dm^3 of any ideal gas at STP contains exactly 6.022×10^{23} molecules.

Conclusion:

- Molar volume links the physical volume of a gas to the number of particles (via Avogadro's number) under standard conditions.

17. 39 g of potassium and 56 g of iron have equal number of atoms in them. Justify.

Ans. Molar mass of K (potassium) = 39 g/mol

Molar mass of Fe (iron) = 56 g/mol

It means Moles of K = 39 g/mol ; $39 \text{ g} = 1 \text{ mol}$

Moles of Fe = 56 g/mol ; $56 \text{ g} = 1 \text{ mol}$

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We know that 1 mole of any element contains Avogadro's number of atoms = 6.022×10^{23} atoms Thus,

39 g of K = 1 mol = 6.022×10^{23}

56 g of Fe = 1 mol = 6.022×10^{23}

In short, 39 g of potassium and 56 g of iron contain an equal number of atoms, because both represent 1 mole of their respective elements.

18.4 g of He, 17 g of NH₃ and 64 g of SO₂ occupy separately the volumes of 22.414 dm³ although the sizes and masses of molecules of three gases are very different from each other. Explain.

Ans. Molar Masses: He (helium) 4 g/mol, NH₃ (ammonia) 17 g/mol, SO₂ (sulfur dioxide) 64 g/mol At STP (Standard Temperature and Pressure), 1 mole of any ideal gas occupies: 22.414 dm³

Even though the masses and sizes of individual He, NH₃, and SO₂ molecules differ:

The **number of molecules** in each case is the same:

1 mol = 6.022×10^{23} molecules

The volume a gas occupies depends mainly on:

- Number of particles (moles)
- Temperature
- Pressure

It does not depend on mass or size of individual molecules (according to ideal gas behaviour).

Although He, NH₃, and SO₂ differ in molecular mass:

If you take **1 mole of each**, they will all occupy **22.414 dm³** at STP.

Because the **volume of a gas** is determined by **number of moles**, not the mass of molecules.

19. Do you think 1 mole of H₂ and 1 mole of NH₃ at 0 °C and 1 atm will have Avogadro's number of particles?

Ans. According to Avogadro's Law:

Equal volumes of all gases at the same temperature and pressure contain an equal number of molecules. 1 mole of H₂ (hydrogen gas) and 1 mole of NH₃ (ammonia gas) at 0°C and 1 atm will each contain Avogadro's number of particles, i.e.: 6.022×10^{23} molecules

1 mole of H₂ gas = 6.022×10^{23} H₂ molecules,

1 mole of NH₃ gas = 6.022×10^{23} NH₃ molecules.

20. What is stoichiometry? Give the basic assumptions of stoichiometric calculations.

Ans. Stoichiometry

Stoichiometry is a branch of chemistry which tells us the quantitative relationship between reactants and products in a balanced chemical equation.

Assumptions of Stoichiometry:

The following assumptions must be made while performing stoichiometric calculations:

- All the reactants are completely converted into the products.
- Law of conservation of mass and law of definite proportions are obeyed.
- No side reaction occurs.

21. What is a limiting reactant? How does it control the quantity of the product formed?

Ans. The limiting reactant (or limiting reagent) is the reactant that is completely consumed first during a chemical reaction. Once it is used up, the reaction stops, and no more product can

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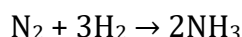
form, even If other reactants are still available.

Chemical reactions require specific mole ratios between reactants.

If one reactant runs out, the remaining reactants can't react further - they become excess.

The amount of product is directly determined by how much of the limiting reactant was present at the start.

Example:



Suppose we have:

1 mole of N_2 and 2 moles of H_2 . According to the equation, we need 3 moles of H_2 for every 1 mole of N_2 . But we only have 2 moles of H_2 . Thus H_2 is the limiting reactant.

22. Differentiate theoretical and actual yields. How is the percentage yield of a reaction calculated?

Ans. Differentiate Between Theoretical and Actual Yield

Theoretical yield	Actual yield
1. The amount of product calculated from a balanced chemical equation is called theoretical yield.	1. The amount of product obtained while performing a chemical reaction is called actual yield.
2. It is also called expected yield or calculated yield.	2. It is also called experimental yield.
3. Theoretical yield is always greater than actual yield.	3. Actual yield is always lesser than theoretical yield.
4. There is no need to perform experiment. It is easily calculated from balanced chemical equation.	4. In order to get actual yield experiment has to be performed.

We can calculate the percentage yield of a chemical reaction with the help of actual yield and theoretical yield of the reaction. The efficiency of a reaction is also expressed in the form of percentage yield.

$$\text{Percentage yield} = \frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100$$

Greater the percentage yield, more amount of reactants will convert into product and high will be the efficiency of the reaction i.e. % age yield $\propto$ Efficiency of the reaction.

23. What are the factors which are mostly responsible for the low yield of the products in chemical reactions?

Ans. Actual yield of a chemical reaction is usually lesser than theoretical yield due to many reasons. The reasons are:

- Practically inexperienced worker has many shortcomings and cannot get expected yield.
- Mechanical loss during experimentation e.g., filtration, separation by distillation or by a separating funnel, washing, drying and crystallization if not properly carried out, decrease the yield.
- Some of the reactants might take part in a competing side reaction.
- The reaction might be reversible.
- The reactants might be impure.
- Sometimes the reaction conditions are not suitably maintained.