

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  $5.00 \times 10^{-3}$  contains 3 significant figures.  
 9. True  
 10. True  
 11. True  
 12. True

4. two  
 7. Gay-Lussac law of gaseous volumes  
 8.  $7.64 \times 10^{-23}$   
 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.  $9.0 \times 10^{-5}$  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  $6.022 \times 10^{26}$  particles. Thus,

1kg-mole of  $CH_4$  contains  $6.022 \times 10^{26}$  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  $50^\circ C$  be same, less or more than molarity at  $25^\circ C$ ?**

**Ans.** Molarity at  $50^\circ C$  of a solution will be less than that at  $25^\circ C$  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 do not 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  $36.5 \times 10^3$  g and  $36.50 \times 10^3$  g.**

**Ans.**  $36.5 \times 10^3$  g has three significant figures while  $36.50 \times 10^3$  has four significant figures. Hence 36.50 represents greater accuracy than 36.5.

**Q.8. How many significant figures are there in  $\pi$ ?**

**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  $1000 \text{ kg/m}^3$ .**

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

$$\begin{aligned} 1 \text{ L of water} &= 1000 \text{ cm}^3 = 1000 \text{ g} \\ & \quad (\because 1000 \text{ kg/m}^3 = 1 \text{ g/cm}^3) \\ &= \frac{1000}{18} \\ &= 55.56 \text{ moles} \end{aligned}$$

$$\therefore \text{Molarity} = 55.56 \text{ M.}$$

**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  $\text{H}_2\text{SO}_4$ ?**

**Ans.** Applying molarity equation,

$$\begin{aligned} M_1 V_1 &= M_2 V_2 \\ \text{Volume of } 18 \text{ M } (V_2) \text{ } \text{H}_2\text{SO}_4 \text{ required to prepare } 250 \text{ mL} \\ (V_1) \text{ of concentration } 0.50 \text{ M } (M_1). \\ 0.50 \times 250 &= 18 \times V_2 \end{aligned}$$

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

Volume of 18 M  $\text{H}_2\text{SO}_4$  required = 6.94 mL

Volume of water required =  $250 - 6.94 = 243.06 \text{ mL}$ .

**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

- atomic masses of the elements A, B, C and D,
- simple ratio,
- molecular formula of the compound.

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

The relative number of atoms

$$\begin{aligned} &= \frac{\text{Percentage of element}}{\text{Atomic mass}} \\ \text{Atomic mass} &= \frac{\text{Percentage of element}}{\text{Relative number of atoms}} \end{aligned}$$

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

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

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

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

**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 =  $\text{ABC}_4\text{D}_7$ .

**Step III. Calculation of molecular formula**

$$\begin{aligned} \text{Empirical formula mass} &= 24 + 32 + 4 \times 16 + 7 \times 18 \\ &= 246 \end{aligned}$$

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

$$\begin{aligned} \text{Molecular formula of compound} &= (\text{ABC}_4\text{D}_7)_1 \\ &= \text{ABC}_4\text{D}_7 \end{aligned}$$

**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  $\text{NaSH}_5\text{O}_4$ .

## Step II. Calculation of molecular formula

$$\text{Empirical formula mass} = 23 + 32 + 5 \\ \times 1 + 4 \times 16 = 124$$

$$\text{Molecular mass} = 248$$

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

$$\therefore \text{Molecular formula} = (\text{NaSH}_5\text{O}_4)_2 \\ = \text{Na}_2\text{S}_2\text{H}_{10}\text{O}_8$$

Since all the 10 hydrogen atoms are present as water molecules ( $\text{H}_2\text{O}$ ), the total number of water molecules is  $5\text{H}_2\text{O}$ .

$$\text{Molecular formula} = \text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$$

**Q.14.** The vapour density of a mixture of  $\text{NO}_2$  and  $\text{N}_2\text{O}_4$  is 38.3 at  $26.7^\circ\text{C}$ . Calculate the number of moles of  $\text{NO}_2$  in 100 g of the mixture.

$$\text{Ans. V.D. of mixture of } \text{NO}_2 \text{ and } \text{N}_2\text{O}_4 = 38.3$$

$$\text{Mol. wt. of mixture of } \text{NO}_2 \text{ and } \text{N}_2\text{O}_4 = 38.3 \times 2 = 76.6 \\ (\text{Mol. wt.} = 2 \times \text{V.D.})$$

$$\text{Let } \text{NO}_2 \text{ present in 100 g of mixture} = x$$

$$\text{N}_2\text{O}_4 \text{ present in 100 g of mixture} = 100 - x$$

$$\text{Mol. wt. of } \text{NO}_2 = 46, \text{ Mol. wt. of } \text{N}_2\text{O}_4 = 92$$

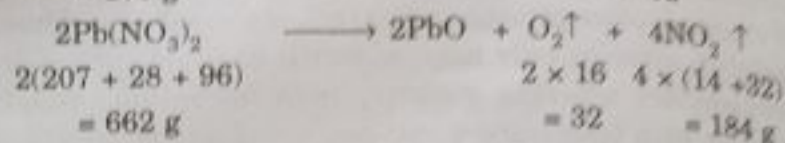
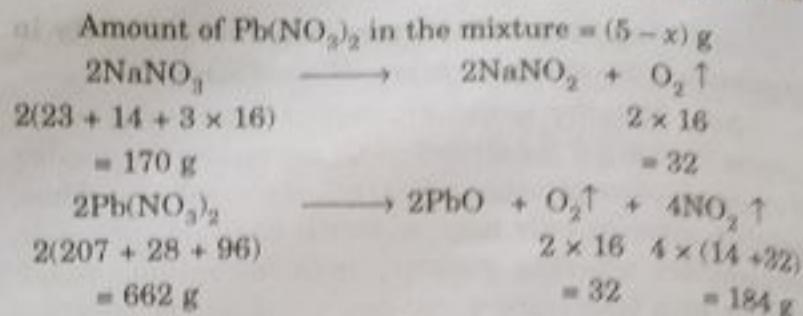
$$\text{Now, } \frac{x}{46} + \frac{100-x}{92} = \frac{100}{76.6}$$

$$\text{Solving for } x, \text{ we get } x = 20.1 \text{ g}$$

$$\therefore \text{Moles of } \text{NO}_2 \text{ in the mixture} = \frac{20.1}{46} \\ = 0.437$$

**Q.15.** A solid mixture (5.0 g) consisting of lead nitrate and sodium nitrate is heated below  $600^\circ\text{C}$  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  $\text{NaNO}_3$  in the mixture =  $x$  g



$$170 \text{ g of } \text{NaNO}_3 \text{ give } \text{O}_2 = 32 \text{ g}$$

$$x \text{ g of } \text{NaNO}_3 \text{ give } \text{O}_2 = \frac{32}{170} \times x \text{ g}$$

Similarly,

$$662 \text{ g of } \text{Pb}(\text{NO}_3)_2 \text{ give } \text{O}_2 \text{ and } \text{NO} = 216 \text{ g}$$

$$(5-x) \text{ g of } \text{Pb}(\text{NO}_3)_2 \text{ give gases} = \frac{216}{662} \times (5-x) \text{ g}$$

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

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

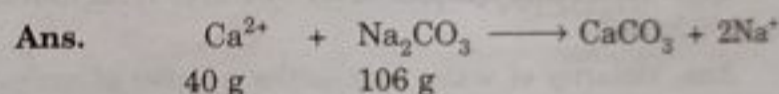
$$\therefore \frac{32x}{170} + \frac{216}{662}(5-x) = 1.4$$

$$\text{Solving for } x, \text{ we get } x = 1.676 \text{ g}$$

$$\therefore \text{Wt. of } \text{NaNO}_3 = 1.676 \text{ g}$$

$$\text{Wt. of } \text{Pb}(\text{NO}_3)_2 = 5 - 1.676 \\ = 3.324 \text{ g}$$

**Q.16.** A sample of hard water contains 20 mg of  $\text{Ca}^{2+}$  ions per litre. How many milliequivalents of  $\text{Na}_2\text{CO}_3$  would be required to soften 1 litre of sample?



$$40 \text{ g of } \text{Ca}^{2+} \text{ react with } \text{Na}_2\text{CO}_3 = 106 \text{ g}$$

$$20 \times 10^{-3} \text{ g of } \text{Ca}^{2+} \text{ react with } \text{Na}_2\text{CO}_3 = \frac{106}{40} \times 20 \times 10^{-3} \\ = 5.3 \times 10^{-2} \text{ g}$$

$$\text{Eq. wt. of } \text{Na}_2\text{CO}_3 = \frac{\text{Mol. wt.}}{2} = \frac{106}{2} = 53$$

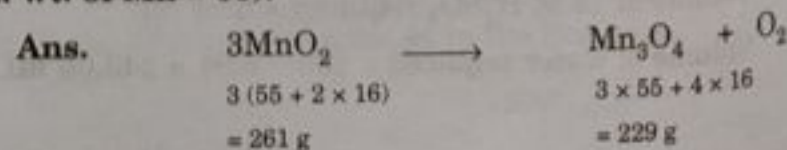
$$\text{Equivalents of } \text{Na}_2\text{CO}_3 = \frac{5.3 \times 10^{-2}}{53} = 1 \times 10^{-3} \text{ equiv.}$$

$$\text{Milliequivalents of } \text{Na}_2\text{CO}_3 = \frac{1 \times 10^{-3}}{10^{-3}} \\ = 1 \text{ milliequivalent.}$$

**Q.17.** Igniting  $\text{MnO}_2$  converts it quantitatively to  $\text{Mn}_3\text{O}_4$ . A sample of pyrolusite is of the following composition :

$\text{MnO}_2 = 80\%$ ,  $\text{SiO}_2$  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).



Let the amount of pyrolusite ignited = 100 g

Wt. of  $\text{MnO}_2$  = 80 g

Wt. of  $\text{SiO}_2$  and other inert contents = 15 g

Wt. of water =  $100 - (80 + 15) = 5$  g

Now, 261 g of  $\text{MnO}_2$  gives  $\text{Mn}_3\text{O}_4$  = 229 g

$$\begin{aligned} 80 \text{ g of } \text{MnO}_2 \text{ give } \text{Mn}_3\text{O}_4 &= \frac{229}{261} \times 80 \\ &= 70.19 \text{ g.} \end{aligned}$$

During ignition, water present in pyrolusite is removed while  $\text{SiO}_2$  and other inert contents remain as such.

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

$$\begin{aligned} \therefore \text{Percentage of } \text{Mn}_3\text{O}_4 \text{ in the residue} &= \frac{70.19}{85.19} \times 100 \\ &= 82.39\% \end{aligned}$$

$$\begin{array}{l} \text{Now} \quad 3 \text{ Mn} \quad = \quad \text{Mn}_3\text{O}_4 \\ \quad 3 \times 55 \quad \quad \quad 3 \times 55 + 4 \times 16 \\ \quad = 165 \quad \quad \quad = 229 \end{array}$$

$\therefore$  229 g of  $\text{Mn}_3\text{O}_4$  contain Mn = 165

$$\begin{aligned} 82.39 \text{ g of } \text{Mn}_3\text{O}_4 \text{ contain Mn} &= \frac{165}{229} \times 82.39 \\ &= 59.36 \text{ g} \end{aligned}$$

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

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

$$\begin{aligned} \text{Ans. Volume of gold sphere} &= \frac{\text{Mass}}{\text{Density}} \\ &= \frac{422 \text{ g}}{19.3 \text{ g cm}^{-3}} \\ &= 21.865 \text{ cm}^3 \end{aligned}$$

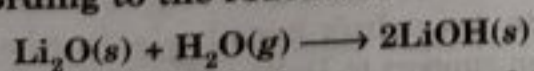
$$\text{Volume of sphere} = \frac{4}{3}\pi r^3$$

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

$$\begin{aligned} &= \left( \frac{21.865 \times 3 \times 7}{4 \times 22} \right)^{1/3} \\ &= (5.218)^{1/3} = 1.73 \text{ cm} \end{aligned}$$

$$\begin{aligned} \therefore \text{Diameter} &= 2 \times r \\ &= 1.73 \times 2 = 3.46 \text{ cm} \end{aligned}$$

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



If 72 kg of water is to be removed and 35 kg of  $\text{Li}_2\text{O}$  is available

(i) which reactant is limiting ?

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

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

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

$$\text{Moles of } \text{Li}_2\text{O} = \frac{35 \times 10^3}{30}$$

$$= 1.167 \times 10^3 \text{ mol}$$

(i)  $\text{Li}_2\text{O}$  is limiting reagent because 1 mole of  $\text{Li}_2\text{O}$  reacts with 1 mole of water.

(ii) Moles of water which will react =  $1.167 \times 10^3$  mol

Moles of water left unreacted

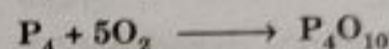
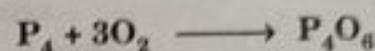
$$= 4 \times 10^3 - 1.167 \times 10^3$$

$$= 2.833 \times 10^3$$

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

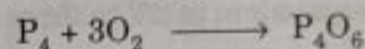
$$= 50.99 \text{ kg}$$

**Q.20.**  $\text{P}_4\text{O}_6$  and  $\text{P}_4\text{O}_{10}$  are formed by burning  $\text{P}_4$  with  $\text{O}_2$  as :



What are the masses of  $\text{P}_4\text{O}_6$  and  $\text{P}_4\text{O}_{10}$  that will be produced by the combustion of 2.0 g of  $\text{P}_4$  in 2.0 g of oxygen leaving no  $\text{P}_4$  and  $\text{O}_2$  ?

**Ans.**  $\text{P}_4\text{O}_6$  and  $\text{P}_4\text{O}_{10}$  are formed as :



Let  $x$  be the mass of  $\text{P}_4$  that is converted into  $\text{P}_4\text{O}_6$  so that

Mass of  $\text{P}_4$  which is converted to  $\text{P}_4\text{O}_{10} = 2 - x$

Mass of oxygen required for forming  $\text{P}_4\text{O}_6$

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

Mass of oxygen required for forming  $\text{P}_4\text{O}_{10}$

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

Total oxygen required,

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

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

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

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

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

Mass of  $\text{P}_4\text{O}_6$  formed

$$= \frac{\text{Mass of } \text{P}_4}{\text{Molar mass of } \text{P}_4} \times \text{Molar mass of } \text{P}_4\text{O}_6$$

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

Mass of  $P_4P_{10}$  formed

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

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



## 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.

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

### 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 mole. What does one mole of ammonia represent ?