3. True
4. **False** : Mass of a substance is a constant quantity but its weight varies from place to place.
5. True
6. **False** : Homogeneous as well as heterogeneous mixtures do not have sharp melting and boiling points.
7. True
8. **False** : 0.006 g contains one significant figure while 5.00×10^{-3} contains 3 significant figures.
9. True
10. True
11. True
12. True

4. two
7. Gay-Lussac law of gaseous volumes
8. 7.64×10^{-23} 9. 8/3 10. 2 : 11 11. 1.9
12. 0.65 13. 0.25 14. 1.8 g 15. CH

C. Choose the correct alternative

1. H_2 2. mole fraction 3. more 4. different
5. Dalton 6. 10^{-15} 7. pressure 8. two
9. 13.1 10. 9.0×10^{-5} g.

HOTS Higher Order Thinking Skills & Brain Twisting

QUESTIONS WITH ANSWERS

Q.1. In the combustion of methane in air, what is the limiting reactant and why ?

Ans. Methane is the limiting reactant because the other reactant is oxygen of the air which is always present in excess. Thus, the amounts of carbon dioxide and water formed will depend upon the amount of CH_4 burnt.

Q.2. What is kg-mole ? How many electrons are present in 1 kg mole of methane (CH_4)?

Ans. One kg-mole is the molecular mass of the substance expressed in kilograms. It is also called kilomole (k mol). One k mol contains 6.022×10^{26} particles. Thus,

1kg-mole of CH_4 contains 6.022×10^{26} molecules.

Since one molecule of methane contains 10 electrons and therefore, 1 kg mole of CH_4 contains $10 \times 6.022 \times 10^{26}$ $= 6.022 \times 10^{27}$ electrons.

Q.3. Which aqueous solution has higher concentration : 1 molar or 1 molal solution of the same solute. Give reason.

Ans. 1 molar aqueous solution has higher concentration than 1 molal solution.

A molar solution contains one mole of solute in one litre of solution while a one molal solution contains one mole of solute in 1000 g of solvent.

If density of water is 1, then one mole of solute is present in 1000 mL of water in 1 molal solution while one mole of solute is present in less than 1000 mL of water in 1 molar solution (1000 mL solution = amount of solute + amount of solvent). Thus, 1 molar solution is more concentrated.

Q.4. Will the molarity of a solution at 50°C be same, less or more than molarity at 25°C?

Ans. Molarity at 50°C of a solution will be less than that at 25°C because molarity decreases with increase in temperature. This is because volume of the solution increases with increase in temperature but number of moles of solution remain the same.

Q.5. Is the law of constant composition true for all types of compounds ? Explain why or why not.

Ans. No, law of constant composition is not true for all types of compounds. It is true for only those compounds which are obtained from one isotope. For example, carbon exists in two common isotopes : ^{12}C and ^{14}C. When it forms $^{12}CO_2$, the ratio of masses is 12 : 32 or 3 : 8. However, when it is formed from ^{14}C i.e., $^{14}CO_2$, the ratio will be 14 : 32 *i.e.*, 7 : 16, which is not same as in the first case.

Q.6. Why is molality preferred over molarity in expressing the concentration of a solution ?

Ans. Molality is the number of moles of a solute present in 1000 g of the solvent while molarity is the number of moles of solute present in 1000 mL of the solution. Thus, molality involves only masses which donot change with temperature whereas molarity involves volume which changes with temperature and hence molality is preferred over molarity.

Q.7. What is the difference in expressing a weight of a solid as 36.5×10^3 g and 36.50×10^3 g.

Ans. 36.5×10^3 g has three significant figures while 36.50×10^3 has four significant figures. Hence 36.50 represents greater accuracy than 36.5.

Q.8. How many significant figures are there in 'π' ?

Ans. Infinite number.

Q.9. In calculations involving more than one arithmetic operation, rounding off to the proper number of significant figures may be done once at the end if all the operations are multiplication and/or division or if they are all additions and/or subtractions but not if they are combinations of additions or subtractions with multiplications or divisions. Explain.

Ans. There are different rules for the number of significant digits in the answer to an addition or subtraction and to a multiplication or division. Therefore, they must be applied separately when a mixed calculation is performed.

Q.10. Calculate the molarity of water if its density is 1000 kg/m³.

Ans. Molarity of water means the number of moles of water in 1 litre of water.

1 L of water = 1000 cm³ = 1000 g

$(\because 1000 \text{ kg/m}^3 = 1 \text{g/cm}^3)$

$$1000 \text{ g of water} = \frac{1000}{18} = 55.56 \text{ moles}$$

$\therefore$ Molarity = **55.56 M.**

Q.11. Sulphuric acid is generally available in market as 18.0 M solution. How would you prepare 250 mL of 0.50 M aqueous H_2SO_4?

Ans. Applying molarity equation,

$$M_1V_1 = M_2V_2$$

Volume of 18 M (V_2) H_2SO_4 required to prepare 250 mL (V_1) of concentration 0.50 M (M_1).

$$0.50 \times 250 = 18 \times V_2$$

$$\therefore \quad V_2 = \frac{0.50 \times 250}{18} = 6.94 \text{ mL}$$

Volume of 18 M H_2SO_4 required = 6.94 mL

Volume of water required = 250 − 6.94 = **243.06 mL.**

Q.12. A compound (molecular mass = 246) has the following data :

Element	% Composition	Relative no. of atoms
A	9.76	0.406
B	13.01	0.406
C	26.01	1.625
D	51.22	2.846

From the data find out

(*i*) atomic masses of the elements A, B, C and D,

(*ii*) simple ratio,

(*iii*) molecular formula of the compound.

Ans. Step I. *To calculate the atomic masses :*

The relative number of atoms

$$= \frac{\text{Percentage of element}}{\text{Atomic mass}}$$

$$\text{Atomic mass} = \frac{\text{Percentage of element}}{\text{Relative number of atoms}}$$

$$\therefore \quad \text{Atomic mass of A} = \frac{9.76}{0.406} = 24,$$

$$\text{Atomic mass of B} = \frac{13.01}{0.406} = 32$$

$$\therefore \quad \text{Atomic mass of C} = \frac{26.01}{1.625} = 16,$$

$$\text{Atomic mass of D} = \frac{51.22}{2.846} = 18$$

Step II. *To calculate the simple ratio of atoms.*

Element	Relative no. of atoms	Simple atomic ratio
A	0.406	$\frac{0.406}{0.406} = 1$
B	0.406	$\frac{0.406}{0.406} = 1$
C	1.625	$\frac{1.625}{0.406} = 4$
D	2.846	$\frac{2.846}{0.406} = 7$

Thus, the atomic ratio of A : B : C : D is 1 : 1 : 4 : 7.

Hence, the empirical formula = $\mathbf{ABC_4D_7}$.

Step III. *Calculation of molecular formula*

Empirical formula mass = 24 + 32 + 4 × 16 + 7 × 18 = 246

$$n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}} = \frac{246}{246} = 1$$

Molecular formula of compound $= (ABC_4D_7)_1 = ABC_4D_7$

Q.13. A compound on analysis gave the following percentage composition : Sodium = 18.59%, Sulphur = 25.80%, Hydrogen = 4.03% and Oxygen = 51.58%. Calculate the molecular formula of crystalline salt on the assumption that all the hydrogen atoms in the compound are present in combination with oxygen as water of crystallisation. The molecular weight of the compound is 248 a.m.u.

Solution.

Step I. *Calculation of empirical formula*

Element	Percentage of element	At. mass	Moles of atoms	Mole ratio
Na	18.59	23	$\frac{18.59}{23} = 0.80$	$\frac{0.80}{0.80} = 1$
S	25.80	32	$\frac{25.80}{32} = 0.80$	$\frac{0.80}{0.80} = 1$
H	4.03	1	$\frac{4.03}{1} = 4.03$	$\frac{4.03}{0.80} = 5$
O	51.58	16	$\frac{51.58}{16} = 3.22$	$\frac{3.22}{0.80} = 4$

Thus, the simple ratio of Na : S : H : O is 1 : 1 : 5 : 4. Therefore, the empirical formula of the compound is $NaSH_5O_4$.

Step II. *Calculation of molecular formula*

Empirical formula mass = 23 + 32 + 5 × 1 + 4 × 16 = 124

Molecular mass = 248

$$n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}} = \frac{248}{124} = 2$$

∴ Molecular formula = $(NaSH_5O_4)_2$

$= Na_2S_2H_{10}O_8$

Since all the 10 hydrogen atoms are present as water molecules (H_2O), the total number of water molecules is $5H_2O$.

Molecular formula = $\mathbf{Na_2S_2O_3 . 5H_2O}$

Q.14. The vapour density of a mixture of NO_2 and N_2O_4 is 38.3 at 26.7°C. Calculate the number of moles of NO_2 in 100 g of the mixture.

Ans. V.D. of mixture of NO_2 and N_2O_4 = 38.3

Mol. wt. of mixture of NO_2 and N_2O_4 = 38.3 × 2 = 76.6

(Mol. wt. = 2 × V.D.)

Let NO_2 present in 100 g of mixture = x

N_2O_4 present in 100 g of mixture = $100 - x$

Mol. wt. of NO_2 = 46, Mol. wt. of N_2O_4 = 92

Now,
$$\frac{x}{46} + \frac{100-x}{92} = \frac{100}{76.6}$$

Solving for x, we get x = 20.1 g

∴ Moles of NO_2 in the mixture = $\frac{20.1}{46}$

= **0.437**

Q.15. A solid mixture (5.0 g) consisting of lead nitrate and sodium nitrate is heated below 600°C until the weight of the residue was constant. If the loss in weight is 28.0%, calculate the amount of lead nitrate and sodium nitrate in the mixture.

Ans. Let the amount of $NaNO_3$ in the mixture = x g

Amount of $Pb(NO_3)_2$ in the mixture = $(5 - x)$ g

$$2NaNO_3 \longrightarrow 2NaNO_2 + O_2\uparrow$$

$2(23 + 14 + 3 \times 16) = 170$ g $\quad\quad 2 \times 16 = 32$

$$2Pb(NO_3)_2 \longrightarrow 2PbO + O_2\uparrow + 4NO_2\uparrow$$

$2(207 + 28 + 96) = 662$ g $\quad\quad 2 \times 16 = 32 \quad 4 \times (14 + 32) = 184$ g

170 g of $NaNO_3$ give O_2 = 32 g

x g of $NaNO_3$ give $O_2 = \frac{32}{170} \times x$ g

Similarly,

662 g of $Pb(NO_3)_2$ give O_2 and NO = 216 g

$(5 - x)$ g of $Pb(NO_3)_2$ give gases = $\frac{216}{662} \times (5 - x)$ g

Total loss on heating = $\frac{32x}{170} + \frac{216}{662}(5 - x)$

Actual loss on heating = 28% of 5 g = $\frac{28 \times 5}{100}$ = 1.4 g

∴ $\frac{32x}{170} + \frac{216}{662}(5 - x) = 1.4$

Solving for x, we get x = 1.676 g

∴ Wt. of $NaNO_3$ = **1.676 g**

Wt. of $Pb(NO_3)_2$ = 5 − 1.676

= **3.324 g.**

Q.16. A sample of hard water contains 20 mg of Ca^{2+} ions per litre. How many milliequivalents of Na_2CO_3 would be required to soften 1 litre of sample?

Ans. $$Ca^{2+} + Na_2CO_3 \longrightarrow CaCO_3 + 2Na^+$$

40 g $\quad\quad$ 106 g

40 g of Ca^{2+} react with Na_2CO_3 = 106 g

20×10^{-3} g of Ca^{2+} react with $Na_2CO_3 = \frac{106}{40} \times 20 \times 10^{-3}$

$= 5.3 \times 10^{-2}$ g

Eq. wt. of $Na_2CO_3 = \frac{\text{Mol. wt.}}{2} = \frac{106}{2} = 53$

Equivalents of $Na_2CO_3 = \frac{5.3 \times 10^{-2}}{53} = 1 \times 10^{-3}$ equiv.

Milliequivalents of $Na_2CO_3 = \frac{1 \times 10^{-3}}{10^{-3}}$

= **1 milliequivalent.**

Q.17. Igniting MnO_2 converts it quantitatively to Mn_3O_4. A sample of pyrolusite is of the following composition :

MnO_2 = 80%, SiO_2 and other inert contents = 15%, rest being water.

The sample is ignited in air to constant weight. What is the percentage of Mn in the ignited sample? (At. wt. of Mn = 55).

Ans. $$3MnO_2 \longrightarrow Mn_3O_4 + O_2$$

$3(55 + 2 \times 16) = 261$ g $\quad\quad 3 \times 55 + 4 \times 16 = 229$ g

Let the amount of pyrolusite ignited = 100 g

Wt. of MnO_2 = 80 g

Wt. of SiO_2 and other inert contents = 15 g

Wt. of water = 100 − (80 + 15) = 5 g

Now, 261 g of MnO_2 gives Mn_3O_4 = 229 g

$$80 \text{ g of } MnO_2 \text{ give } Mn_3O_4 = \frac{229}{261} \times 80 = 70.19 \text{ g.}$$

During ignition, water present in pyrolusite is removed while SiO_2 and other inert contents remain as such.

Total wt. of residue = 70.19 + 15 = 85.19 g

$$\therefore \text{Percentage of } Mn_3O_4 \text{ in the residue} = \frac{70.19}{85.19} \times 100 = 82.39\%$$

Now	3 Mn	=	Mn_3O_4
	3 × 55		3 × 55 + 4 × 16
	= 165		= 229

$\therefore$ 229 g of Mn_3O_4 contain Mn = 165

$$82.39 \text{ g of } Mn_3O_4 \text{ contain Mn} = \frac{165}{229} \times 82.39 = 59.36 \text{ g}$$

$\therefore$ Percentage of Mn in ignited sample = **59.36%**

Q.18. The density of gold is 19.3 g cm^{-3}. Calculate the diameter of a solid gold sphere having a mass of 422 g.

Ans. Volume of gold sphere $= \dfrac{\text{Mass}}{\text{Density}}$

$$= \frac{422 \text{ g}}{19.3 \text{ g cm}^{-3}} = 21.865 \text{ cm}^3$$

$$\text{Volume of sphere} = \frac{4}{3}\pi r^3$$

$$\text{or radius, } r = \left(\text{Volume} \times \frac{3}{4\pi}\right)^{1/3}$$

$$= \left(\frac{21.865 \times 3 \times 7}{4 \times 22}\right)^{1/3}$$

$$= (5.218)^{1/3} = 1.73 \text{ cm}$$

$$\therefore \text{Diameter} = 2 \times r = 1.73 \times 2 = \mathbf{3.46 \text{ cm}}$$

Q.19. Lithium oxide is used to remove water from air according to the reaction :

$$Li_2O(s) + H_2O(g) \longrightarrow 2LiOH(s)$$

If 72 kg of water is to be removed and 35 kg of Li_2O is available

(i) which reactant is limiting ?

(ii) how many kg of excess reactant is left ?

Ans. Moles of water $= \dfrac{72 \times 10^3}{18}$

$$= 4 \times 10^3 \text{ mol}$$

$$\text{Moles of } Li_2O = \frac{35 \times 10^3}{30} = 1.167 \times 10^3 \text{ mol}$$

(i) Li_2O is limiting reagent because 1 mole of Li_2O reacts with 1 mole of water.

(ii) Moles of water which will react = 1.167×10^3 mol

Moles of water left unreacted

$$= 4 \times 10^3 - 1.167 \times 10^3 = 2.833 \times 10^3$$

$$\text{Mass of water left} = 2.833 \times 10^3 \times 18 = \mathbf{50.99 \text{ kg}}$$

Q.20. P_4O_6 and P_4O_{10} are formed by burning P_4 with O_2 as :

$$P_4 + 3O_2 \longrightarrow P_4O_6$$

$$P_4 + 5O_2 \longrightarrow P_4O_{10}$$

What are the masses of P_4O_6 and P_4O_{10} that will be produced by the combustion of 2.0 g of P_4 in 2.0 g of oxygen leaving no P_4 and O_2 ?

Ans. P_4O_6 and P_4O_{10} are formed as :

$$P_4 + 3O_2 \longrightarrow P_4O_6$$

$$P_4 + 5O_2 \longrightarrow P_4O_{10}$$

Let x be the mass of P_4 that is converted into P_4O_6 so that

Mass of P_4 which is converted to $P_4O_{10} = 2 - x$

Mass of oxygen required for forming P_4O_6

$$= \frac{x}{4 \times 31} \times 96$$

Mass of oxygen required for forming P_4O_{10}

$$= \frac{2-x}{4 \times 31} \times 160$$

Total oxygen required,

$$\left(\frac{x}{4 \times 31} \times 96\right) + \left(\frac{2-x}{4 \times 31} \times 160\right) = 2.0$$

$$\text{or} \quad \frac{96x}{124} + \frac{320}{124} - \frac{160x}{124} = 2.0$$

$$\text{or} \quad -\frac{64x}{124} = 2.0 - \frac{320}{124}$$

$$\text{or} \quad -\frac{64x}{124} = -\frac{72}{124}$$

$$x = \frac{72}{64} = 1.125 \text{ g}$$

Mass of P_4O_6 formed

$$= \frac{\text{Mass of } P_4}{\text{Molar mass of } P_4} \times \text{Molar mass of } P_4O_6$$

$$= \frac{1.125}{124} \times 220 = 1.996\,g$$

Mass of P_4P_{10} formed

$$= \frac{\text{Mass of } P_4}{\text{Molar mass of } P_4} \times \text{Molar mass of } P_4O_{10}$$

$$= \frac{0.875}{124} \times 284 = 2.004\,g$$

Revision Exercises

Very Short Answer Questions *carrying 1 mark*

1. Define Avogadro's law.
2. What is meant by a.m.u. ?
3. Define significant figure.
4. What is a mole ?
5. Define precision.
6. State the law of definite proportions.

...of an element.

30. What volume will 250 g of mercury occupy ? (Density of mercury = 13.6 g cm^{-3}).

Short Answer Questions *Carrying 2 or 3 marks*

1. What do you understand by the terms element, compound and mixture ? Give two examples in each case.
2. Explain the term m... What does one mole of ammonia represe...