CHAPTER 15

STOICHIOMETRY
(Chemical Formulae and Equations)

In the discovery of a new chemical compound, the first question to answer is, what is the formula of the compound? The answer begins with stoichiometric calculation and analysis of the compound.

The percentage composition of a compound leads directly to its empirical formula. An **empirical formula** or simplest formula for a compound is the formula of a substance written with the smallest integer (whole number) subscripts.

The molecular formula of a compound is a multiple of its empirical formula.

$$\text{Molecular mass} = n \times \text{empirical formula mass.}$$

The calculations of empirical and molecular formulae are dealt in the very first chapter of this book.

Stoichiometry: Quantitative Relations in Chemical Reactions

Stoichiometry is the calculation of the quantities of reactants and products involved in a chemical reaction.

It is based on the chemical equation and on the relationship between mass and moles.

A chemical equation can be interpreted as follows:

$$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$$

$$\text{1 molecule } N_2 + \text{3 molecules } H_2 \longrightarrow \text{2 molecules } NH_3$$

(Molecular interpretation)

$$\text{1 mol } N_2 + \text{3 mol } H_2 \longrightarrow \text{2 mol } NH_3 \quad \text{(Molar interpretation)}$$

$$28 \text{ g } N_2 + 6 \text{ g } H_2 \longrightarrow 34 \text{ g } NH_3 \quad \text{(Mass interpretation)}$$

$$\text{1 vol. } N_2 + \text{3 vol. } H_2 \longrightarrow \text{2 vol. } NH_3 \quad \text{(Volume interpretation)}$$

Thus, calculations based on chemical equations are divided into four types:

(i) Calculations based on mole-mole relationship.
(ii) Calculations based on mass-mass relationship.
(iii) Calculations based on mass-volume relationship.
(iv) Calculations based on volume-volume relationship.

(i) Calculations based on mole-mole relationship

In such calculations, number of moles of reactants are given and those of products required. Conversely, if number of moles of products are given, then number of moles of reactants are required.

SOME SOLVED EXAMPLES

Example 1. *Oxygen is prepared by catalytic decomposition of potassium chlorate ($KClO_3$). Decomposition of potassium chlorate gives potassium chloride (KCl) and oxygen (O_2). How many moles and how many grams of $KClO_3$ are required to produce 2.4 mole O_2?*

Solution: Decomposition of $KClO_3$ takes place as,

$$2KClO_3(s) \longrightarrow 2KCl(s) + 3O_2(g)$$

$$\text{2 mole of } KClO_3 \equiv \text{3 mole of } O_2$$

$\because$ 3 mole O_2 formed by 2 mole $KClO_3$

$\therefore$ 2.4 mole O_2 will be formed by $\left(\frac{2}{3} \times 2.4\right)$ mole $KClO_3$

$$= 1.6 \text{ mole of } KClO_3$$

$$\text{Mass of } KClO_3 = \text{Number of moles} \times \text{Molar mass}$$

$$= 1.6 \times 122.5 = 196 \text{ g}$$

ILLUSTRATIONS OF OBJECTIVE QUESTIONS

1. One mole of calcium phosphide on reaction with excess of water gives:
(a) three moles of phosphine
(b) one mole of phosphoric acid
(c) two moles of phosphine
(d) one mole of P_2O_5

[**Ans.** (c)]

[**Hint:** $Ca_3P_2 + 6H_2O \longrightarrow 3Ca(OH)_2 + 2PH_3$

1 mole of $Ca_3P_2 \equiv$ 2 mole of PH_3]

2. $Mg(OH)_2$ in the form of milk of magnesia is used to neutralize excess stomach acid. How many moles of stomach acid can be neutralized by 1 g of $Mg(OH)_2$? (Molar mass of $Mg(OH)_2$ = 58.33)

(a) 0.0171 (b) 0.0343 (c) 0.686 (d) 1.25

[**Ans.** (b)]

[**Hint:** $Mg(OH)_2 + 2HCl \longrightarrow MgCl_2 + 2H_2O$

Number of moles of stomach acid neutralized

$$= 2 \times \text{number of moles of } Mg(OH)_2$$

$$= 2 \times \frac{1}{58.33} = 0.0343]$$

3. When a mixture of 10 moles of SO_2 and 16 moles of O_2 were passed over a catalyst, 8 moles of SO_3 were formed at equilibrium. The number of moles of SO_2 and O_2 remaining unreacted were:

(a) 2, 12 (b) 12, 2 (c) 3, 10 (d) 10, 3

[**Ans.** (a)]

[**Hint:**

$$\begin{array}{cccccc} & 2SO_2(g) & + & O_2(g) & \rightleftharpoons & 2SO_3(g) \\ t=0 & 10 & & 16 & & 0 \\ t_{eq.} & (10-2x) & & (16-x) & & 2x \end{array}$$

$$2x = 8, \quad i.e., \quad x = 4$$

$\therefore$ Remaining $SO_2 = 10 - 8 = 2$ mol

Remaining $O_2 = 16 - 4 = 12$ mol]

4. Calcium carbonate decomposes on heating according to the following equation:

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$$

How many moles of CO_2 will be obtained by decomposition of 50 g $CaCO_3$?

(a) $\frac{3}{2}$ (b) $\frac{5}{2}$ (c) $\frac{1}{2}$ (d) 1

[**Ans.** (c)]

[**Hint:**

Number of moles of CO_2 = Number of moles of $CaCO_3$

$$= \frac{\text{Mass}}{\text{Molar mass}} = \frac{50}{100} = \frac{1}{2}]$$

5. Sulphur trioxide is prepared by the following two reactions:

$$S_8(s) + 8O_2(g) \longrightarrow 8SO_2(g)$$

$$2SO_2(g) + O_2(g) \longrightarrow 2SO_3(g)$$

How many grams of SO_3 are produced from 1 mole of S_8?

(a) 1280 (b) 640 (c) 960 (d) 320

[**Ans.** (b)]

[**Hint:** From the given reaction, it is clear that 1 mole of S_8 will give 8 moles of SO_3.

Mass of SO_3 formed = Number of moles × Molar mass

$$= 8 \times 80 = 640 \text{ g}]$$

(ii) Calculations based on mass-mass relationship

In making necessary calculations, following steps are followed:

(a) Write down the balanced chemical equation.

(b) Write down the theoretical amount of reactants and products involved in the reaction.

(c) Calculate the unknown amount of substance using unitary method.

SOME SOLVED EXAMPLES

Example 2. *Calculate the mass of (CaO) that can be prepared by heating 200 kg of limestone $CaCO_3$ which is 95% pure.*

Solution: Amount of pure $CaCO_3 = \frac{95}{100} \times 200 = 190$ kg

$$= 190000 \text{ g}$$

$$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$$

$$1 \text{ mole } CaCO_3 \equiv 1 \text{ mole } CaO$$

$$100 \text{ g } CaCO_3 \equiv 56 \text{ g } CaO$$

$\because$ 100 g $CaCO_3$ give 56 g CaO

$\therefore$ 190000 g $CaCO_3$ will give $\frac{56}{100} \times 190000$ g CaO

$$= 106400 \text{ g} = 106.4 \text{ kg}$$

Example 3. *Chlorine is prepared in the laboratory by treating manganese dioxide (MnO_2) with aqueous hydrochloric acid according to the reaction,*

$$MnO_2 + 4HCl \longrightarrow MnCl_2 + Cl_2 + 2H_2O$$

How many grams of HCl will react with 5 g MnO_2?

Solution: 1 mole of MnO_2 reacts with 4 mole of HCl

or 87 g MnO_2 reacts with 146 g HCl

$\therefore$ 5 g MnO_2 will react with $\frac{146}{87} \times 5$ g HCl = 8.39 g HCl

Example 4. *How many grams of oxygen are required to burn completely 570 g of octane?*

Solution: Balanced equation,

$$\underset{\substack{2\text{ mol} \\ 2\times 114}}{2C_8H_{18}} + \underset{\substack{25\text{ mol} \\ 25\times 32}}{25O_2} \longrightarrow 16CO_2 + 18H_2O$$

First method: For burning 2×114 g of octane, oxygen required

$$= 25 \times 32 \text{ g}$$

For burning 1 g of octane, oxygen required $= \frac{25 \times 32}{2 \times 114}$ g

Thus, for burning 570 g of octane, oxygen required

$$= \frac{25 \times 32}{2 \times 114} \times 570 \text{ g} = 2000 \text{ g}$$

Mole method: Number of moles of octane in 570 grams

$$= \frac{570}{114} = 5.0$$

For burning 2.0 moles of octane, oxygen required

$$= 25 \text{ mol} = 25 \times 32 \text{ g}$$

For burning 5 moles of octane, oxygen required

$$= \frac{25 \times 32}{2.0} \times 5.0 \text{ g} = 2000 \text{ g}$$

Proportion method: Let x g of oxygen be required for burning 570.0 g of octane. It is known that 2×114 g of the octane require 25×32 g of oxygen; then, the proportion,

$$\frac{25\times 32 \text{ g oxygen}}{2\times 114 \text{ g octane}} = \frac{x}{570.0 \text{ g octane}}$$

$$\therefore \quad x = \frac{25\times 32\times 570}{2\times 114} = 2000 \text{ g}$$

Example 5. *Calculate the number of grams of magnesium chloride that could be obtained from 17.0 g of HCl when HCl is reacted with an excess of magnesium oxide.*

Solution: Balanced equation,

$$\underset{1 \text{ mol}}{MgO} + \underset{\substack{2 \text{ mol} \\ (2\times 36.5)\text{g} \\ = 73\text{ g}}}{2HCl} \longrightarrow \underset{\substack{1 \text{ mol} \\ (24+71)\text{g} \\ = 95\text{ g}}}{MgCl_2} + \underset{1 \text{ mol}}{H_2O}$$

$$73 \text{ g of HCl produce } MgCl_2 = 95 \text{ g}$$

$$1 \text{ g of HCl produce } MgCl_2 = \frac{95}{73} \text{ g}$$

$$17 \text{ g of HCl will produce } MgCl_2 = \frac{95}{73}\times 17 \text{ g} = 22.12 \text{ g}$$

Example 6. *How many kilograms of pure H_2SO_4 could be obtained from 1 kg of iron pyrites (FeS_2) according to the following reactions?*

$$4FeS_2 + 11O_2 \longrightarrow 2Fe_2O_3 + 8SO_2$$
$$2SO_2 + O_2 \longrightarrow 2SO_3$$
$$SO_3 + H_2O \longrightarrow H_2SO_4$$

Solution: Final balanced equation,

$$\underset{\substack{4 \text{ mol} \\ 4\times 120\text{ g}}}{4FeS_2} + 15O_2 + 8H_2O \longrightarrow 2Fe_2O_3 + \underset{\substack{8 \text{ mol} \\ 8\times 98\text{ g}}}{8H_2SO_4}$$

$$4\times 120 \text{ g of } FeS_2 \text{ yield } H_2SO_4 = 8\times 98 \text{ g}$$

$$1000 \text{ g of } FeS_2 \text{ will yield } H_2SO_4 = \frac{8\times 98}{4\times 120}\times 1000$$

$$= 1.63 \text{ kg}$$

Limiting reagent: *Limiting reactant or reagent is the reactant that is entirely consumed when a reaction goes to completion.* Other reactants which are not completely consumed in the reaction are called excess reactants.

OR

The reactant which gives least amount of product on being completely consumed is called limiting reactant.

Example 7. *If 20 g of $CaCO_3$ is treated with 20 g of HCl, how many grams of CO_2 can be generated according to the following equation?*

$$CaCO_3(s) + 2HCl(aq.) \longrightarrow CaCl_2(aq.) + H_2O(l) + CO_2(g)$$

Solution:

$$\underset{\substack{1 \text{ mol} \\ 100\text{ g}}}{CaCO_3(s)} + \underset{\substack{2 \text{ mol} \\ 73\text{ g}}}{2HCl(aq.)} \longrightarrow CaCl_2(aq.) + H_2O(l) + \underset{\substack{1 \text{ mol} \\ 44\text{ g}}}{CO_2(g)}$$

Let $CaCO_3(s)$ be completely consumed in the reaction.

$\because$ 100 g $CaCO_3$ give 44 g CO_2

$\therefore$ 20 g $CaCO_3$ will give $\frac{44}{100}\times 20$ g CO_2 = 8.8 g CO_2

Let HCl be completely consumed.

$\because$ 73 g HCl give 44 g CO_2

$\therefore$ 20 g HCl will give $\frac{44}{73}\times 20$ g CO_2 = 12.054 g CO_2

Since, $CaCO_3$ gives least amount of product CO_2, hence, $CaCO_3$ is limiting reactant. Amount of CO_2 formed will be 8.8 g.

Example 8. *100 g sample of calcium carbonate is reacted with 70 g of orthophosphoric acid. Calculate:*

(*a*) *the number of grams of calcium phosphate that could be produced.*

(*b*) *the number of grams of excess reagent that will remain unreacted.*

Solution: (a) The balanced equation is:

$$\underset{\substack{3 \text{ mol} \\ 3(40+12+48) \\ = 300\text{ g}}}{3CaCO_3} + \underset{\substack{2 \text{ mol} \\ 2(3+31+64) \\ = 196\text{ g}}}{2H_3PO_4} \longrightarrow \underset{\substack{1 \text{ mol} \\ (3\times 40+2\times 95) \\ = 310\text{ g}}}{Ca_3(PO_4)_2} + 3CO_2 + 3H_2O$$

300 g of $CaCO_3$ produce $Ca_3(PO_4)_2$ = 310 g or 1 mol

100 g of $CaCO_3$ would produce

$$Ca_3(PO_4)_2 = \frac{310}{300}\times 100$$
$$= 103 \text{ g}$$
$$= 0.33 \text{ mol}$$

196 g of H_3PO_4 produce $Ca_3(PO_4)_2$ = 310 g or 1 mol

$$70 \text{ g of } H_3PO_4 \text{ would produce } Ca_3(PO_4)_2 = \frac{310}{196}\times 70$$
$$= 110.7 \text{ g or } 0.356 \text{ mol}$$

The above values suggest that $CaCO_3$ is the limiting reagent. Hence, calcium phosphate formed is 103 g or 0.33 mole.

(b) For producing 103 g of $Ca_3(PO_4)_2$, H_3PO_4 required will be

$$= \frac{196}{310}\times 103 = 65.12 \text{ g}$$

Mass of remaining H_3PO_4 = (70 − 65.12) = 4.88 g

Example 9. *1 g of Mg is burnt in a closed vessel which contains 0.5 g of O_2:*

(*i*) *Which reactant is left in excess?*

(*ii*) *Find the mass of the excess reactant.*

Solution: (i) The balanced equation is:

$$\underset{\substack{2\times 24 \\ = 48\text{ g}}}{2Mg} + \underset{\substack{2\times 16 \\ = 32\text{ g}}}{O_2} \longrightarrow \underset{\substack{2(24+16) \\ = 80\text{ g}}}{2MgO}$$

48 g of Mg require oxygen = 32 g

1 g of Mg requires oxygen $= \frac{32}{48} = 0.66$ g

But only 0.5 g oxygen is available. Hence, O_2 is a limiting agent and a part of magnesium will not burn.

$\therefore$ Magnesium will be left in excess.

(ii) 32 g of O_2 react with magnesium = 48 g

0.5 g of O_2 will react with magnesium $= \frac{48}{32} \times 0.5 = 0.75$ g

Hence, the mass of excess magnesium

$= (1.0 - 0.75) = 0.25$ g

Example 10. *The reaction,*

$$2C(s) + O_2(g) \longrightarrow 2CO(g)$$

is carried out by taking 24 g of carbon and 96 g O_2. Find out:

(a) Which reactant is left in excess?

(b) How much of it is left?

(c) How many moles of CO are formed?

(d) How many grams of other reactant should be taken so that nothing is left at the end of the reaction?

Solution: $\underset{\substack{2\text{ mol}\\24\text{ g}}}{2C(s)} + \underset{\substack{1\text{ mol}\\32\text{ g}}}{O_2(g)} \longrightarrow \underset{\substack{2\text{ mol}\\56\text{ g}}}{2CO(g)}$

Let carbon be completely consumed.

24 g carbon give 56 g CO

Let O_2 is completely consumed.

$\because$ 32 g O_2 give 56 g CO

$\therefore$ 96 g O_2 will give $\frac{56}{32} \times 96$ g CO = 168 g CO

Since, carbon gives least amount of product, *i.e.*, 56 g CO or 2 mole CO, hence carbon will be the limiting reactant.

$\therefore$ Excess reactant is O_2.

Amount of O_2 used $= 56 - 24 = 32$ g

Amount of O_2 left $= 96 - 32 = 64$ g

32 g O_2 react with 24 g carbon

$\therefore$ 96 g O_2 will react with 72 g carbon.

Thus, carbon should be taken 72 g so that nothing is left at the end of the reaction.

ILLUSTRATIONS OF OBJECTIVE QUESTIONS

6. 0.5 mole $BaCl_2$ is mixed with 0.2 mole Na_3PO_4; the maximum number of moles of $Ba_3(PO_4)_2$ that can be formed is:

(a) 0.7 (b) 0.5 (c) 0.2 (d) 0.1

[**Ans.** (d)]

[**Hint:** $3BaCl_2 + 2Na_3PO_4 \longrightarrow Ba_3(PO_4)_2 + 6NaCl$

Number of moles of $Ba_3(PO_4)_2$ formed by $BaCl_2$

$= \frac{1}{3} \times 0.5 = 0.166$

Number of moles of $Ba_3(PO_4)_2$ formed by 0.2 mole Na_3PO_4

$= \frac{1}{2} \times 0.2 = 0.1$

Thus, Na_3PO_4 will be limiting and actual amount of product will be 0.1 mole.]

7. In the following reaction:

$$4NH_3(g) + 5O_2(g) \longrightarrow 4NO(g) + 6H_2O(l)$$

when 1 mole ammonia and 1 mole of O_2 are mixed, then the number of moles of NO formed will be:

(a) 0.8 (b) 0.7 (c) 0.6 (d) 0.5

[**Ans.** (a)]

[**Hint:** 1 mole of NH_3 (on complete reaction) gives 1 mole NO. Similarly, 1 mole of O_2 (on complete reaction) gives $\frac{4}{5}$, *i.e.*, 0.8 mole NO. Thus, O_2 will be limiting reactant and actual amount of NO formed in the reaction will be 0.8 mole.]

8. 30 g Mg and 30 g O_2 are reacted and the residual mixture contains:

(a) 60 g of MgO only

(b) 40 g of MgO and 20 g of O_2

(c) 45 g of MgO and 15 g of O_2

(d) 50 g of MgO and 10 g of O_2

[**Ans.** (d)]

[**Hint:** $\underset{\substack{2\text{ mol}\\2\times 24\text{ g}}}{2Mg(s)} + \underset{\substack{1\text{ mol}\\1\times 32\text{ g}}}{O_2(g)} \longrightarrow \underset{\substack{2\text{ mol}\\2\times 40\text{ g}}}{2MgO(g)}$

30 g Mg gives $\left(\frac{80}{48} \times 30\right)$ g MgO on complete reaction,

i.e., 30 g Mg $\equiv$ 50 g MgO

30 g O_2 gives $\left(\frac{80}{32} \times 30\right)$ g MgO on complete reaction,

i.e., 30 g $O_2 \equiv$ 75 g MgO

$\therefore$ Mg is limiting reactant and MgO formed in the reaction will be 50 g.

Unreacted amount of $O_2 = 30 - 20 = 10$ g

$\therefore$ Mixture contains 50 g MgO and 10 g O_2.]

9. 254 g of iodine and 142 g of chlorine are made to react completely to give a mixture of ICl and ICl_3. How many moles of each are formed?

(a) 0.1 mole of ICl and 0.1 mole of ICl_3

(b) 1 mole of ICl and 1 mole of ICl_3

(c) 0.5 mole of ICl and 0.1 mole of ICl_3

(d) 0.5 mole of ICl and 1 mole of ICl_3

[**Ans.** (b)]

[**Hint:** Both reactants are completely consumed, hence, both are limiting.

$$I_2 + 2Cl_2 \longrightarrow ICl + ICl_3$$

254 g or 1 mole I_2 and 142 g or 2 mole Cl_2 will react to give 1 mole ICl and 1 mole ICl_3.]

10. Magnesium hydroxide, $Mg(OH)_2$ is the white milky substance in milk of magnesia. What mass of $Mg(OH)_2$ is formed when 15 mL of 0.18 *M* NaOH are combined with 12 mL of 0.14 *M* $MgCl_2$? The molar mass of $Mg(OH)_2$ is 58.3 g mol^{-1}.

(a) 0.079 g (b) 0.097 g (c) 0.16 g (d) 0.31 g

[**Ans.** (a)]

[**Hint:** $n_{MgCl_2} = \frac{MV}{1000} = \frac{12 \times 0.14}{1000} = 1.68 \times 10^{-3}$

$n_{NaOH} = \frac{15 \times 0.18}{1000} = 2.7 \times 10^{-3}$

NaOH will be limiting reagent because on complete consumption, NaOH gives least amount of $Mg(OH)_2$.

Mass of $Mg(OH)_2 = \frac{1}{2} \times 2.7 \times 10^{-3} \times 58.3 = 0.079$ g]

Calculations involving per cent yield

In general, when a reaction is carried out in the laboratory we do not obtain actually the theoretical amount of the product. The amount of the product that is actually obtained is called the actual yield. Knowing the actual yield and theoretical yield the per cent yield can be calculated by the given formula:

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

Example 11. *For the reaction,*

$$CaO + 2HCl \longrightarrow CaCl_2 + H_2O$$

1.23 g of CaO is reacted with excess of hydrochloric acid and 1.85 g of $CaCl_2$ is formed. What is the per cent yield?

Solution: The balanced equation is:

$$\underset{\substack{1\text{ mol}\\56\text{ g}}}{CaO} + 2HCl \longrightarrow \underset{\substack{1\text{ mol}\\111\text{ g}}}{CaCl_2} + H_2O$$

56 g of CaO produce $CaCl_2 = 111$ g

1.23 g of CaO produce $CaCl_2 = \frac{111}{56} \times 1.23 = 2.43$ g

Thus, Theoretical yield = 2.43 g

Actual yield = 1.85 g

$$\text{Per cent yield} = \frac{1.85}{2.43} \times 100 = 76.1$$

Calculations involving per cent purity

Depending upon the mass of the product, the equivalent amount of the reactant present can be determined with the help of a chemical equation. Knowing the actual amount of the reactant taken and the amount calculated with the help of a chemical equation the percentage purity can be determined.

Example 12. *Chlorine evolved by the reaction of 45.31 g of pyrolusite (impure) and excess of HCl is found to combine completely with the hydrogen produced by the reaction of 10 g of magnesium and excess of dilute hydrochloric acid. Find the percentage of purity of MnO_2 in the given pyrolusite.*

Solution: $\underset{24\text{ g}}{Mg} + \underset{(2\times 36.5)\text{ g}}{2HCl} \longrightarrow MgCl_2 + \underset{2\text{ g}}{H_2}$

$$\underset{87\text{ g}}{MnO_2} + 4HCl \longrightarrow MnCl_2 + \underset{71\text{ g}}{Cl_2} + 2H_2O$$

$$\underset{2\text{ g}}{H_2} + \underset{71\text{ g}}{Cl_2} \longrightarrow 2HCl$$

2 g of hydrogen obtained by using 24 g of Mg will combine completely with 71 g of chlorine produced from 87 g of pure MnO_2.

Thus, when 10 g of Mg are used,

the mass of the pure MnO_2 required is $= \frac{87}{24} \times 10 = 36.25$ g

So, 45.31 g of pyrolusite contain MnO_2 (pure) = 36.25 g

$\therefore$ 100 g of pyrolusite contain MnO_2 (pure)

$$= \frac{36.25}{45.31} \times 100 = 80.00\text{ g}$$

$\therefore$ Percentage of purity = 80.00

ILLUSTRATIONS OF OBJECTIVE QUESTIONS

11. $\underset{\substack{\text{Salicylic acid}\\(138.12\text{ g mol}^{-1})}}{C_7H_6O_3} + \underset{\substack{\text{Acetic anhydride}\\(102.09\text{ g mol}^{-1})}}{C_4H_6O_3} \longrightarrow \underset{\substack{\text{Aspirin}\\(180.15\text{ g mol}^{-1})}}{C_9H_8O_4} + \underset{\substack{\text{Acetic acid}\\(60.05\text{ g mol}^{-1})}}{C_2H_4O_2}$

What is the percentage yield if 0.85 g of aspirin formed in the reaction of 1 g of salicylic acid with excess of acetic anhydride?

(a) 65% (b) 77% (c) 85% (d) 91%

[**Ans.** (a)]

[**Hint:** Mass of aspirin (theoretical) formed from 1 g salicylic acid $= \frac{180.15}{138.12} = 1.304$g

$$\%\text{ yield} = \frac{\text{Actual amount of product}}{\text{Theoretical amount of product}} \times 100$$

$$= \frac{0.85}{1.304} \times 100 \approx 65\%]$$

12. A sample of impure silver (1.5 g) is heated with sulphur to form Ag_2S. The mass of Ag_2S formed was 0.124 g. What was the percentage yield of silver sulphide?

(a) 6.41% (b) 7.20% (c) 8.27% (d) 10.8%

[**Ans.** (b)]

[**Hint:** $\underset{\substack{2\text{ mol}\\2\times 108 = 216\text{ g}}}{2Ag} + S \longrightarrow \underset{\substack{1\text{ mol}\\248\text{ g}}}{Ag_2S}$

Amount of Ag_2S that can be formed from 1.5 g silver

$$= \frac{248}{216} \times 1.5 = 1.722\text{ g}$$

$$\%\text{ yield of } Ag_2S = \frac{0.124}{1.722} \times 100 = 7.2\,]$$

13. Magnetite, Fe_3O_4, can be converted into metallic iron by heating with carbon monoxide as represented by this equation:

$$Fe_3O_4 + 4CO \longrightarrow 3Fe + 4CO_2$$

How many kilogram of Fe_3O_4 must be processed in this way to obtain 5 kg iron; if the process is 85% efficient? (Molar mass of Fe_3O_4 is 232 g mol^{-1}.)

(a) 6.92 kg (b) 8.12 kg (c) 20.8 kg (d) 24.4 kg

[**Ans.** (b)]

[**Hint:** 1 mole Fe_3O_4 (232 g) = 3 mole Fe (168 g)

Amount of Fe_3O_4 required for 5 kg iron $= \frac{232}{168} \times 5$ kg

$= 6.904$ kg

Since, efficiency of the reaction is 85%, hence, the actual required amount of Fe_3O_4 will be

$$= \frac{100 \times 6.904}{85} \text{ kg, } i.e., = 8.12 \text{ kg}]$$

14. Iodobenzene is prepared from aniline ($C_6H_5NH_2$) in a two step process as shown here:

$$C_6H_5NH_2 + HNO_2 + HCl \longrightarrow C_6H_5N_2^+Cl^- + 2H_2O$$

$$C_6H_5N_2^+Cl^- + KI \longrightarrow C_6H_5I + N_2 + KCl$$

In an actual preparation, 9.30 g of aniline was converted to 12.32 g of iodobenzene. The percentage yield of iodobenzene is:

(a) 8% (b) 50%
(c) 75% (d) 80%

[**Ans.** (d)]

[**Hint:** 1 mole of $C_6H_5NH_2$ (123 g) $\equiv$ 1 mole of C_6H_5I (204 g)

$\therefore$ 9.3 g aniline will give $= \left(\frac{204}{123} \times 9.3\right)$ g iodobenzene

$$= 15.424 \text{ g iodobenzene}$$

$$\% \text{ yield} = \frac{\text{Actual amount of product}}{\text{Calculated amount of product}} \times 100$$

$$= \frac{12.32}{15.424} \times 100 \approx 80\%]$$

15. Benzamide can be prepared by the action of concentrated ammonia upon benzoyl chloride.

$$\underset{\text{Benzoyl chloride}}{C_6H_5COCl} + 2NH_3 \longrightarrow \underset{\text{Benzamide}}{C_6H_5CONH_2} + NH_4Cl$$

In one such experiment, 65 cc of concentrated ammonia (in excess) was reacted with 15 g of benzoyl chloride to give 11.1 g of pure benzamide. Molar masses: benzoyl chloride (141); benzamide (121). The percentage yield of benzamide is:

(a) $\frac{11.1}{15} \times 100$ (b) $\frac{(15-11.1)}{15} \times 100$
(c) $\frac{11.1}{65} \times 100$ (d) $\frac{121}{141} \times 100$
(e) $\frac{11.1 \times 141}{121 \times 15} \times 100$

[**Ans.** (e)]

[**Hint:** Amount of benzamide from 15 g benzoyl chloride $= \frac{121}{141} \times 15$ g

Actual amount of benzamide formed = 11.1 g

$$\% \text{ yield} = \frac{\text{Actual amount of product}}{\text{Calculated amount of product}} \times 100$$

$$= \frac{11.1 \times 100}{\left(\frac{121}{141} \times 15\right)} = \frac{11.1 \times 141}{121 \times 15} \times 100]$$

Analysis of mixtures: In such problems, one of the components is supposed to be x g and the other will be the difference from the total. Balanced chemical equations for the reactions of both the components are now written and the total amount of the common product produced by the components of the mixture is calculated. It is equated with the data given and the unknown factors are, thus, worked out.

SOME SOLVED EXAMPLES

Example 13. *A solid mixture (5.0 g) consisting of lead nitrate and sodium nitrate was heated below 600°C until the mass of the residue was constant. If the loss in mass is 28.0 per cent, find the amount of lead nitrate and sodium nitrate in the mixture.* (IIT 1990)

Solution: Let the amount of $NaNO_3$ in the mixture be $= x$ g

$\therefore$ The amount of $Pb(NO_3)_2$ in the mixture $= (5.0 - x)$ g

$$\underset{(2 \times 85)\text{ g}}{2NaNO_3} \xrightarrow{\text{Heat}} 2NaNO_2 + \underset{32\text{ g}}{O_2}$$

$$\underset{\substack{(2 \times 331)\text{ g} \\ 662\text{ g}}}{2Pb(NO_3)_2} \xrightarrow{\text{Heat}} 2PbO + \underbrace{\underset{(4 \times 46)\text{ g}}{4NO_2} + \underset{32\text{ g}}{O_2}}_{216\text{ g}}$$

170 g of $NaNO_3$ evolve oxygen = 32 g

x g of $NaNO_3$ evolve oxygen $= \frac{32}{170} \times x$ g

662 g of $Pb(NO_3)_2$ evolve gases = 216 g

$(50 - x)$ g of $Pb(NO_3)_2$ evolve gases $= \frac{216}{662} \times (5.0 - x)$ g

$$\text{Total loss} = \frac{32}{170} \times x + \frac{216}{662} \times (5.0 - x)$$

$$\text{Loss given in the problem} = \frac{28}{100} \times 5 = 1.4 \text{ g}$$

$$\therefore \quad \frac{32}{170} x + \frac{216}{662} (5.0 - x) = 1.4$$

On solving, $x = 1.676$ g

Thus, Mass of $NaNO_3$ = 1.676 g

Mass of $Pb(NO_3)_2 = (5.0 - 1.676)$ g = 3.324 g

Example 14. *3.68 g of a mixture of calcium carbonate and magnesium carbonate when heated strongly leaves 1.92 g of a white residue. Find the percentage composition of the mixture.*

Solution: Let x g of $CaCO_3$ be present in the mixture.

The mass of $MgCO_3$ in the mixture $= (3.68 - x)$ g.

$$\underset{100\text{ g}}{CaCO_3} \xrightarrow{\text{Heat}} \underset{56\text{ g}}{CaO} + CO_2$$

$$\underset{84\text{ g}}{MgCO_3} \xrightarrow{\text{Heat}} \underset{40\text{ g}}{MgO} + CO_2$$

$$\therefore \quad \frac{56 \times x}{100} + \frac{40 \times (3.68 - x)}{84} = 1.92$$

On solving, $x = 2$

$$\text{Percentage of } CaCO_3 = \frac{2}{3.68} \times 100 = 54.35\%$$

$$\text{Percentage of } MgCO_3 = 100 - 54.35 = 45.65\%$$

Example 15. *0.5 g of a mixture of K_2CO_3 and Li_2CO_3 required 30 mL of 0.25 N HCl solution for neutralization. What is the percentage composition of the mixture?*

Solution: Let the amount of K_2CO_3 be 'x' g.

$\therefore$ Amount of $Li_2CO_3 = (0.5 - x)$ g

$$\text{Number of equivalents} = \frac{x}{138/2} + \frac{(0.5-x)}{74/2} \quad \ldots(i)$$

Number of equivalents of HCl used

$$= \frac{NV}{1000} = \frac{0.25 \times 30}{1000} = 7.5 \times 10^{-3} \quad \ldots(ii)$$

Comparing eqs. (i) and (ii), we get

$$x = 0.48 \text{ g}$$

$\therefore$ Mass of $K_2CO_3 = 0.48$ g

Mass of $Li_2CO_3 = 0.02$ g

$$\% K_2CO_3 = \frac{0.48}{0.5} \times 100 = 96$$

$$\% Li_2CO_3 = \frac{0.02}{0.5} \times 100 = 4$$

(iii) Calculations based on mass-volume relationship

In such calculations, masses of reactants are given and volume of the product is required and *vice-versa.*

1 mole of a gas occupies 22.4 litre volume at STP mass of a gas can be related to volume according to the following gas equation:

$$PV = nRT$$

$$PV = \frac{w}{m} RT$$

Example 16. *What volume of $NH_3(g)$ at 27°C and 1 atm pressure will be obtained by thermal decomposition of 26.25 g NH_4Cl?*

Solution: Ammonium chloride undergoes decomposition as;

$$\underset{\substack{1 \text{ mol} \\ 53.5 \text{ g}}}{NH_4Cl(s)} \longrightarrow \underset{\substack{1 \text{ mol} \\ 1 \text{ mol}}}{NH_3(g)} + HCl(g)$$

$\because$ 53.5 g NH_4Cl give 1 mol NH_3

$\therefore$ 26.25 g NH_4Cl will give $\frac{1}{53.5} \times 26.25$ mole NH_3

$$= 0.5 \text{ mole}$$

$$PV = nRT$$

$$1 \times V = 0.5 \times 0.0821 \times 300$$

$$V = 12.315 \text{ litre}$$

Example 17. *What quantity of copper(II) oxide will react with 2.80 litre of hydrogen at NTP?*

Solution: The balanced equation is:

$$\underset{\substack{1 \text{ mol} \\ 79.5 \text{ g}}}{CuO} + \underset{\substack{1 \text{ mol} \\ 22.4 \text{ litre at NTP}}}{H_2} \longrightarrow Cu + H_2O$$

22.4 litre of hydrogen at NTP reduce CuO = 79.5 g

2.80 litre of hydrogen at NTP will reduce CuO

$$= \frac{79.5}{22.4} \times 2.80 \text{ g} = 9.95 \text{ g}$$

Example 18. *Calculate the volume of carbon dioxide at NTP evolved by strong heating of 20 g calcium carbonate.*

Solution: The balanced equation is:

$$\underset{\substack{1 \text{ mol} \\ 100 \text{ g}}}{CaCO_3} \longrightarrow CaO + \underset{\substack{1 \text{ mol} \\ = 22.4 \text{ litre at NTP}}}{CO_2}$$

100 g of $CaCO_3$ evolve carbon dioxide = 22.4 litre

20 g $CaCO_3$ will evolve carbon dioxide

$$= \frac{22.4}{100} \times 20 = 4.48 \text{ litre}$$

Example 19. *Calculate the volume of hydrogen liberated at 27°C and 760 mm pressure by treating 1.2 g of magnesium with excess of hydrochloric acid.*

Solution: The balanced equation is:

$$\underset{\substack{1 \text{ mol} \\ 24 \text{ g}}}{Mg} + 2HCl \longrightarrow MgCl_2 + \underset{\substack{1 \text{ mol} \\ 22.4 \text{ litre at NTP}}}{H_2}$$

24 g of Mg liberate hydrogen = 22.4 litre

1.2 g Mg will liberate hydrogen $= \frac{22.4}{24} \times 1.2 = 1.12$ litre

Volume of hydrogen under given condition can be calculated by applying

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$P_1 = 760$ mm $P_2 = 760$ mm

$T_1 = 273$ K $T_2 = (27 + 273) = 300$ K

$V_1 = 1.12$ litre $V_2 = ?$

$$V_2 = \frac{760 \times 1.12}{273} \times \frac{300}{760} = 1.2308 \text{ litre}$$

Example 20. *A solid mixture (5 g) consisting of lead nitrate and sodium nitrate was heated below 600°C until the weight of the residue is constant. If the loss in weight is 28%, find the amount of lead nitrate and sodium nitrate in the mixture.* (IIT 1990)

Solution: Loss in weight is due to formation of NO_2 and O_2 gases (weight loss $= \frac{5}{100} \times 28 = 1.4$ g).

$$\underset{x \text{ g}}{Pb(NO_3)_2} \longrightarrow \underset{(x-y) \text{ g}}{PbO} + \underbrace{NO_2 + O_2}_{y \text{ g}}$$

$$\underset{(5-x)}{NaNO_3} \longrightarrow \underset{(3.6-x+y)}{NaNO_2} + \underset{(1.4-y)}{\tfrac{1}{2}O_2}$$

Number of moles of $Pb(NO_3)_2$ = Number of moles of PbO

$$\frac{x}{331} = \frac{(x-y)}{223} \quad \ldots(i)$$

$\because$ M.w. $Pb(NO_3)_2 = 331$, M.w. $PbO = 223$

Number of moles of $NaNO_3$ = Number of moles of $NaNO_2$

$$\frac{5-x}{85} = \frac{3.6-x+y}{69} \quad \ldots(ii)$$

Solving eqs. (i) and (ii), we get

$$\text{Mass of } Pb(NO_3)_2 = x = 3.3246 \text{ g}$$

$$\text{Mass of } NaNO_3 = 5 - 3.3246 = 1.6754 \text{ g}$$

(iv) Calculations based on volume-volume relationship

These calculations are based on two laws:

(i) Avogadro's law (ii) Gay-Lussac's law

For example:

$$\underset{\substack{1\text{ mol}\\1\times 22.4\text{ L}}}{N_2(g)} + \underset{\substack{3\text{ mol}\\3\times 22.4\text{ L}}}{3H_2(g)} \longrightarrow \underset{\substack{2\text{ mol}\\2\times 22.4\text{ L}}}{2NH_3(g)} \quad \text{(Avogadro's law)}$$

(under similar conditions of temperature and pressure, equal moles of gases occupy equal volumes)

$$\underset{1\text{ vol.}}{N_2(g)} + \underset{3\text{ vol.}}{3H_2(g)} \longrightarrow \underset{2\text{ vol.}}{2NH_3(g)}$$

under similar conditions, ratio of coefficients by mole is equal to ratio of coefficient by volume.

Example 21. *1 litre mixture of CO and CO_2 is taken. This is passed through a tube containing red hot charcoal. The volume now becomes 1.6 litre. The volumes are measured under the same conditions. Find the composition of mixture by volume.*

Solution: Let there be x mL CO in the mixture, hence, there will be $(1000-x)$ mL CO_2. The reaction of CO_2 with red hot charcoal may be given as,

$$\underset{\substack{1\text{ vol.}\\(1000-x)}}{CO_2(g)} + C(s) \longrightarrow \underset{\substack{2\text{ vol.}\\2(1000-x)}}{2CO(g)}$$

Total volume of the gas becomes $= x + 2(1000-x)$

$$x + 2000 - 2x = 1600$$

$$x = 400 \text{ mL}$$

$\therefore$ Volume of CO = 400 mL and volume of CO_2 = 600 mL

Example 22. *What volume of air containing 21% oxygen by volume is required to completely burn 1 kg of carbon containing 100% combustible substances?*

Solution: Combustion of carbon may be given as,

$$\underset{\substack{1\text{ mol}\\12\text{ g}}}{C(s)} + \underset{\substack{1\text{ mol}\\1\text{ mol}}}{O_2(g)} \longrightarrow CO_2(g)$$

$\because$ 12 g carbon requires 1 mole O_2 for complete combustion

$\therefore$ 1000 g carbon will require $\frac{1}{12} \times 1000$ mole O_2 for combustion, *i.e.*, 83.33 mole O_2

Volume of O_2 at NTP $= 83.33 \times 22.4$ litre $= 1866.592$ litre

$\because$ 21 litre O_2 is present in 100 litre air

$\therefore$ 1866.592 litre O_2 will be present in $\frac{100}{21} \times 1866.592$ litre O_2

$$= 8888.5 \text{ litre} = 8.8885 \times 10^3 \text{ litre}$$

Example 23. *What volume of oxygen gas at NTP is necessary for complete combustion of 20 litre of propane measured at 27° C and 760 mm pressure?*

Solution: The balanced equation is:

$$\underset{\substack{1\text{ vol.}\\1\text{ litre}}}{C_3H_8} + \underset{\substack{5\text{ vol.}\\5\text{ litre}}}{5O_2} \longrightarrow 3CO_2 + 4H_2O$$

1 litre of propane requires = 5 litre of oxygen

20 litre of propane will require $= 5 \times 20 = 100$ litre of oxygen at 760 mm pressure and 27° C.

This volume will be converted to NTP conditions.

Given conditions	NTP conditions
$P_1 = 760$ mm	$P_2 = 760$ mm
$V_1 = 100$ litre	$V_2 = ?$
$T_1 = 27 + 273 = 300$ K	$T_2 = 273$

Applying $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

$$V_2 = \frac{P_1V_1}{T_1} \times \frac{T_2}{P_2}$$

$$= \frac{760 \times 100}{300} \times \frac{273}{760} = 91.0 \text{ litre}$$

Example 24. *One litre of oxygen at NTP is allowed to react with three times of carbon monoxide at NTP. Calculate the volume of each gas found after the reaction.*

Solution: The desired equation is:

$$\underset{2\text{ vol.}}{2CO} + \underset{1\text{ vol.}}{O_2} \longrightarrow \underset{2\text{ vol.}}{2CO_2}$$

1 vol. of O_2 reacts with 2 vol. of CO

or 1 litre of O_2 reacts with 2 litre of CO

Thus, 1 litre of CO remains unreacted.

1 vol. of O_2 produces CO_2 = 2 vol.

or 1 litre of O_2 will produce CO_2 = 2 litre

Thus, gaseous mixture after the reaction consists

Volume of CO = 1 litre

Volume of CO_2 = 2 litre

ILLUSTRATIONS OF OBJECTIVE QUESTIONS

16. 10 litre of O_2 gas is reacted with 30 litre of CO gas at STP. The volumes of each gas present at the end of reaction are: **[CMC (Vellore) 2008]**

(a) CO (10 litre), CO_2 (20 litre)
(b) O_2 (10 litre), CO (30 litre)
(c) CO (20 litre), CO_2 (10 litre)
(d) O_2 (10 litre), CO_2 (20 litre)
(e) O_2 (10 litre), CO (10 litre)

[**Ans.** (a)]

[**Hint:** $CO(g) + \frac{1}{2}O_2(g) \longrightarrow CO_2(g)$

$t = 0$	30 L	10 L	0
After reaction	(30 − 20)L	0	20 L]

17. When 10 g of 90% pure limestone is heated, the volume of CO_2 (in litre) liberated at STP is: **[JEE (WB) 2007]**

(a) 22.4 litre (b) 2.24 litre
(c) 20.16 litre (d) 2.016 litre

[**Ans.** (d)]

[**Hint:** Mass of $CaCO_3$ in the sample $= 10 \times \frac{90}{100} = 9$ g

$$\underset{\substack{1\text{ mol}\\100\text{ g}}}{CaCO_3(s)} \longrightarrow CaO(s) + \underset{\substack{1\text{ mol}\\22.4\text{ L}}}{CO_2(g)}$$

9 gm $CaCO_3$ will give $\left(\frac{22.4}{100} \times 9\right)$ litre of CO_2, *i.e.*, 2.016 litre of CO_2.]

18. 100 mL of PH_3 on heating forms P_4 and H_2, volume changes in the reaction is: **(DPMT 2009)**

(a) an increase of 50 mL (b) an increase of 100 mL
(c) an increase of 150 mL (d) a decrease of 50 mL

[**Ans.** (a)]

[**Hint:** $\underset{\substack{4\text{ mol}\\4\text{ mL}}}{4PH_3(g)} \longrightarrow P_4(s) + \underset{\substack{6\text{ mol}\\6\text{ mL}}}{6H_2(g)}$

volume of H_2 produced by 100 mL PH_3 $= \frac{6}{4} \times 100 = 150$ mL

Thus, there is increase of 50 mL.]

MISCELLANEOUS NUMERICAL EXAMPLES

Example 1. *Calculate the weight of CaO required to remove the hardness of 1000000 litre of water containing 1.62 g of $CaCO_3$ per litre.*

Solution: Mass of $Ca(HCO_3)_2$ in the water

$$= 1.62 \times 1000000$$
$$= 1620000\text{ g} = 1620\text{ kg}$$

Reaction involved in the removal of hardness may be given as,

$$\underset{162\text{ kg}}{Ca(HCO_3)_2} + \underset{56\text{ kg}}{CaO} \longrightarrow 2CaCO_3 + H_2O$$

∵ 162 kg $Ca(HCO_3)_2$ require 56 kg CaO.

∴ 1620 kg $Ca(HCO_3)_2$ will require 560 kg CaO.

Example 2. *A mixture in which the mole ratio of H_2 and O_2 is 2:1 is used to prepare water by the reaction,*

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(g)$$

The total pressure in the container is 0.8 atm at 20°C before the reaction. Determine the final pressure at 120°C after reaction assuming 80% yield of water. **(IIT 1999)**

Solution: $p_{H_2} = \frac{2}{3} \times 0.8 = 0.533$ atm

$$p_{O_2} = \frac{1}{3} \times 0.8 = 0.266\text{ atm}$$

	$2H_2$ +	O_2 ⟶	$2H_2O$
$t = 0$	0.533	0.266	0
After the reaction	$\frac{0.533 \times 20}{100}$ = 0.1066	$\frac{0.266 \times 20}{100}$ = 0.0533	$\frac{0.533 \times 80}{100}$ = 0.4264

Total pressure = 0.1066 + 0.0533 + 0.4264 = 0.5863 atm

Using Gay-Lussac's law, $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

$$\frac{0.5863}{293} = \frac{P_2}{393}$$

$$P_2 = 0.7864\text{ atm}$$

Example 3. *An impure sample of calcium carbonate contains 80% pure calcium carbonate. 25 g of the impure sample reacted with excess of hydrochloric acid. Calculate the volume of carbon dioxide at NTP obtained from this sample.*

Solution: 100 g of impure calcium carbonate contain

= 80 g pure calcium carbonate

25 g of impure calcium carbonate sample contain

$$= \frac{80}{100} \times 25$$

= 20 g pure calcium carbonate

The desired equation is:

$$\underset{\substack{1\text{ mol}\\100\text{ g}}}{CaCO_3} + 2HCl \longrightarrow CaCl_2 + \underset{\substack{22.4\text{ litre}\\\text{at NTP}}}{CO_2} + H_2O$$

100 g pure $CaCO_3$ liberate = 22.4 litre CO_2

20 g pure $CaCO_3$ liberate $= \frac{22.4}{100} \times 20$

= 4.48 litre CO_2

Example 4. *The weight of 1 litre sample of ozonised oxygen at NTP was found to be 1.5 g. When 100 mL of this mixture at NTP were treated with turpentine oil, the volume was reduced to 90 mL. Hence, calculate the molecular weight of ozone.*

Solution: Volume of ozone

= volume absorbed in turpentine oil
= 10 mL

Volume of oxygen = 90 mL

Mass of 100 mL mixture $= \frac{10}{22400} \times M + \frac{90}{22400} \times 32 = 0.15$

On solving, we get $M = 48$

∴ Molecular mass of ozone = 48

Example 5. *A mixture of $NaHCO_3$ and Na_2CO_3 weighed 1.0235 g. The dissolved mixture was reacted with excess of $Ba(OH)_2$ to form 2.1028 g $BaCO_3$, by the following reactions:*

$$Na_2CO_3 + Ba(OH)_2 \longrightarrow BaCO_3 + 2NaOH$$
$$NaHCO_3 + Ba(OH)_2 \longrightarrow BaCO_3 + NaOH + H_2O$$

What was the percentage of $NaHCO_3$ in the original mixture?

Solution: Let x g of $NaHCO_3$ be present in the mixture.

Mass of Na_2CO_3 in the mixture $= (1.0235 - x)$ g

Number of moles of $NaHCO_3 = \dfrac{x}{84}$

Number of moles of $Na_2CO_3 = \dfrac{(1.0235 - x)}{106}$

Number of moles of $BaCO_3$

$= $ Number of moles of $NaHCO_3$ + Number of moles of Na_2CO_3

$$\frac{2.1028}{197} = \frac{x}{84} + \frac{(1.0235 - x)}{106}$$

$\therefore$ $x = 0.4122$

Amount of $NaHCO_3 = 0.4122$ g

Percentage of $NaHCO_3 = \dfrac{0.4122}{1.0235} \times 100 = 40.27$

Example 6. *A mixture of ethane and ethene occupies 40 litre at 1.00 atm and at 400 K. The mixture reacts completely with 130 g of O_2 to produce CO_2 and H_2O. Assuming ideal gas behaviour, calculate the mole fractions of C_2H_6 and C_2H_4 in the mixture.* **(IIT 1995)**

Solution: Volume of the mixture at NTP

$$= \frac{40 \times 1}{400} \times \frac{273}{1} = 27.3 \text{ litre}$$

Let the volume of ethane $= x$ litre

Volume of ethene $= (273 - x)$ litre

Balanced equations:

$$\underset{1\text{ vol.}}{C_2H_6} + \underset{7/2\text{ vol.}}{7/2\, O_2} \longrightarrow 2CO_2 + 3H_2O$$

$$\underset{1\text{ vol.}}{C_2H_4} + \underset{3\text{ vol.}}{3O_2} \longrightarrow 2CO_2 + 2H_2O$$

Total volume of oxygen required for complete combustion of the mixture is:

$$\left[\frac{7}{2}x + (27.3 - x) \times 3\right] \text{litre}$$

or $$\left[\frac{7x + (27.3 - x) \times 6}{2}\right] \text{litre}$$

$$\text{Mass of oxygen} = \left[\frac{7x + (27.3 - x) \times 6}{2}\right] \times \frac{32}{22.4}$$

$$130 = (x + 163.8) \times \frac{16}{22.4}$$

$\therefore$ $x = 18.2$

Hence, mole fraction of ethane $= \dfrac{18.2}{27.3} \times 100 = 66.66$

Mole fraction of ethene $= 33.34$

Example 7. *A mixture of HCOOH and $H_2C_2O_4$ is heated with concentrated H_2SO_4. The gas produced is collected and on treating with KOH solution, the volume of the gas decreases by 1/6th. Calculate the molar ratio of the two acids in the original mixture.* **(IIT 1990)**

Solution: $$\underset{1\text{ mol}}{HCOOH} \xrightarrow[\text{Heat}]{\text{Conc. } H_2SO_4} \underset{1\text{ mol}}{CO} + H_2O$$

$$\underset{1\text{ mol}}{H_2C_2O_4} \xrightarrow[\text{Heat}]{\text{Conc. } H_2SO_4} \underset{1\text{ mol}}{CO} + \underset{1\text{ mol}}{CO_2} + H_2O$$

Let a moles of HCOOH and b moles of $H_2C_2O_4$ be present in the original mixture.

Moles of CO formed $= a + b$

Moles of CO_2 formed $= b$

Total moles of gases $= a + b + b = a + 2b$

CO_2 is absorbed by KOH and the volume reduces by 1/6th.

Moles of $CO_2 = \dfrac{a + 2b}{6}$

or $b = \dfrac{a + 2b}{6}$

or $a = 4b$

or $\dfrac{a}{b} = 4$

or $a : b = 4 : 1$

Example 8. 3.6 g *mixture of sodium chloride and potassium chloride is dissolved in water. The solution is treated with excess of silver nitrate solution. 7.74 g of silver chloride is obtained. Find the percentage of sodium chloride and potassium chloride in the mixture.*

Solution: The balanced equation between NaCl and $AgNO_3$ is:

$$\underset{\substack{1\text{ mol}\\58.5\text{ g}}}{NaCl} + AgNO_3 \longrightarrow \underset{\substack{1\text{ mol}\\143.5\text{ g}}}{AgCl} + NaNO_3$$

Let x g of NaCl be present in the mixture.

58.5 g NaCl produce $= 143.5$ g AgCl

x g NaCl will produce $= \dfrac{143.5}{58.5} \times x$ g AgCl

The balanced equation between KCl and $AgNO_3$ is:

$$\underset{\substack{1\text{ mol}\\74.5\text{ g}}}{KCl} + AgNO_3 \longrightarrow \underset{\substack{1\text{ mol}\\143.5\text{ g}}}{AgCl} + KNO_3$$

KCl present in the mixture $= (3.60 - x)$ g

74.5 g of Cl produce $= 143.5$ g of AgCl

$(3.6 - x)$ g of KCl will produce $= \dfrac{143.5}{74.5} \times (3.6 - x)$ g of AgCl

Thus, $$\frac{143.5}{58.5}x + \frac{143.5}{74.5}(3.6 - x) = 7.74$$

$$x = 1.54$$

$$\% \text{ of NaCl} = \frac{1.54}{3.60} \times 100 = 42.7$$

$$\% \text{ of KCl} = \frac{(3.60 - 1.54)}{3.60} \times 100 = 57.3$$

Example 9. *5 g of K_2SO_4 were dissolved in 250 mL of solution. How many mL of this solution should be used so that 1.2 g of $BaSO_4$ may be precipitated from $BaCl_2$ solution?*

Solution: The desired equation is:

$$\underset{}{BaCl_2} + \underset{\substack{2 \times 39 + 32 + 64 \\ = 174\,g}}{K_2SO_4} \longrightarrow \underset{\substack{137 + 32 + 64 \\ = 233\,g}}{BaSO_4} + 2KCl$$

233 g of $BaSO_4$ obtained from 174 g of K_2SO_4

1.2 g of $BaSO_4$ will be obtained from $\frac{174}{233} \times 1.2$

$$= 0.8961 \text{ g of } K_2SO_4$$

5 g of K_2SO_4 are present in 250 mL of solution

So, 0.8961 g of K_2SO_4 will be present in $\frac{250}{5} \times 0.8961$

$$= 44.8 \text{ mL of solution}$$

Example 10. *A 2.00 g of sample containing Na_2CO_3 and $NaHCO_3$ loses 0.248 g when heated to 300° C, the temperature at which $NaHCO_3$ decomposes into Na_2CO_3, CO_2 and steam. What is the percentage of Na_2CO_3 in the mixture?*

Solution: $\underset{168\,g}{2NaHCO_3} \longrightarrow Na_2CO_3 + \underbrace{\underset{44}{CO_2} + \underset{18}{H_2O}}_{62\,g}$

The loss comes due to evolution of CO_2 and steam.

62 g loss occurs when the quantity of $NaHCO_3$ is 168 g.

0.248 g loss will occur when the quantity of $NaHCO_3$

$$= \frac{168}{62} \times 0.248 = 0.672 \text{ g}$$

Quantity of Na_2CO_3 in the sample $= (2.0 - 0.672) = 1.328$ g

$$\% \text{ of } Na_2CO_3 = \frac{1.328}{2} \times 100 = 66.4$$

Example 11. *A 1.00 g sample of $KClO_3$ was heated under such conditions that a part of it was decomposed according to the equation,*

$$2KClO_3 \longrightarrow 2KCl + 3O_2 \qquad \ldots (i)$$

and the remaining underwent change according to the equation,

$$4KClO_3 \longrightarrow 3KClO_4 + KCl \qquad \ldots (ii)$$

If the amount of oxygen evolved was 146.8 mL at STP, calculate the percentage by mass of $KClO_4$ in the residue.

Solution: $\underset{\substack{2(39 + 35.5 + 48) \\ 245\,g}}{2KClO_3} \longrightarrow \underset{\substack{2(39 + 35.5) \\ 149\,g}}{2KCl} + \underset{\substack{3 \times 22.4 \text{ litre} \\ 67.2 \text{ litre}}}{3O_2}$

67.2 litre of oxygen evolved from 245 g of $KClO_3$

0.1468 litre of oxygen will be evolved $= \frac{245}{67.2} \times 0.1468$

$$= 0.5352 \text{ g of } KClO_3$$

Hence, $KClO_3$ left for eq. (ii) reaction,

$$(1.00 - 0.5352) = 0.4648 \text{ g}$$

245 g $KClO_3$ will yield KCl = 149 g

0.5352 g $KClO_3$ will yield KCl $= \frac{149}{245} \times 0.5352 \text{ g} = 0.3254$ g

Considering eq. (ii),

$$\underset{\substack{4(39 + 35.5 + 48) \\ 490\,g}}{4KClO_3} \longrightarrow \underset{\substack{3(39 + 35.5 + 64) \\ 415.5\,g}}{3KClO_4} + \underset{\substack{(39 + 35.5) \\ 74.5\,g}}{KCl}$$

490 g of $KClO_3$ yield = 415.5 g of $KClO_4$

0.4648 g of $KClO_3$ will yield $= \frac{415.5}{490} \times 0.4648$

$$= 0.3941 \text{ g of } KClO_4$$

490 g $KClO_3$ yield = 74.5 g of KCl

0.4648 g of $KClO_3$ will yield $= \frac{74.5}{490} \times 0.4648$

$$= 0.0707 \text{ g of KCl}$$

Total mass of residue $= 0.3254 + 0.3941 + 0.0707$

$$= 0.7902 \text{ g}$$

$$\% \, KClO_4 = \frac{0.3941}{0.7902} \times 100 = 49.8$$

Example 12. *A mixture of FeO and Fe_3O_4 when heated in air to a constant weight gains 5% in its mass. Find the composition of the initial mixture.*

Solution: Let the % of FeO in the mixture be $= x$

So, % of Fe_3O_4 in the mixture $= (100 - x)$

FeO on heating is converted into Fe_2O_3.

$$\underset{288\,g}{4FeO} + O_2 \longrightarrow \underset{320\,g}{2Fe_2O_3}$$

288 g of FeO yield = 320 g of Fe_2O_3

x g of FeO will yield $= \frac{320}{288} x$ g of Fe_2O_3

$$\underset{464\,g}{2Fe_3O_4} + \frac{1}{2} O_2 \longrightarrow \underset{480\,g}{3Fe_2O_3}$$

464 g of Fe_3O_4 yield = 480 g of Fe_2O_3

$(100 - x)$ g of Fe_2O_3 will yield $= \frac{480}{464}(100 - x)$ of Fe_2O_3

$$\text{Total } Fe_2O_3 = \frac{320}{288} x + \frac{480}{464}(100 - x)$$

According to the question,

$$\frac{320}{288} x + \frac{480}{464}(100 - x) = 105$$

$$x = 20.2$$

So, percentage of FeO = 20.2

and percentage of $Fe_3O_4 = 79.8$

Example 13. *A mixture in which the mole ratio of H_2 and O_2 is 2 : 1, is used to prepare water by the reaction:*

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(g)$$

The total pressure in the container is 0.8 atm at 20° C before the reaction. Determine the final pressure at 120° C after the reaction, assuming 80% yield of water. **(IIT 1999)**

Solution: The given reaction is:

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(g)$$

	$2H_2(g)$	$O_2(g)$	$2H_2O(g)$
Initial moles	$2n$	n	0
Final moles	$(2n-2x)$	$(n-x)$	$2x$

$$\% \text{ yield} = 80$$

$$\therefore \quad \frac{2x}{2n} \times 100 = 80$$

$$x = 0.8\,n$$

After the reaction,

Number of moles of $H_2 = 2n - 2 \times 0.8n = 0.4n$

Number of moles of $O_2 = 0.2n$

Number of moles of $H_2O = 1.6n$

$$\text{Total moles} = 0.4n + 0.2n + 1.6n = 2.2n$$

Initial state: $PV = nRT$

$$0.8 \times V = 3n \times R \times 293 \quad \ldots(i)$$

After the reaction, $P \times V = 2.2n \times R \times 393 \quad \ldots(ii)$

Solving eqs. (i) and (ii), we get

$$P = 0.787 \text{ atm}$$

Questions

1. 500 mL of 0.25 M Na_2SO_4 solution is added to an aqueous solution of 15 g of $BaCl_2$ resulting in the formation of a white precipitate of insoluble $BaSO_4$. How many moles and how many grams of $BaSO_4$ are formed?
2. Zinc and hydrochloric acid react according to the reaction:
$$Zn(s) + 2HCl(aq.) \longrightarrow ZnCl_2(aq.) + H_2(g)$$
If 0.3 mole Zn are added to hydrochloric acid containing 0.52 mole HCl, how many moles of H_2 are produced?
3. Calcium carbonate reacts with aqueous HCl to give $CaCl_2$ and CO_2 according to the reaction:
$$CaCO_3(s) + 2HCl(aq.) \longrightarrow CaCl_2(aq.) + H_2O + CO_2(g)$$
What mass of $CaCO_3$ is required to react completely with 25 mL of 0.75 M HCl?
4. Calculate the mass of iron which will be converted into its oxide by the action of 18 g of steam. **(MLNR 1996)**
5. How much potassium chlorate is needed to obtain 2.4 litre oxygen at NTP?
6. Calculate the volume of carbon dioxide obtained at NTP by heating 8.4 g of sodium bicarbonate.
7. Calculate the volume of air needed for the combustion of 1 kg of carbon.
[**Hint:** 100 parts of air contain 21 parts of oxygen by volume.]
8. How many grams of oxygen will be formed by the action of 12 g of sodium peroxide on water? Calculate also the volume of the gas at NTP.
9. A gaseous compound of carbon and nitrogen containing 53.8% by weight of nitrogen was found to have a vapour density of 25.8. What is the molecular formula of the compound?
10. Calculate the weight of lime (CaO) that can be obtained by heating 200 kg of limestone which is 93% pure.
11. How many moles of impure potassium chlorate of 75% purity are required to produce 48 g of oxygen?
12. What weight of zinc will react with dil. sulphuric acid to liberate 1000 mL of hydrogen at 27°C and 750 mm pressure?
13. 1.2 g sample of Na_2CO_3 and K_2CO_3 was dissolved in water to form 100 mL solution. 20 mL of this solution required 40 mL of 0.1 N HCl for complete neutralization. Calculate the weight of Na_2CO_3 in the mixture. If another 20 mL of this solution is treated with excess of $BaCl_2$, what will be the weight of the precipitate? **(IIT 1997)**
14. Calculate the volume of air containing 21% by volume of oxygen at NTP required to convert 294 mL of SO_2 into SO_3 under the same conditions.
15. 4 g of an impure sample of $CaCO_3$ on treatment with excess HCl produce 0.88 g CO_2. What is the per cent purity of $CaCO_3$ sample?
16. What weight of AgCl will be precipitated when a solution containing 4.77 g of NaCl is added to a solution of 5.77 g of $AgNO_3$?
[**Hint:** $AgNO_3$ is a limiting reagent in this problem.]
17. 1.0 g of an alloy of aluminium and magnesium is treated with excess of dil. HCl. The evolved hydrogen collected over mercury at 0°C has a volume of 1.20 litre at 0.29 atm pressure. Calculate the percentage composition of the alloy.
18. How much iron can be theoretically obtained by the reduction of 1.0 kg of Fe_2O_3? (At. wt. of Fe = 56)
19. 34 g of pure H_2O_2 is decomposed. Calculate the mass and volume at NTP of oxygen that will be evolved.
20. Find the percentage composition of iron and magnesium, 5.0 g, which when dissolved in acid, gave 2.81 litre of H_2 at NTP.
21. Equal weights of Hg and iodine are allowed to react completely to form a mixture of mercurous iodide and mercuric iodide. Calculate the ratio of the masses of mercurous and mercuric iodides formed. (Hg = 201, I = 117)
[**Hint:** $\underset{201\text{ g}}{Hg} + \underset{254\text{ g}}{I_2} \longrightarrow \underset{455\text{ g}}{HgI_2}$;

$$\underset{402\text{ g}}{2Hg} + \underset{254\text{ g}}{I_2} \longrightarrow \underset{656\text{ g}}{Hg_2I_2}$$

Let the wt. of Hg_2I_2 formed be x and HgI_2 formed be y.

In the case of Hg_2I_2, $Hg = \frac{402}{656}x$, $I_2 = \frac{254}{656}x$

In the case of HgI_2, $Hg = \frac{201}{455}y$, $I_2 = \frac{254}{455}y$

So, $$\frac{402}{656}x + \frac{201}{455}y = \frac{254}{656}x + \frac{254}{455}y$$

From this equation, x/y can be calculated.]

22. A mixture of NaI and NaCl gave with sulphuric acid, Na_2SO_4 equal in mass to the original mixture taken. Find the percentage composition of the mixture.
23. A mixture of calcium and magnesium carbonates weighing 1.4 g was strongly heated until no further loss of weight was perceived. The residue weighed 0.76 g. What percentage of $MgCO_3$ was present in the mixture?

Answers

1. 0.072 mol, 16.8 g
2. 0.26
3. $CaCO_3 = 0.94$ g
4. 42 g
5. 8.75 g
6. 1.12 L
7. 8890 L
8. 2.462 g; 1.723 L
9. C_2N_2
10. 104.16 kg
11. 1.33 mol
12. 2.245 g of zinc
13. $Na_2CO_3 = 0.5962$ g, $K_2CO_3 = 0.6038$ g, $BaCO_3 = 0.394$ g
14. 700 mL
15. 50%
16. $AgCl = 4.87$ g
17. Al = 54.87%, Mg = 45.13%
18. 700 g
19. 16 g; 11.2 litre
20. Fe = 69.60%, Mg = 30.40%
21. 0.513 : 1
22. NaI = 28.86%, NaCl = 71.14%
23. 20.45%

OBJECTIVE QUESTIONS

Set–1 : Questions with single correct answer

1. The formula which represents the simple ratio of atoms in a compound is called:
(a) empirical formula (b) molecular formula
(c) structural formula (d) rational formula

2. The empirical formula of a compound is CH. Its molecular weight is 78. The molecular formula of the compound will be:
(a) C_2H_2 (b) C_3H_3 (c) C_4H_4 (d) C_6H_6

3. An organic compound on analysis gave C = 5.45%, H = 9.1% by mass. Its empirical formula is:
(a) CHO_2 (b) CH_2O (c) C_2H_4O (d) C_3H_4O

4. The chloride of a metal has the formula MCl_3. The formula of its phosphate will be:
(a) M_2PO_4 (b) MPO_4 (c) M_3PO_4 (d) $M(PO_4)_2$

5. The formula of chloric acid is $HClO_3$. The formula for calcium chlorate is:
(a) $CaClO_3$ (b) $Ca(ClO_3)_2$
(c) Ca_2ClO_3 (d) $Ca(ClO_3)_3$

6. An element A is tetravalent and another element B is divalent. The formula of the compound formed from these elements will be:
(a) A_2B (b) AB (c) AB_2 (d) A_2B_3

7. A compound of aluminium and chlorine is composed of 9.0 g Al for every 35.5 g of chlorine. The empirical formula of the compound is:
(a) AlCl (b) $AlCl_2$ (c) $AlCl_4$ (d) $AlCl_3$

8. Two elements A (At. mass = 75) and B (At. mass = 16) combine to yield a compound. The % by mass of A in the compound was found to be 75.08. The formula of the compound is: (MLNR 1991)
(a) A_2B (b) AB (c) AB_2 (d) A_2B_3

9. On analysis, a certain compound was found to contain iodine and oxygen in the ratio of 254 : 80. The formula of the compound is: (At. mass I = 127, O = 16)
(a) IO (b) I_2O (c) I_5O_2 (d) I_2O_5

10. The haemoglobin from red corpuscles of most mammals contains approximately 0.33% of iron by weight. The molecular weight of haemoglobin is 67,200. The number of iron atoms in each molecule of haemoglobin is:
(a) 1 (b) 2 (c) 3 (d) 4

11. 24.9 g of sodium thiosulphate (Mol. mass = 249) is weighed by a chemist. The moles of sodium thiosulphate he has weighed, are:
(a) $\frac{1}{10}$ (b) $\frac{1}{5}$ (c) $\frac{1}{2}$ (d) 1

12. The mass of sulphuric acid needed for dissolving 3 g magnesium carbonate is:
(a) 3.5 g (b) 7.0 g (c) 1.7 g (d) 17.0 g

13. 10 mL of a solution of H_2O_2 liberated 0.5 g of iodine from KI solution. The percentage of H_2O_2 in the solution is:
(a) 0.27 g (b) 0.67 g (c) 0.47 g (d) 0.87 g

14. The mass of CO_2 obtained when 60 g of calcium carbonate is treated with excess of hydrochloric acid is:
(a) 30.0 g (b) 15.0 g (c) 13.2 g (d) 26.4 g

15. The % loss in mass after heating a pure sample of potassium chlorate (Mol. mass = 122.5) will be:
(a) 12.25 (b) 24.50 (c) 39.17 (d) 49.0

16. The volume of oxygen required for complete oxidation of 2.0 litre methane at NTP is:
(a) 2 litre (b) 4 litre (c) 1 litre (d) 3 litre

17. 3 volumes of hydrogen are required to combine with one volume of nitrogen to form 2 volumes of ammonia. When 1 mole of hydrogen is allowed to react with the mole of nitrogen, the two gases:
(a) do not combine
(b) combine and both the gases are used up completely
(c) 2/3 mole of nitrogen remains unreacted
(d) some hydrogen remains uncombined

18. The percentage of nitrogen in urea is about:
(a) 38.4 (b) 46.6 (c) 59.1 (d) 61.3

19. If a mixture containing 3 moles of hydrogen and 1 mole of nitrogen is converted completely into ammonia, the ratio of initial and final volumes under the same temperature and pressure would be:
(a) 3 : 1 (b) 1 : 3 (c) 2 : 1 (d) 1 : 2

20. The mass of residue left after strongly heating 1.38 g of silver carbonate will be:
(a) 1.16 g (b) 1.33 g (c) 2.66 g (d) 1.08 g

21. The mass of oxygen with which 13.5 g of aluminium will completely react is:
(a) 4 g (b) 8 g (c) 12 g (d) 16 g

22. 1.6 g of an organic compound on combustion gave 4.4 g carbon dioxide. The % of carbon in the organic compound is:
(a) 30 (b) 45 (c) 60 (d) 75

23. At NTP, 10 litre of hydrogen sulphide gas reacted with 10 litre of sulphur dioxide gas. The volume of gas, after the reaction is complete, would be:
(a) 5 litre (b) 10 litre (c) 15 litre (d) 20 litre

24. A substance contains 0.25% iron by weight. The molecular mass of the substance is 89600. The number of iron atoms per molecule of the substance is:
(a) 5 (b) 4 (c) 3 (d) 2

25. The minimum amount of hydrogen required to reduce 7.95 g of CuO (Mol. mass = 79.5) will be:
(a) 2 g (b) 4 g
(c) 2240 mL at NTP (d) 22400 mL at NTP

26. 2.0 g mixture of sodium carbonate and sodium bicarbonate on heating to constant mass gave 224 mL of CO_2 at NTP. The % mass of sodium bicarbonate in the mixture is:
(a) 50 (b) 54 (c) 80 (d) 84

27. What volume of hydrogen at NTP will be liberated when 3.25 g of zinc completely dissolve in dilute HCl? (At. mass of Zn = 65)
(a) 1.12 litre (b) 11.20 litre
(c) 2.24 litre (d) 22.40 litre

28. The volume of oxygen at NTP evolved when 1.70 g of sodium nitrate is heated to a constant mass is:
(a) 0.112 litre (b) 0.224 litre (c) 22.4 litre (d) 11.2 litre

29. 50 g limestone is heated. The quantity of quicklime produced is:
(a) 56 g (b) 28 g (c) 14 g (d) 10 g

30. Assuming that petrol is octane (C_8H_{18}) and has a density of $0.8\ g\ mL^{-1}$, 1.425 litre of petrol on combustion will consume:
(a) 100 mole of oxygen (b) 124 mole of oxygen
(c) 150 mole of oxygen (d) 175 mole of oxygen

31. 1 mole of calcium phosphide on reaction with excess of water gives: **(IIT 1999)**
(a) 1 mole of phosphine
(b) 2 mole of phosphine
(c) 2 mole of phosphoric acid
(d) 1 mole of phosphorus pentoxide

32. Assuming fully decomposed, the volume of CO_2 released at STP on heating 9.85 g of $BaCO_3$ will be: (Atomic mass of Ba = 137) **[CBSE (PMT) 2004]**
(a) 0.84 L (b) 2.24 L (c) 4.06 L (d) 1.12 L

33. MnO_4^{2-} (1 mole) in neutral aqueous medium disproportionates to: **(AIIMS 2003)**
(a) 2/3 mole MnO_4^- and 1/3 mole MnO_2
(b) 1/3 mole MnO_4^- and 2/3 mole MnO_2
(c) 1/3 mole Mn_2O_7 and 1/3 mole MnO_2
(d) 2/3 mole Mn_2O_7 and 1/3 mole of MnO_2

34. 56 g of nitrogen and 8 g of hydrogen gas are heated in a closed vessel. At equilibrium 34 g of ammonia are present. The equilibrium number of moles of nitrogen, hydrogen and ammonia are respectively: **(KCET 2004)**
(a) 1, 2, 2 (b) 2, 2, 1 (c) 1, 1, 2 (d) 2, 1, 2

35. If 30 mL of H_2 and 20 mL of O_2 reacts to form H_2O, what is left at the end of the reaction? **(AFMC 200..)**
(a) 10 mL of H_2 (b) 5 mL of H_2
(c) 10 mL of O_2 (d) 5 mL of O_2

[**Hint:** $H_2(g) + \frac{1}{2}O_2(g) \longrightarrow H_2O(g)$]

	$H_2(g)$	$O_2(g)$	$H_2O(g)$
Initially	30	20	0
After the reaction	0	(20 – 15)	30

36. For the formation of 3.65 g of hydrogen chloride gas, what volumes of hydrogen gas and chlorine gas are required at NTP conditions? **[PMT (Kerala) 2005]**
(a) 1.12 L, 1.12 L (b) 1.12 L, 2.24 L
(c) 3.65 L, 1.83 L (d) 1 L, 1 L

37. An alkaloid contains 17.28% of nitrogen and its molecular mass is 162. The number of nitrogen atoms present in one molecule of alkaloid is: **[PMT (Kerala) 2005]**
(a) five (b) four (c) three (d) two

38. x gm of $CaCO_3$ was completely burnt in air. The weight of the solid residue formed is 28 g. What is the value of 'x' in grams? **(EAMCET 2005)**
(a) 44 (b) 200 (c) 150 (d) 50

39. Sodium bicarbonate on heating decomposes to form sodium carbonate, CO_2 and water. If 0.2 mole of sodium bicarbonate is completely decomposed, how many mole of sodium carbonate is formed? **[CET (J&K) 2006; SCRA 2009]**
(a) 0.1 (b) 0.2 (c) 0.05 (d) 0.025
[**Hint:** The reaction involved is :
$$2NaHCO_3(s) \xrightarrow{\Delta} Na_2CO_3(s) + CO_2(g) + H_2O(l)$$]

40. One mole of acidified $K_2Cr_2O_7$ on reaction with excess of KI will liberate . . . . moles of I_2. **[PET (Kerala) 2006]**
(a) 6 (b) 1 (c) 7 (d) 3
[**Hint:** $Cr_2O_7^{2-} + 14H^+ + 6I^- \longrightarrow 2Cr^{3+} + 3I_2 + 7H_2O$]

41. The decomposition of a certain mass of $CaCO_3$ gave 11.2 dm^3 of CO_2 gas at STP. The mass of KOH required to completely neutralise the gas is: **[KCET 2006; Indraprastha (Engg.) 2007]**
(a) 56 g (b) 28 g (c) 42 g (d) 20 g

42. At T K, 100 litre of dry oxygen is present in a sealed container. It is subjected to silent electric discharge, till the volumes of oxygen and ozone become equal. What is the volume (in litre) of ozone formed at T K? **[EAMCET (Engg.) 2006]**
(a) 50 L (b) 60 L (c) 30 L (d) 40 L
[**Hint:** $3O_2 \longrightarrow 2O_3$

	$3O_2$	$2O_3$
$t = 0$	100	0
After the reaction	$100 - 3x$	$2x$

$\because$ $100 - 3x = 2x$ or $x = 20$
$\therefore$ Volume of ozone $= 2x = 40$ L]

43. In the reaction,
$2Al(s) + 6HCl(aq.) \longrightarrow 2Al^{3+}(aq.) + 6Cl^-(aq.) + 3H_2(g)$: **(AIEEE 2007)**
(a) 11.2 L $H_2(g)$ at STP is produced for every mole of $HCl(aq.)$ consumed
(b) 6 L $HCl(aq.)$ is consumed for every 3 L $H_2(g)$ produced
(c) 33.6 L $H_2(g)$ is produced regardless of temperature and pressure for every mole of Al that reacts
(d) 67.2 L $H_2(g)$ at STP is produced for every mole of Al that reacts

44. The weight of iron which will be converted into its oxide (Fe_3O_4) by the action of 18 g of steam on it will be: (Atomic mass of Fe = 56) **[CMC (Vellore) 2007]**
(a) 168 g (b) 84 g (c) 42 g (d) 21 g
[**Hint:** $3Fe(s) + 4H_2O(g) \longrightarrow Fe_3O_4(s) + 4H_2(g)$

$3Fe(s)$	$4H_2O(g)$
3 mol	4 mol
3×56	4×18
$= 168$ g	$= 72$ g

$\because$ 72 g steam reacts with 168 g of iron
$\therefore$ 18 g steam will react with 42 g of iron.]

45. Match the following :

List-I	List-II (at STP)
(A) 10 g $CaCO_3 \xrightarrow[\text{Decomposition}]{\Delta}$	(i) 0.224 L CO_2
(B) 1.06 g $Na_2CO_3 \xrightarrow{\text{Excess HCl}}$	(ii) 4.48 L CO_2
	(iii) 0.448 L CO_2
(C) 2.4 g C $\xrightarrow[\text{Combustion}]{\text{Excess } O_2}$	(iv) 2.24 L CO_2
(D) 0.56 g CO $\xrightarrow[\text{Combustion}]{\text{Excess } O_2}$	(v) 22.4 L CO_2

The correct match is: [EAMCET (Engg.) 2008]

	A	B	C	D
(a)	(iv)	(i)	(ii)	(iii)
(b)	(v)	(i)	(ii)	(iii)
(c)	(iv)	(i)	(iii)	(ii)
(d)	(i)	(iv)	(ii)	(iii)

[**Hint:** (A) $\underset{\substack{100\text{ g}\\10\text{ g}}}{CaCO_3} \xrightarrow{\Delta} CaO + \underset{\substack{22.4\text{ L}\\2.24\text{ L}}}{CO_2}$

(B) $\underset{\substack{1\text{ mol }(106\text{ g})\\1.06\text{ g}}}{Na_2CO_3} + 2HCl \longrightarrow 2NaCl + H_2O + \underset{\substack{22.4\text{ L}\\0.224\text{ L}}}{CO_2}$

(C) $\underset{\substack{12\text{ g}\\2.4\text{ g}}}{C} + O_2 \longrightarrow \underset{\substack{22.4\text{ L}\\4.48\text{ L}}}{CO_2}$

(D) $\underset{\substack{28\text{ g}\\0.56\text{ g}}}{CO} + \frac{1}{2}O_2 \longrightarrow \underset{\substack{22.4\text{ L}\\0.448\text{ L}}}{CO_2}$]

46. $Fe^{2+} \longrightarrow Fe^{3+} + e^-$, $MnO_4^- + 5e^- \longrightarrow Mn^{2+}$, the ratio of stoichiometric coefficient of Fe^{2+} and MnO_4^- is: (UPMT 2008)
(a) 1: 5 (b) 5 : 1 (c) 2 : 3 (d) 6 : 1

47. What volume of oxygen gas (O_2) measured at 0°C and 1 atm, is needed to burn completely 1L of propane gas (C_3H_8) measured under the same conditions ? [CBSE-PMT (Pre.) 2008]
(a) 5 L (b) 10 L (c) 7 L (d) 6 L
[**Hint:** $\underset{\substack{1\text{ vol.}\\1\text{ L}}}{C_3H_8(g)} + \underset{\substack{5\text{ vol.}\\5\text{ L}}}{5O_2(g)} \longrightarrow \underset{\substack{3\text{ vol.}\\3\text{ L}}}{3CO_2(g)} + \underset{\substack{4\text{ vol.}\\4\text{ L}}}{4H_2O(g)}$]

48. How many moles of lead (II) chloride will be formed from a reaction between 6.5 g PbO and 3.2 g HCl ? [CBSE-PMT (Pre.) 2008]
(a) 0.011 (b) 0.029 (c) 0.044 (d) 0.333
[**Hint:** $n_{PbO} = \frac{6.5}{224} = 0.029$; $n_{HCl} = \frac{3.2}{36.5} = 0.087$
The reaction is,
$$PbO + 2HCl \longrightarrow PbCl_2 + H_2O$$
PbO will be limiting reagent because on complete consumption, it gives least amount of product, *i.e.*, 0.029 mol $PbCl_2$.]

49. 1 mole of methylamine on reaction with nitrous acid gives at NTP:
(a) 1 litre of nitrogen (b) 22.4 litre of nitrogen
(c) 11.2 litre of nitrogen (d) 5.6 litre of nitrogen
[**Hint:** $\underset{1\text{ mol}}{CH_3—NH_2} + HONO \longrightarrow CH_3—OH + \underset{\substack{22.4\text{ litre}\\\text{at STP}}}{N_2} + H_2O$]

50. The value of 'n' in the reaction :
$$Cr_2O_7^{2-} + 14H^+ + nFe^{2+} \longrightarrow 2Cr^{3+} + nFe^{3+} + 7H_2O$$
will be : [PET (MP) 2008]
(a) 2 (b) 3 (c) 6 (d) 7

51. In the complex with formula $MCl_3 \cdot 4H_2O$, the coordination number of the metal M is six and there is no molecule of hydration in it. The volume of 0.1 M $AgNO_3$ solution needed to precipitate the free chloride ions in 200 mL of 0.01 M solution of the complex is: [PMT (Kerala) 2008]
(a) 40 mL (b) 20 mL (c) 60 mL (d) 80 mL
[**Hint:** The complex will be $[M(H_2O)_4Cl_2]Cl$, the complex will have free chloride ion concentration of (0.01 M).
$$1\,Cl^- + 1AgNO_3 \longrightarrow AgCl + NO_3^-$$
$$\frac{M_1V_1}{n_1} = \frac{M_2V_2}{n_2} \text{ or } \frac{0.01 \times 200}{1} = \frac{0.1 \times V_2}{1}$$
$$V_2 = 20\text{ mL}$$]

52. 1.5 g $CdCl_2$ was found to contain 0.9 g Cd. Calculate the atomic weight of Cd. [EAMCET (Engg.) 2009]
(a) 118 (b) 112 (c) 106.5 (d) 53.25
[**Hint:** ∵ 0.6 g chlorine combines with 0.9 g Cd
∴ 71 g chlorine will combine with $\frac{0.9}{0.6} \times 71$ g Cd, *i.e*, 106.5 g Cd
∴ Atomic weight of Cd = 106.5]

53. 10 g of hydrogen and 64 g of oxygen were filled in a steel vessel and exploded. Amount of water produced in this reaction will be : (AIPMT 2009)
(a) 1 mol (b) 2 mol (c) 3 mol (d) 4 mol
[**Hint:** 10 g H_2, *i.e.*, 5 mol is mixed with 64 g O_2, *i.e.*, 2 mol
$$\underset{2\text{ mol}}{2H_2(g)} + \underset{1\text{ mol}}{O_2(g)} \longrightarrow \underset{2\text{ mol}}{2H_2O(g)}$$
Case I : Let H_2 is completely consumed
∵ 2 mol H_2 gives 2 mol H_2O
∴ 5 mol H_2 gives 5 mol H_2O
Case II : Let O_2 is completely consumed
∵ 1 mol O_2 gives 2 mol H_2O
∴ 2 mol O_2 gives 4 mol H_2O
Since O_2 gives least amount of product on complete consumption hence it is limiting reagent and amount of H_2O formed will be 4 mol.]

54. In an experiment, 4 g of M_2O_x oxide was reduced to 2.8 g of the metal. If the atomic mass of the metal is 56 g mol^{-1}, the number of oxygen atoms in the oxide is: (AFMC 2010)
(a) 1 (b) 2 (c) 3 (d) 4

55. A vessel fitted with a weightless, frictionless piston of 0.025 m^2 area contains conc. HCl. The piston moved 1 m outward when 0.075 kg of iron fillings were added at 300 K. The solution left behind was found to contain Fe(II). The approximate purity of the iron sample is: (ISAT 2010)
(a) 50% (b) 75% (c) 90% (d) 40%
[**Hint:** Volume of H_2 gas produced = $0.025 \times 1 = 0.025\text{ m}^3$
= 25 L
$$PV = nRT$$
$$1 \times 25 = n \times 0.082 \times 300$$
$$n_{H_2} = 1.016$$
The reaction involved is :
$$Fe + 2HCl \longrightarrow FeCl_2 + H_2\uparrow$$
Thus, number of moles of iron will be 1.016.
i.e., Mas iron is 1.016×56 *i.e.*, 56.896 g
% purity of iron sample = $\frac{56.896}{75} \times 100 \approx 75\%$]

56. The reaction of calcium with water is represented by the equation:
$$Ca + 2H_2O \longrightarrow Ca(OH)_2 + H_2\uparrow$$

What volume of H_2 at STP would be liberated when 8 g of calcium completely reacts with water? **(AIIMS 2010)**

(a) 0.2 cm^3 (b) 0.4 cm^3 (c) 224 cm^3 (d) 4480 cm^3

57. What volume of hydrogen will be liberated at NTP by the reaction of Zn on 50 mL dilute H_2SO_4 of specific gravity 1.3 and having purity 40%? **[BHU (Mains) 2010]**

(a) 3.5 litre (b) 8.25 litre (c) 6.74 litre (d) 5.94 litre

[**Hint:** Mass of $H_2SO_4 = \frac{50 \times 1.3 \times 40}{100} = 26 \text{ g}$

$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$$

Volume of H_2 at NTP $= \frac{22.4}{98} \times 26 = 5.94$ litre]

Answers : OBJECTIVE QUESTIONS

1. (a)	**2.** (d)	**3.** (c)	**4.** (b)	**5.** (b)	**6.** (c)	**7.** (d)	**8.** (b)
9. (d)	**10.** (d)	**11.** (a)	**12.** (a)	**13.** (b)	**14.** (d)	**15.** (c)	**16.** (b)
17. (c)	**18.** (b)	**19.** (c)	**20.** (d)	**21.** (c)	**22.** (d)	**23.** (a)	**24.** (b)
25. (c)	**26.** (d)	**27.** (a)	**28.** (b)	**29.** (b)	**30.** (a)	**31.** (b)	**32.** (d)
33. (a)	**34.** (c)	**35.** (d)	**36.** (a)	**37.** (d)	**38.** (d)	**39.** (a)	**40.** (d)
41. (b)	**42.** (d)	**43.** (c)	**44.** (c)	**45.** (a)	**46.** (b)	**47.** (a)	**48.** (b)
49. (b)	**50.** (c)	**51.** (b)	**52.** (c)	**53.** (d)	**54.** (c)	**55.** (b)	**56.** (d)
57. (d)							

BRAIN STORMING PROBLEMS

OBJECTIVE QUESTIONS for IIT ASPIRANTS

The following questions contain single correct option:

1. What mass of $Mg(OH)_2$ is required to neutralize 125 mL of 0.136 *M* hydrochloric acid solution?
Molar mass of $Mg(OH)_2 = 58.33\ g\ mol^{-1}$.
(a) 0.248 g (b) 0.496 g (c) 0.992 g (d) 1.98 g
[**Hint:** $Mg(OH)_2 + 2HCl \longrightarrow MgCl_2 + 2H_2O$
$$\text{Number of moles of HCl} = \frac{MV}{1000} = \frac{0.136 \times 125}{1000} = 0.017$$
2 mole HCl is neutralized by 58.33 g of $Mg(OH)_2$
$$\therefore 0.017 \text{ mole HCl will be neutralized by } \frac{58.33}{2} \times 0.017 \text{ g of } Mg(OH)_2 = 0.496 \text{ g}]$$

2. Calculate the mass of ammonia that can be produced from the decomposition of a sample of $(NH_4)_2PtCl_6$ containing 0.1 g Pt: Molar mass of $(NH_4)_2PtCl_6$ is 443.9 g mol^{-1}.
(a) 0.0811 g (b) 0.0766 g (c) 0.0175 g (d) 0.00766 g

3. Consider the following data:

Element	Atomic mass
A	12.01
B	35.5

A and *B* combine to form new substance *X*. If 4 moles of *B* combine with 1 mole of *A* to give 1 mole of *X*, then weight of one mole of *X* is:
(a) 154 g (b) 74 g (c) 47.5 g (d) 166 g
[**Hint:** $A + 4B \longrightarrow X$
Molar mass of $X = 12.01 + 4 \times 35.5 = 154\ g\ mol^{-1}$]

4. Chlorine can be prepared by reacting HCl with MnO_2. The reaction is represented by this equation:
$$MnO_2(s) + 4HCl(aq.) \longrightarrow Cl_2(g) + MnCl_2(aq.) + 2H_2O(l)$$
Assuming the reaction goes to completion, what mass of concentrated HCl solution (36% HCl by mass) is needed to produce 2.5 g of Cl_2?
(a) 5.15 g (b) 14.3 g (c) 19.4 g (d) 26.4 g

5. What volume of 3 *M* Na_2SO_4 must be added to 25 mL of 1 *M* $BaCl_2$ to produce 5 g $BaSO_4$?
(a) 7.2 mL (b) 8.3 mL (c) 10 mL (d) 14 mL
[**Hint:** $Na_2SO_4 + BaCl_2 \longrightarrow BaSO_4 + 2NaCl$
$$\text{Number of moles of } BaSO_4 = \frac{\text{Mass}}{\text{Molar mass}} = \frac{5}{233} = 0.0215$$
Number of moles of Na_2SO_4 needed = 0.0215
$$\frac{MV}{1000} = 0.0215$$
$$\frac{3 \times V}{1000} = 0.0215$$
$$V = 7.2 \text{ mL}]$$

6. When $FeCl_3$ is ignited in an atmosphere of pure oxygen, this reaction takes place:
$$4FeCl_3(s) + 3O_2(g) \longrightarrow 2Fe_2O_3(s) + 6Cl_2(g)$$
If 3 moles of $FeCl_3$ are ignited in the presence of 2 moles of O_2 gas, how much of which reagent is present in excess and therefore, remains unreacted?
(a) 0.33 mole $FeCl_3$ remains unreacted
(b) 0.67 mole $FeCl_3$ remains unreacted
(c) 0.25 mole O_2 remains unreacted
(d) 0.50 mole O_2 remains unreacted

7. A self-contained breathing apparatus uses potassium superoxide, KO_2, to convert the carbon dioxide and water in exhaled air into oxygen, as shown by the equation:
$$4KO_2(s) + 2H_2O(g) + 4CO_2(g) \longrightarrow 4KHCO_3(s) + 3O_2(g)$$
How many molecules of oxygen gas will be produced from 0.0468 g of carbon dioxide that is exhaled in a typical breath?
(a) 4.8×10^{20} (b) 6.4×10^{20} (c) 8.5×10^{20} (d) 1.9×10^{21}
[**Hint:** $\because$ 4 mole CO_2 gives 3 mole O_2
$$\therefore \left(\frac{0.0468}{44}\right) \text{ mole } CO_2 \text{ will give } \frac{3}{4} \times \frac{0.0468}{44} \text{ mole } O_2 = 7.977 \times 10^{-4} \text{ mol}$$
$$\text{Number of molecules of } O_2 = 7.977 \times 10^{-4} \times 6.023 \times 10^{23} = 4.8 \times 10^{20}]$$

8. Antimony reacts with chlorine according to this equation:
$$2Sb + 3Cl_2 \rightleftharpoons 2SbCl_3$$
How many grams of $SbCl_3$ can be prepared if 0.012 mole of antimony are reacted with 0.02 mole of chlorine? The molar mass of $SbCl_3$ equals 228.2 g mol^{-1}.
(a) 1.52 g (b) 1.83 g (c) 2.74 g (d) 4.56 g

9. A gaseous mixture of propane and butane of volume 3 L on complete combustion produces 10 L of CO_2 under standard conditions of temperature and pressure. The ratio of volumes of propane to butane is:
(a) 1 : 2 (b) 2 : 1 (c) 3 : 2 (d) 3 : 1

10. What amount of silver will be obtained on thermal decomposition of 2.76 g of silver carbonate, Ag_2CO_3 (276 amu)?
(a) 2.16 g (b) 0.216 g (c) 216 g (d) 21.6 g

11. $PH_3(g)$ decomposes on heating to produce phosphorous and hydrogen. The change in volume when 100 mL of such gas decomposed is:
(a) +50 mL (b) +500 mL (c) −50 mL (d) −500 mL
[**Hint:** $4PH_3(g) \xrightarrow{\text{Heat}} P_4(s) + 6H_2(g)$
Volume of H_2 formed by decomposition of 100 mL PH_3
$$= \frac{6}{4} \times 100 = 150 \text{ mL}$$
Thus, change in volume = (150 − 100) = 50 mL]

12. What amount of $BaSO_4$ can be obtained on mixing 0.5 mole $BaCl_2$ with 1 mole of H_2SO_4?
(a) 0.5 mol (b) 0.15 mol (c) 0.1 mol (d) 0.2 mol
[**Hint:**

	$BaCl_2$	+ H_2SO_4	$\longrightarrow$ $BaSO_4$	+ 2HCl]
Initially	0.5	1	0	0
After the reaction	0	(1 − 0.5)	0.5	2 × 0.5

13. In the reaction,

$$CrO_5 + H_2SO_4 \longrightarrow Cr_2(SO_4)_3 + H_2O + O_2$$

one mole of CrO_5 will liberate how many moles of O_2?

(a) 5/2 (b) 5/4
(c) 9/2 (d) None of these

14. Calcium carbonate decomposes on heating according to the equation;

$$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$$

At STP, the volume of CO_2 obtained by thermal decomposition of 50 g of $CaCO_3$ will be:

(a) 22.4 litre (b) 44 litre (c) 11.2 litre (d) 1 litre

15. The volume in litre of CO_2 liberated at STP when 10 g of 90% pure limestone is heated completely, is:

(a) 22.4 L (b) 2.24 L (c) 20.16 L (d) 2.016 L

[**Hint:** $\underset{\substack{1\text{ mole}\\(100\text{ g})}}{CaCO_3} \longrightarrow CaO + \underset{22.4\text{ litre at STP}}{CO_2(g)}$

$\because$ 100 g $CaCO_3 \equiv$ 22.4 L CO_2 at STP

$\therefore$ 9 g $CaCO_3 \equiv \frac{22.4}{100} \times 9$ L CO_2 at STP

= 2.016 L CO_2 at STP]

16. A metal oxide has the formula Z_2O_3. It can be reduced by hydrogen to give free metal and water. 0.1596 g of the metal requires 6 mg of hydrogen for complete reduction. The atomic mass of the metal is:

(a) 27.9 g mol^{-1} (b) 159.6 g mol^{-1}
(c) 79.8 g mol^{-1} (d) 55.8 g mol^{-1}

[**Hint:** $Z_2O_3 + 3H_2(g) \longrightarrow 2Z + 3H_2O$

$\because$ 6 g H_2 gives 2 mole Z

$\therefore$ 6×10^{-3} g H_2 will give 0.002 mole Z

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

$$0.002 = \frac{0.1596}{\text{Molar mass}}$$

$\therefore$ $\text{Molar mass} = \frac{0.1596}{0.002} = 79.8 \text{ g mol}^{-1}$]

17. 10 g $CaCO_3$ is completely decomposed to X and CaO. X is passed into an aqueous solution containing one mole of sodium carbonate. What is the number of moles of sodium bicarbonate formed?

[Molar mass: $CaCO_3$(100); Na_2CO_3(106); $NaHCO_3$(84)].

(a) 0.2 (b) 0.1 (c) 0.01 (d) 10

18. Chlorine gas can be produced by reacting sulphuric acid with a mixture of MnO_2 and NaCl. The reaction follows the equation:

$$2NaCl + MnO_2 + 3H_2SO_4 \longrightarrow 2NaHSO_4 + MnSO_4 + Cl_2 + 2H_2O$$

What volume of chlorine can be produced from 1 g of sodium chloride under standard conditions of temperature and pressure?

(a) 1.915 L (b) 19.15 L (c) 20.22 L (d) 0.191 L

[**Hint:** 2 mole NaCl (117 g) $\equiv$ 1 mole Cl_2 (22.4 L at STP)

$\therefore$ 1 g NaCl will give $= \frac{22.4}{117}$ L Cl_2 at STP

= 0.191 L Cl_2 at STP]

19. 1 mole of a gaseous aliphatic compound $C_nH_{3n}O_m$ is completely burnt in an excess of oxygen. The contraction in volume is:

(a) $\left(1 + \frac{1}{2}n - \frac{3}{4}m\right)$ (b) $\left(1 + \frac{3}{4}n - \frac{1}{4}m\right)$
(c) $\left(1 - \frac{1}{2}n - \frac{3}{4}m\right)$ (d) $\left(1 + \frac{3}{4}n - \frac{1}{2}m\right)$

20. A mixture of CH_4 and C_2H_4 was completely burnt in an excess of oxygen, yielding equal volumes of CO_2 and steam. Calculate the percentages of the compounds in the original mixture:

(a) 25% CH_4 and 75% C_2H_4 (b) 30% CH_4 and 70% C_2H_4
(c) 75% CH_4 and 25% C_2H_4 (d) 50% CH_4 and 50% C_2H_4

21. When same amount of zinc is treated separately with excess of H_2SO_4 and NaOH, the ratio of volumes of H_2 evolved is:

(a) 1 : 1 (b) 1 : 2 (c) 2 : 1 (d) 9 : 4

[**Hint:** $Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$

$Zn + 2NaOH \longrightarrow Na_2ZnO_2 + H_2$]

22. 10 mole of SO_2 and 15 mole of O_2 were passed over a catalyst to produce 8 mole of SO_3. The ratio of SO_2 and SO_3 moles in mixture is:

(a) 5/4 (b) 1/4 (c) 1/2 (d) 3/4

[**Hint:** $SO_2(g) + \frac{1}{2}O_2(g) \xrightarrow{\text{Catalyst}} SO_3(g)$

	SO_2	O_2	SO_3
$t = 0$	10	15	0
Final	$10 - x$	$15 - \frac{x}{2}$	x

$x = 8$

$\therefore$ $n_{SO_2} = 10 - x = 2, n_{SO_3} = 8$

$\frac{n_{SO_2}}{n_{SO_3}} = \frac{2}{8} = \frac{1}{4}$]

23. $HgCl_2 + 4KI \longrightarrow K_2[HgI_4] + 2KCl$

1 mole each of Hg^{2+} and I^- will form how many moles of HgI_4^{2-}?

(a) 1 mol (b) 0.5 mol (c) 0.25 mol (d) 2 mol

24. 25 mL of 0.15 M $Pb(NO_3)_2$ reacts completely with 20 mL of $Al_2(SO_4)_3$. The molar concentration of $Al_2(SO_4)_3$ will be:

$$3Pb(NO_3)_2(aq.) + Al_2(SO_4)_3(aq.) \longrightarrow 3PbSO_4(s) + 2Al(NO_3)_3(aq.)$$

(a) 0.0625 M (b) 0.0242 M
(c) 0.1875 M (d) 0.2346 M

[**Hint:** $\frac{M_1V_1}{n_1} Pb(NO_3)_2 = \frac{M_2V_2}{n_2} Al_2(SO_4)_3$

$$\frac{0.15 \times 25}{3} = \frac{M_2 \times 20}{1}$$

$M_2 = 0.0625$]

25. In the reaction,

$$2NH_3(g) + 5F_2 \longrightarrow N_2F_4 + 6HF$$

3.56 g N_2F_4 is obtained by mixing 2 g NH_3 and 8 g F_2. The percentage yield of the production is:

(a) 81.28% (b) 71.2% (c) 68% (d) 79%

[**Hint:** $\underset{34\text{ g}}{2NH_3(g)} + \underset{190\text{ g}}{5F_2} \longrightarrow \underset{104\text{ g}}{N_2F_4} + 6HF$

Amount of N_2F_4 formed by 2 g $NH_3 = \frac{104}{34} \times 2 = 6.12$ g

Amount of N_2F_4 formed by 8 g $F_2 = \frac{104}{190} \times 8 = 4.38$ g

N_2F_4 will be limiting and actual amount of product is 3.56 g

$\therefore$ % yield $= \frac{\text{Actual amount of product}}{\text{Calculated amount of product}} \times 100$

$= \frac{3.56}{4.38} \times 100$

$= 81.28\%$]

The following questions may have more than one correct options:

1. 1.5 g of oxygen is produced by heating $KClO_3$. How much KCl is produced in the reaction?
(a) 4.15×10^{-2} mol (b) 4.33 g
(c) 1.78×10^{-2} mol (d) 1.33 g

2. Calculate the amount of lime that can be produced by heating 100 g of 90% pure limestone:
(a) 50.4 g (b) 0.98 mol (c) 0.9 mol (d) 56 g
[**Hint:** $\underset{100\ g}{CaCO_3} \longrightarrow \underset{56\ g}{CaO} + CO_2$

100 g $CaCO_3 \equiv$ 56 g CaO

$\therefore$ 90 g $CaCO_3 \equiv \frac{56}{100} \times 90$ g CaO, *i.e.*, 50.4 g CaO

Number of moles of CaO $= \frac{50.4}{56} = 0.9$]

3. In an experiment, the following four gases were produced. 11.2 L of which two gases at STP will weigh 14 g?
(a) N_2O (b) NO_2 (c) N_2 (d) CO

4. 2 mole of CO_2 is required to prepare:
(a) 336 g of $NaHCO_3$ (b) 168 g of $NaHCO_3$
(c) 462 g of $Ca(HCO_3)_2$ (d) 162 g of $Ca(HCO_3)_2$

5. 8.7 g of pure MnO_2 is heated with an excess of HCl and the gas evolved is passed into a solution of KI. Calculate the amount of the iodine liberated (Mn = 55, Cl = 35.5, I = 127):
(a) 0.1 mol (b) 25.4 g
(c) 15.4 g (d) 7.7 g

6. 100 mL of gaseous mixture containing CO, CO_2 and O_2 was sparked; there was contraction of 80 mL volume when the mixture was passed through aqueous caustic potash KOH. The composition of initial gaseous mixture will be respectively:
(a) 20 mL, 70 mL, 10 mL (b) 50 mL, 30 mL, 20 mL
(c) 30 mL, 50 mL, 20 mL (d) 30 mL, 60 mL, 10 mL
[**Hint :** (d) $CO + \frac{1}{2}O_2 \longrightarrow CO_2$

10 mL O_2 will give 20 mL CO_2 in above reaction. Thus, total volume of CO_2 will be 80 mL which will be absorbed in caustic potash KOH.

Similarly in (c) option, 30 mL CO_2 will be formed on sparking.

$$\underset{\substack{30\ mL\\(Limiting)}}{CO} + \frac{1}{2}O_2 \longrightarrow \underset{30\ mL}{CO_2}$$

Total volume of CO_2 will be 80 mL]

7. SO_2 gas is slowly passed through an aqueous suspension containing 12 g $CaSO_3$ till the milkiness just disappears, what amount of SO_2 would be required? [BHU (Mains) 2010]
(a) 12.8 g (b) 6.4 g (c) 0.2 mole (d) 0.1 mole
[**Hint :** The reaction involved is

$$\underset{\substack{milky\\1\ mol\\120\ g}}{CaSO_3} + H_2O + \underset{\substack{1\ mol\\64\ g}}{SO_2} \longrightarrow \underset{colourless}{Ca(HSO_3)_2}$$

12 g $CaSO_3$ will react with 6.4 g SO_2 or 0.1 mol SO_2.]

Answers

• Single correct option

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

• One or more than one correct options

1. (c, d)	2. (a, c)	3. (c, d)	4. (b, d)	5. (a, b)	6. (c, d)	7. (b, d)

LINKED COMPREHENSION TYPE QUESTIONS

• Passage 1

In a reaction vessel, $100\,g\ H_2$ *and* $100\,g\ Cl_2$ *are mixed and suitable conditions are provided for the following reaction:*

$$H_2(g) + Cl_2(g) \xrightarrow{?} 2HCl(g)$$

Quantum yield of this reaction is $\phi = 10^5$.

Answer the following questions:

1. Select the correct statement(s) for the above reaction:
   (a) Presence of light is required for this reaction
   (b) It is a chain reaction
   (c) Catalyst is required
   (d) All of the above
2. The limiting reagent in this reaction will be:
   (a) H_2 (b) Cl_2
   (c) both (d) cannot be predicted
3. The actual amount of HCl formed in this reaction is:
   (a) 102.8 g (b) 73 g
   (c) 36.5 g (d) 142 g
4. The amount of excess reactant remaining is:
   (a) 50 g (b) 97.2 g
   (c) 46 g (d) 64 g
5. The amount of HCl formed (at 90% yield) will be:
   (a) 36.8 g (b) 62.5 g
   (c) 80 g (d) 92.53 g

• Passage 2

Dissolved oxygen in water is determined by using a redox reaction. Following equations describe the procedure:

I. $2Mn^{2+}(aq.) + 4OH^-(aq.) + O_2(g) \longrightarrow 2MnO_2(s) + 2H_2O(l)$

II. $MnO_2(s) + 2I^-(aq.) + 4H^+(aq.) \longrightarrow Mn^{2+}(aq.) + I_2(aq.) + 2H_2O(l)$

III. $2S_2O_3^{2-}(aq.) + I_2(aq.) \longrightarrow S_4O_6^{2-}(aq.) + 2I^-(aq.)$

Answer the following questions:

1. How many moles of $S_2O_3^{2-}$ are equivalent to each mole of O_2?
   (a) 0.5 (b) 1 (c) 2 (d) 4
2. What amount of I_2 will be liberated from 8 g dissolved oxygen?
   (a) 127 g (b) 254 g (c) 504 g (d) 1008 g
3. If 3×10^{-3} moles O_2 is dissolved per litre of water, then what will be the molarity of I^- produced in the given reaction?
   (a) $3 \times 10^{-3}\ M$ (b) $4 \times 3 \times 10^{-3}\ M$
   (c) $2 \times 3 \times 10^{-3}\ M$ (d) $\frac{1}{2} \times 3 \times 10^{-3}\ M$
4. Number of which two chemical species will be same in the given procedure?
   (a) MnO_2 (b) I_2 (c) I^- (d) $S_2O_3^{2-}$
5. 8 mg dissolved oxygen will consume:
   (a) 5×10^{-4} mol Mn^{2+} (b) 2.5×10^{-4} mol Mn^{2+}
   (c) 10^{-3} mol Mn^{2+} (d) 2 mol Mn^{2+}

Answers

Passage 1.	**1.** (a, b)	**2.** [illegible])	**3.** (a)	**4.** (b)	**5.** (d)
Passage 2.	**1.** (d)	**2.** [illegible]	**3.** (b)	**4.** (a)	**5.** (a)

SELF ASSESSMENT

ASSIGNMENT NO. 15

Straight Objective Type Questions

This section contains 10 multiple choice questions. Each question has 4 choices (a), (b), (c) and (d), out of which only one is correct.

1. An oxide of iodine contains 25.4 g of iodine for 8 g of oxygen. Its molecular formula will be:
(a) I_2O_3 (b) I_2O (c) I_2O_5 (d) I_2O_7

2. 2 g H_2 and 1 g O_2 are allowed to react according to following equation:
$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(g)$$
Amount of H_2O formed in the reaction will be:
(a) 3 g (b) 1.125 g
(c) 4.5 g (d) 2.50 g

3. 20 cc of CO_2 gas is passed over red hot coke. The volume of carbon monoxide evolved is:
(a) 10 cc (b) 20 cc (c) 30 cc (d) 40 cc

4. In the Haber process:
$$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$$
30 L of H_2 and 30 L of N_2 were taken for reaction which yielded only 50% of expected product. What will be the composition of the gaseous mixture in the end ?
(a) 20 L NH_3, 25 L N_2 and 20 L H_2
(b) 10 L NH_3, 25 L N_2 and 15 L H_2
(c) 20 L NH_3, 10 L N_2 and 30 L H_2
(d) 20 L NH_3, 25 L N_2 and 15 L H_2

5. $KMnO_4$ reacts with oxalic acid according to the equation:
$$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \longrightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$
20 mL of 0.1 *M* $KMnO_4$ will react with:
(a) 120 mL of 0.25 *M* oxalic acid
(b) 150 mL of 0.1 *M* oxalic acid
(c) 50 mL of 0.1 *M* oxalic acid
(d) 50 mL of 0.2 *M* oxalic acid

6. Orthoboric acid, on heating, decomposes in two ways:
$$\text{(I) } H_3BO_3 \longrightarrow HBO_2 + H_2O$$
$$\text{(II) } H_3BO_3 \longrightarrow B_2O_3 + H_2O$$
If 9 moles of H_3BO_3 decomposes by (I) pathway and remaining by (II) pathway. If total 11 moles of water are formed, then the number of moles of B_2O_3 formed is:
(a) 6 (b) 5 (c) 3 (d) 2

7. 2 moles of H_2S and 11.2 L of SO_2 at NTP react to give *x* mole of sulphur. The value of '*x*' will be:
Reaction: $SO_2(g) + 2H_2S(g) \longrightarrow 3S + 2H_2O$
(a) 1.5 (b) 3 (c) 11.2 (d) 6

8. A sample of argentite ore contains 1.34% of Ag_2S by mass. How many grams of this ore would give 1 g of Ag on extraction?
(a) 134 g (b) 108 g (c) 85.7 g (d) 74.6 g

9. What mass of HNO_3 is needed to convert 5 g of iodine into iodic acid according to the reaction?
$$I_2 + HNO_3 \longrightarrow HIO_3 + NO_2 + H_2O$$
(a) 12.4 g (b) 24.8 g (c) 0.248 g (d) 49.6 g

10. $$KI + I_2 + HNO_3 \longrightarrow HIO_3 + KIO_3 + NO_2$$
If 3 moles of KI and 2 moles of I_2 are mixed with excess HNO_3, then volume of NO_2 gas evolved at NTP is:
(a) 716.8 litre (b) 1075.2 litre
(c) 44.8 litre (d) 67.2 litre

11. The decomposition of certain mass of $CaCO_3$ gave 11.2 dm^3 of CO_2 gas at STP. The mass of KOH required to completely neutralise the gas is : [BHU (Screening) 2010]
(a) 56 g (b) 28 g (c) 42 g (d) 20 g

Answers

1. (c) 2. (b) 3. (d) 4. (b) 5. (c) 6. (d) 7. (a) 8. (c)
9. (a) 10. (a) 11. (a)

SPONTANEOUS ASSESSMENT SECTION

MODULE–1

IIT Entrance Test Paper

There are 59 questions in this module.

(1) Q. 1 – 20. *Have single correct answer.*
(2) Q. 21 – 30. *Have more than one correct answers.*
(3) Q. 31 – 35. *True/false problems.*
(4) Q. 36 – 40. *Statement/explanation problems.*
(5) Q. 41 – 48. *Thought type/comprehensive problems.*
(6) Q. 49 – 53. *Multiple true/false problems.*
(7) Q. 54 – 58. *True or false type questions.*
(8) Q. 59. *Matching type question.*

1. Kinetic energy of 0.3 mole of 'He' gas in a container of maximum capacity of 4 litre at 5 atm, must be: ($R = 0.0821$ atm litre mol^{-1} K^{-1})
(a) 30 atm litre (b) 100 atm litre
(c) 9 atm litre (d) 11.11 atm litre

[**Hint:** $PV = \frac{1}{3} mnc^2$

$$\frac{3}{2} PV = \frac{1}{2} mnc^2 = \text{KE}$$

$$\text{KE} = \frac{3}{2} PV = \frac{3}{2} \times 5 \times 4 = 30 \text{ atm litre}]$$

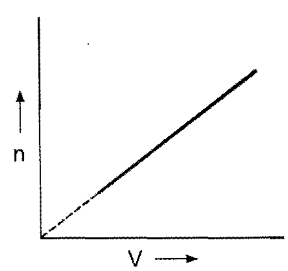
2. What will be the maximum spin multiplicity for $4d$- orbital?
(a) 4 (b) 6 (c) 5 (d) 10

[**Hint:** Spin multiplicity $= 2\Sigma s + 1$

$$= 2 \times 5 \times \frac{1}{2} + 1 = 6]$$

3. Number of 'He' atoms in 52 amu sample is:
(a) $2 \times 6.023 \times 10^{23}$ (b) 13
(c) 4 (d) $4 \times 6.023 \times 10^{23}$

4. For a given one mole of ideal gas kept at 6.5 atm in a container of capacity 2.463 litre. The Avogadro proportionality constant for the hypothesis is: (see figure)



(a) 0.406 (b) 2.46
(c) 22.4 (d) none of these

[**Hint:** $PV = nRT$

$$6.5 \times 2.463 = 1 \times 0.0821 \times T$$
$$T = 195 \text{ K}$$
$$V = n\left[\frac{RT}{P}\right]$$

Avogadro proportionality constt. $= \frac{RT}{P} = \frac{0.0821 \times 195}{6.5} = 2.461$]

5. $A(s) \rightleftharpoons B(g) + C(g)$. Total pressure at time of equilibrium is 40 atmosphere. If all the contents of this reactor have been shifted to another reactor of double capacity, then the total equilibrium pressure in the new reactor will be: (in atmosphere)
(a) 20 (b) 40 (c) 400 (d) 1600

[**Hint:** Since, gaseous species are not present on both sides, hence the equilibrium will not shift.]

6. Gadolinium-153 is used in the detection of osteoporosis disease of bones. Half life of gadolinium-153 is 500 days. After how many days, on an average, the nuclide can be considered absent from the body of patients?
(a) 500 days (b) 1000 days
(c) Infinite (d) 350 days

[**Hint:** The radioactive element will disappear from the body of patient after infinite time.]

7. Amount of energy required to excite an electron of an atom from the lower energy state to its next higher energy state is defined as:
(a) ionization potential (b) electron affinity
(c) critical potential (d) reduction potential

8. Consider the values for $\Delta H°$ (in kJ mol^{-1}) and for $\Delta S°$ (in J mol^{-1} K^{-1}) given for four different reactions. For which reaction will $\Delta G°$ increase the most (becoming more positive), when the temperature is increased from 0°C to 25°C?
(a) $\Delta H° = 50, \Delta S° = 50$ (b) $\Delta H° = 90, \Delta S° = 20$
(c) $\Delta H° = -20, \Delta S° = -50$ (d) $\Delta H° = -90, \Delta S° = -20$
(e) None of these

9. The energy of the orbitals decreases in the order:
(a) $s > p > sp^3 > sp > sp^2$ (b) $p > sp^3 > sp^2 > sp > s$
(c) $sp^3 > sp^2 > sp > s > p$ (d) $s > sp > sp^2 > sp^3 > p$
(e) none of these

[**Hint:** Greater the percentage of 'p' character, more is the energy of the orbital.]

10. These are the first eight ionization energies for a particular neutral atom. All values are expressed in MJ mol^{-1}. How many valence electrons do/does this atom possess?

1st	2nd	3rd	4th	5th	6th	7th	8th
1.31	3.39	5.30	7.47	10.99	13.33	71.33	84.01

(a) 1 (b) 2 (c) 4 (d) 6
(e) None of these

11. Consider the reaction:

$$2H_2(g) + 2NO(g) \longrightarrow N_2(g) + 2H_2O(g)$$

The rate law for this reaction is,

$$\text{Rate} = k\,[H_2][NO]^2$$

Under what conditions could these steps represent the mechanism?

Step 1. $2NO \rightleftharpoons N_2O_2$

Step 2. $N_2O_2 + H_2 \longrightarrow N_2O + H_2O$

Step 3. $N_2O + H_2 \longrightarrow N_2 + H_2O$

(a) These steps cannot be the mechanism under any circumstances
(b) These steps could be the mechanism if step 1 is the slowest step
(c) These steps could be the mechanism if step 2 is the slowest step
(d) These steps could be the mechanism if step 3 is the slowest step
(e) None of the above

12. Match the following:

1. Energy of ground state of He^+	(i) -6.04 eV
2. Potential energy of 1st orbit of H-atom	(ii) -27.2 eV
3. Kinetic energy of 2nd excited state of He^+	(iii) 8.7×10^{-18} J
4. Ionisation potential of He^+	(iv) -54.4 eV

(a) 1–(i); 2–(ii); 3–(iii); 4–(iv)
(b) 1–(iv); 2–(iii); 3–(ii); 4–(i)
(c) 1–(iv); 2–(ii); 3–(i); 4–(iii)
(d) 1–(ii); 2–(iii); 3–(i); 4–(iv)

13. If electrons are transited from n_2 excited state to n_1 excited state, then number of lines observed in the spectrum will be:

(a) $\frac{(n_2-n_1)(n_2-n_1+1)}{2}$ (b) $\frac{(n_1-n_2)(n_2-n_1+1)}{2}$
(c) $\frac{(n_2+n_1)(n_1+n_2+1)}{2}$ (d) $2(n_1-n_2)(n_1+n_2-1)^2$

14. When an electron is transited from $2E$ to E energy level, the wavelength of photon produced is λ_1. In making electronic transition from $\frac{4}{3}E$ to E level, the wavelength λ_2 is:

(a) $\lambda_2 = \lambda_1$ (b) $\lambda_2 = \frac{3\lambda_1}{4}$ (c) $\lambda_2 = 3\lambda_1$ (d) $\lambda_2 = \frac{4\lambda_1}{3}$

15. Completely filled orbitals have special stability and are spherically symmetrical like d^{10}, p^6, f^{14}, etc. The species among Cl^-, Ar and N_3^- which have such orbitals are:

(a) Cl^-, Ar (b) N_3^-, Cl^-
(c) Ar, N_3^- (d) Ar, Cl^-, N_3^-

16. An atom has x energy levels; then total number of lines in the emission spectrum will be:

(a) $1+2+3+\ldots+(x+1)$
(b) $1+2+3+\ldots+x^2$
(c) $1+2+3+\ldots+x$
(d) $1+2+3+\ldots+(x-1)$

17. Carbon atom has electronic configuration, $C = 1s^2$, $2s^2$ and $2p^2$. The spin multiplicity of carbon atom is:

(a) 3 (b) 2 (c) 1 (d) 4

18. An electron moves around protons (nucleus) in a circle of radius r. Assuming that the uncertainty of momentum of electron is of the same order as the momentum itself, the momentum of the electron will be:

(a) $\frac{h}{4\pi r}$ (b) $\frac{h}{2\pi r}$ (c) $4\pi hr$ (d) $2\pi hr$

19. The oxidation state of iron in sodium nitroprusside is:

(a) -3 or -2 (b) $+3$ or -3 (c) $+2$ or -2 (d) -2 or -3

20. The oxidation state of sodium in sodium amalgam is:

(a) $+1$ (b) -1 (c) zero (d) $+2$

Question 21 *to* 30 *have more than one correct answers:*

21. The substance(s) which can act as oxidising as well as reducing agent is/are:

(a) H_2O_2 (b) O_3
(c) NH_2-NH_2 (d) HNO_3

22. Which of the following statements is/are correct?

(a) The electronic configuration of Cr is [Ar] $3d^5 4s^1$
(b) The magnetic quantum number may have negative value
(c) In silver, 23 electrons have a spin of one type and 24 of the opposite type
(d) The oxidation state of hydrogen in NH_3 is +3

23. Which of the following statement(s) about wave function ψ of an electron is/are correct?

(a) ψ has no physical significance
(b) ψ^2 represents the probability of finding electrons
(c) $\psi\psi^* = \psi^2 = |\psi|^2$
(d) ψ is continuous, definite, finite and single valued

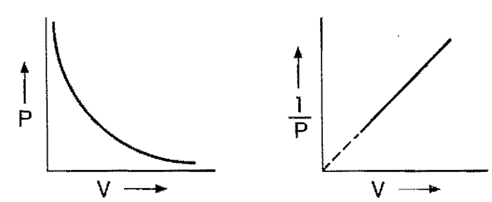
24. Loss of a β-particle is equivalent to:

(a) increase in number of protons by one
(b) decrease in number of neutrons by one
(c) change in atomic mass by one unit
(d) none of the above

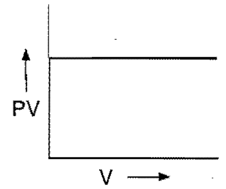
25. The maximum velocity of liquid molecules up to which its flow is streamline is called critical velocity. The critical velocity of a liquid depends upon:

(a) coefficient of viscosity (b) radius of the tube
(c) density of the liquid (d) mass of the tube

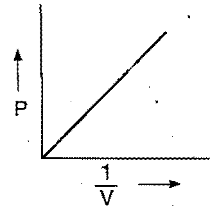
26. Which of the following curves represent(s) Boyle's law?



(a) (b)



(c)



(d)

27. Which of the following set(s) of compounds is/are used as semipermeable membrane?
(a) Calcium phosphate, cellulose nitrate
(b) Calcium phosphate, copper ferrocyanide
(c) Cellulose nitrate, copper ferrocyanide
(d) Copper ferrocyanide, copper sulphate

28. For exact determination of molecular mass:
(a) solute must be volatile
(b) solution must be very dilute
(c) solvent must be non-volatile
(d) solute must not be dissociated or associated

29. For the reaction to be spontaneous:
(a) ΔS should be positive
(b) $(\Delta H - T\Delta S)$ should be negative
(c) $(\Delta H + T\Delta S)$ should be negative
(d) ΔH should be negative

30. When a colloidal solution X is converted into two different solutions Y and Z, the osmotic pressures of Y and Z were found to be respectively higher and lower than X. This indicates that:
(a) X is a colloidal solution and Y is suspension
(b) X is a colloidal solution and Z is true solution
(c) X is colloidal solution and Z is suspension
(d) X is a colloidal solution and Y is true solution

In the following questions (31–35), indicate 'a' if the statement is true and 'b' if the statement is false:

31. The plot of PV *versus* P at constant temperature is a straight line passing through origin.
32. Bohr model could not explain the fine line spectrum of hydrogen.
33. $_{21}$Sc and Cr^{3+} are isoelectronic, hence they have same electronic configuration.
34. van't Hoff factor is equal to unity if the solute undergoes 100% dissociation.
35. A mixture of ideal gas is cooled up to liquid helium temperature (4.22 K) to form an ideal solution.

*In each of the following questions, a **Statement (S)** and **Explanation (E)** are given. Choose the correct answer from the codes a, b, c and d given for each question:*

(*a*) ***S** is correct but **E** is wrong.*
(*b*) ***S** is wrong but **E** is correct.*
(*c*) *Both **S** and **E** are correct and **E** is the correct explanation of **S**.*
(*d*) *Both **S** and **E** are correct but **E** is not correct explanation of **S**.*

36. (S) All Arrhenius acids are also Bronsted acids.
(E) All Bronsted bases are also Lewis bases.
37. (S) 1 amu equals to 1.66×10^{-24} g.
(E) 1.66×10^{-24} g equals 1/12th mass of ^{12}C atom.
38. (S) Spectral lines are not observed for $2p_x - 2p_z$ transition.
(E) p_x, p_y and p_z are three-fold degenerate orbitals.
39. (S) Compressibility factor (Z) for non-ideal gas is always greater than unity.
(E) Non-ideal gases exert less pressure compared to ideal gases under identical conditions.
40. (S) If in zero order reaction, the concentration of the reactant is doubled, the half life period is also doubled.
(E) For a zero order reaction, the rate of reaction is independent of initial concentration.

When 2 g non-volatile solute is dissolved in 100 g of benzene, the vapour pressure of benzene at 20°C is lowered from 74.66 mm to 74.01 mm.

Answer the following questions:

41. Mole fraction of benzene in the solution will be:
(a) 0.89 (b) 0.69 (c) 0.99 (d) 0.79
42. The molar mass of solute will be:
(a) 200 (b) 277.624 (c) 177.624 (d) 350
43. Molecular formula of solute may be:
(a) $C_{14}H_{10}$ (b) $C_{12}H_{26}$ (c) $C_{14}H_{30}$ (d) $C_{14}H_{28}$
44. If the solute is a hydrocarbon containing 94.4% carbon, then the number of moles of carbon in 1 mol of it will be:
(a) 12 (b) 10 (c) 16 (d) 14
45. Molality of solution will be:
(a) 0.013 (b) 0.06 (c) 0.23 (d) 0.05

The age of articles of organic origin can be estimated by radiocarbon dating. The radio-isotope carbon-14 is produced continuously in the upper atmosphere as the nitrogen atoms capture cosmic ray neutrons.

$$^{14}_{7}N + ^{1}_{0}n \longrightarrow ^{14}_{6}C + ^{1}_{1}H$$

The ^{14}C atoms react with oxygen molecules to form $^{14}CO_2$. $^{14}CO_2$ is absorbed by the plants in photosynthesis. Carbon-14 decays with a half life of 5730 years.

$$^{14}_{6}C \longrightarrow ^{14}_{7}N + ^{0}_{-1}e$$

After death, the plant no longer carries out photosynthesis, so it no longer takes-up $^{14}CO_2$. Other organisms that consume plants for food stop doing so at death. The emission from ^{14}C in dead tissue then decreases with the passage of time. The activity per gram of carbon is a measure of the length of time elapsed since death. The carbon-14 technique is useful only for dating objects for a limited period of time.

Answer the following questions:

46. Which one is correct?
(a) Carbon dating is predicted only for wood not older than 60000 years.
(b) Carbon dating is predicted only for wood not older than 600 years.
(c) Age of any older wood can be predicted by the radio carbon dating.
(d) Radio carbon dating is used only for wooden objects.

47. A piece of wood taken from a cave dwelling in New Mexico is found to have a carbon-14 activity (per gram of carbon) only 0.636 times that of wood cut today. Estimate the age of the wood:
(a) 7430 yr (b) 3740 yr (c) 4370 yr (d) 7340 yr

48. In carbon dating:
(a) the decay rate of $^{14}_{6}C$ is studied
(b) the rate of accumulation of $^{14}_{6}C$ is studied
(c) the rate of decay of $^{12}_{6}C$ is studied
(d) the rate of formation of $^{13}_{6}C$ is studied

In each of the following questions, three statements I, II, III are given. Mark:
(*a*) *if all the statements are correct*
(*b*) *if II and III are correct*
(*c*) *if I and III are correct*
(*d*) *if only II is correct*

49. In CrO_5:
(I) Oxidation number of Cr is +6.
(II) Four oxygen atoms are involved in peroxy linkage.
(III) Only one oxygen atom has −2 state.

50. (I) The conductance of molten NaCl is due to movement of Na^+ and Cl^- ions.
(II) Molten NaCl is a good conductor due to mobility of free electrons.
(III) Solid NaCl is a bad conductor of electricity.

51. (I) Resistance of metals increases on heating.
(II) Unit of cell constant is cm^{-1}.
(III) Specific conductance decreases on dilution.

52. (I) Oxidation number is same as formal charge.
(II) The numerical value of oxidation number and valency may differ.
(III) Absolute value of electrode potential cannot be determined.

53. (I) Cathode is −ve terminal in both electrolytic and electrochemical cells.
(II) Reduction occurs at cathode, both in electrolytic and electrochemical cells.
(III) Chemical change in electrolytic cell is non- spontaneous.

Predict whether the following statements are True or False:

54. At Curie point, ferromagnetic solid changes to paramagnetic solid.
(a) True (b) False (c) cannot be predicted

55. pH of 10^{-10} M HCl is 10.
(a) True (b) False (c) cannot be predicted

56. Specific conductance of electrolyte solution decreases on dilution.
(a) True (b) False (c) cannot be predicted

57. 3*s*-orbital has 2 nodes, inclusive of radial and angular nodes.
(a) True (b) False (c) cannot be predicted

58. Conductance of LiCl is greater than NaCl at infinite dilution.
(a) True (b) False (c) cannot be predicted

59. [A] Match the Column-I with Column-II. Choose the correct one from the alternatives (a), (b), (c) and (d).

Column-I	Column-II
P. Wilkinson catalyst	I. *trans*-$IrCl(CO)(PPh_3)_2$
Q. Speier catalyst	II. Hydrosilylation
R. Water gas shift catalyst	III. $RhCl(PPh_3)_3$
S. Zeolite ZSM-5 catalyst	IV. Synthetic gasoline
	V. Hydroformylation
	VI. Zinc-copper oxide

(a)	(b)	(c)	(d)
P–III	P–I	P–V	P–III
Q–II	Q–V	Q–II	Q–VI
R–VI	R–III	R–VI	R–IV
S–IV	S–IV	S–IV	S–II

[B] Match the Column-I with Column-II. Choose the correct one from the alternatives (a), (b), (c) and (d).

Column-I	Column-II
P. Low temperature	I. $\frac{a}{V^2}$
Q. Mean speed	II. Maxwellian distribution
R. Internal pressure	III. b
S. Excluded volume	IV. Adiabatic demagnetisation
	V. $\left(a+\frac{b}{V^2}\right)$

(a)	(b)	(c)	(d)
P–IV	P–V	P–I	P–IV
Q–II	Q–IV	Q–II	Q–V
R–I	R–II	R–III	R–III
S–III	S–III	S–IV	S–II

Answers

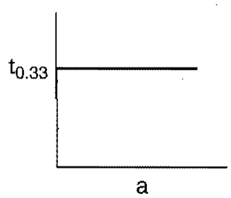
1. (a)	2. (b)	3. (b)	4. (b)	5. (b)	6. (c)	7. (c)	8. (c)
9. (b)	10. (d)	11. (c)	12. (c)	13. (a)	14. (c)	15. (a)	16. (d)
17. (a)	18. (a)	19. (b)	20. (c)	21. (a, b, c)	22. (a, b, c)	23. (a, b, c, d)	24. (a, b)
25. (a, b, c)	26. (a, b, c, d)	27. (a, b, c)	28. (b, d)	29. (a, b)	30. (c, d)	31. (b)	32. (a)
33. (b)	34. (b)	35. (b)	36. (a)	37. (a)	38. (a)	39. (b)	40. (d)
41. (c)	42. (c)	43. (a)	44. (d)	45. (a)	46. (a)	47. (b)	48. (a)
49. (a)	50. (c)	51. (a)	52. (b)	53. (d)	54. (a)	55. (b)	56. (a)
57. (a)	58. (b)	59. (A–d), (B–a)					

MODULE–2

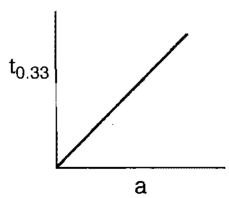
IIT Entrance Test Paper

Following questions have single correct option:

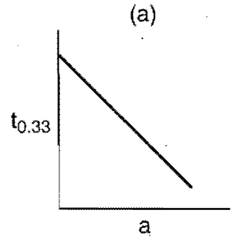
1. The frequency of de Broglie wave associated with a microscopic particle of mass 10^{-27} gm is 2.5×10^4 MHz, then the velocity of the particle will be:
(a) 4.08 km/s (b) 5.81 km/s
(c) 17.32 km/s (d) 1.22 km/s
2. The total number of nodes for $4d$-orbital will be:
(a) 2 (b) 3 (c) 0 (d) 1
3. $N_2 + 3H_2 \rightleftharpoons 2NH_3$ + heat. The activation energy for the forward as well as backward reaction is decreased by 100 J, then the equilibrium amount of NH_3 will:
(a) increase (b) decrease
(c) remain constant (d) cannot be predicted
4. During K-electron capture mainly:
(a) γ-rays are emitted (b) β-particles are emitted
(c) positron are emitted (d) X-rays are emitted
5. The magnetic moment of an iron compound is 5.918 BM, then the oxidation state of iron in this compound will be:
(a) 0 (b) 1 (c) 2 (d) 3
6. Which of the following graphs represents a first order reaction?



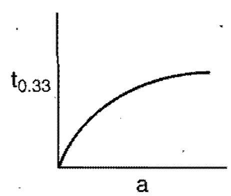
(a)



(b)

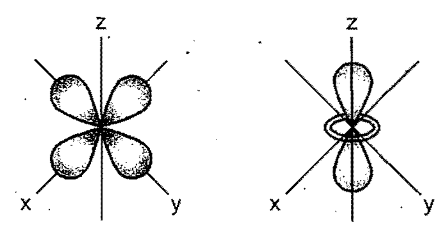


(c)



(d)

7. For the reaction,
$$C_6H_{12}O_6(s) + 6O_2(g) \longrightarrow 6CO_2(g) + 6H_2O(l);$$
$$\Delta U = -2810 \text{ kJ/mol}$$
ΔH in kJ/mol is:
(a) 845 (b) −890 (c) −2810 (d) −2864
8. The standard emf of the cell, set-up from the reaction,
$$2Cu^+(aq.) \rightleftharpoons Cu(s) + Cu^{2+}(aq.)$$
is 0.36 V at 298 K. The standard free energy in kJ/mol for this reaction is:
(a) − 34.73 (b) − 69.46 (c) − 3473 (d) − 6946
9. When the reaction is first order in A and zero order in B, rate constant is:
(a) $\left\{-\dfrac{1}{t[A]_0}\right\} \ln \dfrac{[A]_0}{[A]_t}$ (b) $\left(-\dfrac{1}{t}\right) \ln \dfrac{[A]_0}{[A]_t}$
(c) $\dfrac{1}{t} \ln \dfrac{[A]_0}{[A]_t}$ (d) $\dfrac{1}{t[A]_0} \ln \dfrac{[A]_0}{[A]_t}$
10. A hypothetical reaction, $2X + Y_2 \longrightarrow 2XY$ follows the mechanism:
$$X + X \rightleftharpoons X_2 \quad \text{(fast)}$$
$$X_2 + Y_2 \rightleftharpoons 2XY \quad \text{(slow)}$$
then the order of reaction is:
(a) 1 (b) 2 (c) 3 (d) undefined
11. The inversion of cane sugar in aqueous acidic medium is a reaction of:
(a) zero order (b) first order
(c) second order (d) third order
12. Which of the following belongs to, *e.g.*, (double grade) orbitals?
(a) d_{xy}, d_{yz} (b) d_{yz}, d_{zx}
(c) d_{xy}, d_{zx} (d) $d_{x^2-y^2}, d_{z^2}$
13. Which among the following is correct about the energy sequence (in case of H-atom)?
(a) $3s < 3p < 3d$ (b) $3s = 3p = 3d$
(c) $3s > 3p > 3d$ (d) $3s > 3p < 3d$
14. If the equivalent weight of an element is 32, then the percentage of oxygen in its oxide is:
(a) 16 (b) 40 (c) 32 (d) 20
15. Which of the following statements are true?
(a) For gases, in general, viscosity increases with increase in temperature.
(b) For liquids, viscosity varies directly with pressure.
(c) For gases, viscosity is independent of pressure.
(d) All of the above are true.
(e) None of the above
16. The following figures show the angular probability distribution of:



(a) d_{xy} and d_{yz} orbitals (b) $d_{x^2-y^2}$ and d_{z^2} orbitals
(c) d_{xy} and d_{xz} orbitals (d) none of these
17. The equation $E = h\nu$ indicates that:
(a) photons have both particle and wave nature
(b) photons are waves
(c) photons are stream of particles
(d) no such inference can be drawn from the given equation
18. In which of the following conditions, the density of N_2 is maximum?
(a) STP (b) 273 K and 2 atm
(c) 546 K and 1 atm (d) 546 K and 2 atm

19. A sample of natural gas contains 85% CH_4 and 15% C_2H_6. What is the molecular mass of the mixture?
(a) 16.6 (b) 26.6 (c) 30.6 (d) 20.6

20. Match the List-I and List-II:

	List-I	List-II
(A)	The limits of pH values of buffer solution.	(i) 5×10^{-12}
(B)	The $[H_3O]^+$ concentration in 0.001 M $Ba(OH)_2$ solution.	(ii) Equal
(C)	The buffer capacity of a solution is maximum when conc. of salt to that acid is:	(iii) 1st order reaction
(D)	Hydrolysis of ethyl acetate in acidic solution.	(iv) $pK_a \pm 1$

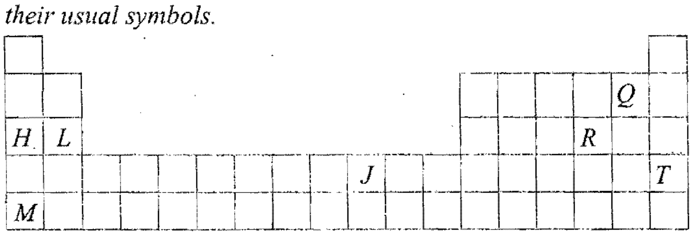
Codes:	(A)	(B)	(C)	(D)
(a)	iv	ii	i	iii
(b)	iv	i	iii	ii
(c)	i	iv	ii	iii
(d)	iv	i	ii	iii

21. Match the List-I and List-II:

	List-I	List-II
(A)	Rate constant has the same unit as the rate of reaction.	(i) One
(B)	Reactions having apparent molecularity more than three.	(ii) Zero order reaction
(C)	Reactions having mole-cularity two but order of reaction is one.	(iii) Complex reaction
(D)	For a reaction, $A \rightarrow B$, the rate of reaction doubles as the concentration of A is doubled.	(iv) Pseudo unimol-ecular reaction

Codes:	(A)	(B)	(C)	(D)
(a)	ii	iv	iii	i
(b)	ii	iii	iv	i
(c)	iii	ii	iv	i
(d)	ii	iv	i	iii

The diagram below shows part of the skeleton of the periodic table in which elements are indicated by letters which are not their usual symbols.



Select whether the following statements are True or False:
True (a) *False (b)*

22. The greatest ionic character of compounds formed by reaction of pairs of the listed elements would be exhibited by the compound with the formula, M_2Q.

23. The J^{2+} ion is coloured and has an electronic configuration of $1s^2, 2s^2\, 2p^6, 3s^2\, 3p^6\, 3d^7$.

24. The carbonate of compound H is insoluble in water.

25. Element R is a gas at room temperature.

26. Element T is an inert gas with an electronic configuration $1s^2, 2s^2\, 2p^6, 3s^2\, 3p^6\, 3d^{10}, 4s^2\, 4p^6$.

20 cm^3 of a gaseous element X reacts with excess of an element Y to form 40 cm^3 of a gaseous compound of X and Y. All volumes are measured under the same conditions of temperature and pressure.

Select whether the following statements are True or False.
True (a) *False (b)*

27. Molecule of X contains at least two atoms of X.

28. The formula of the compound formed is XY.

29. Molecules of X cannot consist of more than two atoms.

30. X is less dense than the compound of X and Y.

31. Y is less dense than the compound of X and Y.

Assertion-Reason Type Questions:

*In the questions 32 to 36, statements are given for **Assertion(A)** and **Reason (R)**. Choose the correct answers from the codes given below:*

(a) *Both (A) and (R) are correct and (R) is the correct explanation of (A).*
(b) *Both (A) and (R) are correct but (R) is not the correct explanation of (A).*
(c) *(R) is correct but (A) is wrong.*
(d) *(A) is correct but (R) is wrong.*

32. (A) In hydrogen spectrum (6569 Å) line is observed in Balmar series.
(R) Balmar lines are found in ultraviolet region.

33. (A) All Arrhenius acids are also Bronsted acids.
(R) All Bronsted bases are also Lewis bases.

34. (A) All p-orbitals are directional.
(R) p-orbitals are oriented along axes.

35. (A) 0.1 M NaCl + 0.05 M HCl solution on mixing in equal volume forms a buffer solution.
(R) The solution is a mixture of salt and acid thus act as a buffer.

36. (A) Number of revolution per second by an electron is same in all shells.
(R) Orbital frequency $= \dfrac{v}{2\pi r}$.

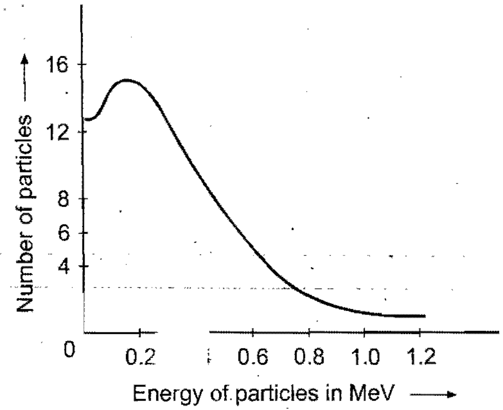
Questions with more than one correct options:

37. The substance(s) which can act as oxidising as well as reducing agent is/are:
(a) H_2O_2 (b) O_3
(c) $NH_2 — NH_2$ (d) HNO_3

38. Which of the following statement(s) is/are correct?
(a) The electronic configuration of Cr is [Ar] $3d^5, 4s^1$.
(b) The magnetic quantum number may have a negative value.
(c) In silver, 23 electrons have clockwise spin and 24 electrons have anticlockwise spin.
(d) The oxidation number of N in N_3H is –3.

39. Loss of a β-particle is equivalent to:
(a) increase in number of protons by one
(b) decrease in number of neutrons by one
(c) change in atomic mass by one unit
(d) none of the above

40. Following curve shows the energy spectrum of β-particles in the figure:



The curve indicates:
(a) β-rays spectrum is continuous
(b) different β-particles (emitted) have different energies
(c) the energy spectrum of β-particles of all the elements is the same
(d) no β-particle has energy more than 1 MeV

41. Maximum velocity of a liquid up to which its flow is stream line is called critical velocity. The critical velocity of a liquid depends upon:
(a) coefficient of viscosity (b) radius of the tube
(c) density of the liquid (d) mass of the tube

42. When a liquid solidifies, generally, there is:
(a) decrease in enthalpy (b) decrease in entropy
(c) increase in enthalpy (d) increase in entropy

43. Which of the following set(s) of chemical compounds is/are used as semipermeable membrane?
(a) calcium phosphate, cellulose nitrate
(b) calcium phosphate, copper ferrocyanide
(c) cellulose nitrate, copper ferrocyanide
(d) copper ferrocyanide, copper sulphate

44. For the depression in freezing point. The correct statement(s) is/are:
(a) The vapour pressure of pure solvent is more than that of solution.
(b) The vapour pressure of pure solvent is less than that of solution.
(c) Only solute molecules solidify at the freezing point.
(d) Only solvent molecules solidify at the freezing point.

45. For exact determination of molecular mass:
(a) solute must be volatile
(b) solution must be very dilute
(c) solution must be of similar components
(d) solute must not be dissociated or associated

46. Match the Column-I with Column-II:

	Column-I		Column-II
(a)	de Broglie equation	(p)	$\lambda = \frac{h}{p}$
(b)	Lyman series	(q)	$\lambda = \frac{h}{\sqrt{2Em}}$
(c)	Wavelength associated with particle of mass m	(r)	Transition from higher shell to K-shell
(d)	6.6×10^{-19} J energy per photon	(s)	Ultraviolet radiation

(a)	p	q	r	s
(b)	p	q	r	s
(c)	p	q	r	s
(d)	p	q	r	s

47. Match the Column-I with Column-II:

	Column-I		Column-II
(a)	Mn	(p)	Radius ratio (0.732–1)
(b)	Body-centred cubic	(q)	Hexagonal close-packed
(c)	ABC ABC ABC	(r)	Packing (0.68)
(d)	Be	(s)	Number of constituent units in one unit cell (1)

(a)	p	q	r	s
(b)	p	q	r	s
(c)	p	q	r	s
(d)	p	q	r	s

48. 75.2 g of C_6H_5COOH is dissolved in a kg of benzene to lower its freezing point by 7 K. K_f for benzene is 14 K kg mol^{-1}. Calculate the percentage association when it forms a dimer.

●	●	0	0
1	1	1	1
2	2	2	2
3	3	●	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	9	9

[**Hint:** $\Delta T = i \times K_f \times \dfrac{w_B \times 1000}{m_B \times w_A}$

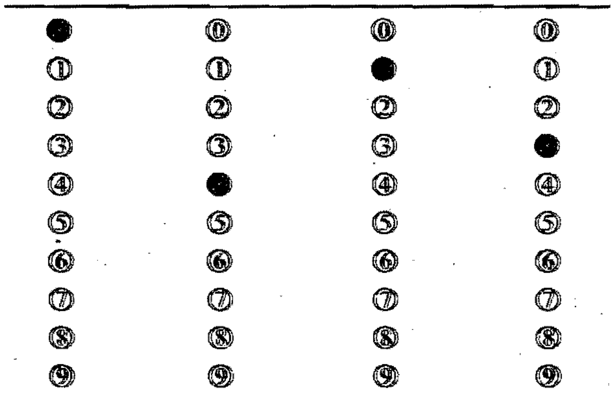
$$7 = i \times 14 \times \frac{75.2 \times 1000}{122 \times 1000}$$

$$i = 0.81$$

$$\alpha = \frac{1-i}{1-1/n} = \frac{1-0.81}{1-1/2} = 0.38$$

Percentage association $= \alpha \times 100 = 38$]

49. A sample of gas present in a cylinder fitted with a frictionless piston expands against a constant pressure of 1 atm from a volume of 2 L to 12 L. During this process, it absorbs 600 J heat from its surroundings. Calculate the decrease in the internal energy of the system in joule.



[**Hint:** $q = 600\text{ J}, \Delta V = 12 - 2 = 10\text{ L}, P = 1\text{ atm}$

$$w = -P\Delta V = -1 \times 10 \times 101.3 = -1013\text{ J}$$

$$\Delta U = q + w = 600 - 1013 = -413\text{ J}]$$

Predict whether the following statements are True/False:

50. For mixing of two ideal gases at 25°C and 1 atm, $\Delta G_{\text{mix}} = 0$.
(a) True (b) False

51. For mixing of two ideal gases at 25°C and 1 atm, $\Delta S_{\text{mix}} = 0$.
(a) True (b) False

52. Isobaric thermal coefficient of an ideal gas is 'R'.
(a) True (b) False

53. The criterion for the spontaneity of a process is $\Delta S_{\text{system}} > 0$.
(a) True (b) False

54. The radioactive element undergoes complete decay in twice of half life.
(a) True (b) False

Answers

1. (a)	**2.** (b)	**3.** (c)	**4.** (d)	**5.** (d)	**6.** (b)	**7.** (c)	**8.** (a)
9. (c)	**10.** (c)	**11.** (b)	**12.** (d)	**13.** (b)	**14.** (c)	**15.** (a)	**16.** (b)
17. (d)	**18.** (b)	**19.** (a)	**20.** (d)	**21.** (b)	**22.** (b)	**23.** (b)	**24.** (b)
25. (b)	**26.** (a)	**27.** (b)	**28.** (a)	**29.** (b)	**30.** (b)	**31.** (b)	**32.** (d)
33. (d)	**34.** (a)	**35.** (b)	**36.** (c)	**37.** (a, b, c)	**38.** (a, b, c)	**39.** (a, b)	**40.** (a, b)
41. (a, b, c)	**42.** (a, b)	**43.** (a, b, c)	**44.** (a, d)	**45.** (b, d)	**46.** (a-p,q) (b-r,s) (c-p,q) (d-r,s)		
47. (a-s, b-p,r) (c-q) (d-q)		**50.** (a)	**51.** (b)	**52.** (a)	**53.** (b)	**54.** (b)	

IIT ENTRANCE TEST PAPERS

TEST SERIES I

SECTION-I

REASONING APTITUDE
(For IIT & AIIMS Aspirants)

The questions given below (1 to 10) consist of an **'Assertion'** (A) in column (1) and **'Reason'** (R) in column (2). Use the following keys to choose the appropriate answer:

(a) If both assertion and reason are correct and reason is the correct explanation of the assertion.
(b) If both assertion and reason are correct but reason is not correct explanation of the assertion.
(c) If assertion is correct but reason is incorrect.
(d) If assertion is incorrect but reason is correct.

Assertion (Column 1)	**Reason (Column 2)**
1. Noble gases can be liquefied.	Attractive forces can exist between non-polar molecules.
2. Boiling point of a solvent increases when a non-volatile solute is dissolved in it.	The boiling point of a liquid is the temperature at which vapour pressure of a liquid equals the vapour pressure of the atmosphere.
3. A mixture of sodium acetate and sodium propionate forms a buffer solution.	A buffer solution reacts with small quantities of hydrogen or hydroxyl ions and keeps the pH almost same.
4. The pressure of a fixed amount of an ideal gas is proportional to its temperature at constant volume.	Ideal gas molecules neither attract nor repel each other.
5. In a radioactive disintegration, an electron is emitted by the nucleus.	Electrons are always present inside the nucleus.
6. The ratio C_P/C_V for a diatomic gas is more than that for a monoatomic gas.	The molecules of a monoatomic gas have less degrees of freedom than those of a diatomic gas.
7. Many endothermic reactions that are not spontaneous at room temperature, become spontaneous at high temperature.	Entropy of the system increases with increase in temperature.
8. No two electrons in an atom can have the same values of four quantum numbers.	No two electrons in an atom can be simultaneously in the same shell, subshell, orbitals and have same spin.
9. In radioactive disintegrations, ${}_2He^4$ nuclei can come out of the nucleus but lighter ${}_2He^3$ cannot.	Binding energy of ${}_2He^3$ is more than that of ${}_2He^4$.
10. A crystal having fcc structure is more closely packed than a crystal having bcc structure.	Packing fraction for fcc structure is double than that of bcc structure.

SECTION-II

SELECT CORRECT ALTERNATIVE AMONG THE GIVEN OPTIONS
(For AIEEE & Medical Entrance Aspirants)

11. Pick out the pair in which the energy change of one is reverse of the energy change in the other:
(1) radio (2) fluorescent lamp (3) toaster (4) photoelectric cell
(a) 1 and 2 (b) 2 and 3 (c) 2 and 4 (d) 3 and 4

12. Consider the following statements about first order reaction:
(1) The rate of reaction is directly proportional to the concentration of the reactant.
(2) Its half life period is always constant.
(3) Concentration of reactant falls exponentially.
(4) It has low activation energy.
Of these statements:
(a) 1, 3 and 4 are correct (b) 1, 2 and 4 are correct
(c) 1, 2 and 3 are correct (d) 2, 3 and 4 are correct

13. Which one of the following is the correct order of energies of $3p$, $3d$, $4s$ and $4p$ orbitals as per Aufbau principle?
(a) $3p < 3d < 4s < 4p$ (b) $3p < 4s < 3d < 4p$
(c) $3d < 4s < 4p < 3p$ (d) $3d < 3p < 4p < 4s$

14. In the emission line spectra of hydrogen atom, how many lines can be accounted for by all possible electron transitions between five lowest energy levels within the atom?
(a) 4 (b) 5 (c) 10 (d) 20

15. In a closed container at 1 atm pressure, 2 mole of $SO_2(g)$ and 1 mole of $O_2(g)$ were allowed to react to form $SO_3(g)$ under the influence of a catalyst. The following reaction occurred:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

At equilibrium it was found that 50% of $SO_2(g)$ was converted to $SO_3(g)$. The partial pressure of $O_2(g)$ at equilibrium will be:
(a) 0.66 atm (b) 0.493 atm (c) 0.33 atm (d) 0.2 atm

16. The electronic configuration $1s^2, 2s^2 2p^5, 3s^1$ describes which one of the following?
(a) An excited state of fluorine atom
(b) The ground state of neon
(c) The excited state of O^{2-}
(d) The ground state of fluoride ion F^-

17. When acetone and chloroform are mixed, hydrogen bonding takes place between them; such a liquid pair will cause:
(a) positive deviation from Raoult's law
(b) negative deviation from Raoult's law
(c) no deviation from Raoult's law
(d) cannot be predicted

18. A maxima or minima obtained in the temperature. Composition curve of a mixture of two liquids indicates:
(a) that the liquids are immiscible with one another
(b) that the liquids are partially miscible at the maximum or minimum
(c) an azeotropic mixture
(d) a eutectic formation

19. The electrode reactions for charging of a lead battery are:

$$PbSO_4 + 2e \longrightarrow Pb + SO_4^{2-}$$
$$PbSO_4 + 2H_2O \longrightarrow PbO_2 + SO_4^{2-} + 4H^+ + 2e$$

The electrolyte in the battery is an aqueous solution of H_2SO_4. After this battery has been charged:
(a) the sulphuric acid will be more concentrated
(b) the sulphuric acid will be less concentrated
(c) the concentration of H_2SO_4 will be unchanged
(d) H_2SO_4 will have been completely decomposed

20. At 291 K, the molar conductivity at infinite dilution of NH_4Cl, NaOH, NaCl are 129.8, 217.4, 108.9 $ohm^{-1}\ cm^2\ mol^{-1}$ respectively. If the molar conductivity of centinormal solution of NH_4OH is 9.33 $ohm^{-1}\ cm^2\ mol^{-1}$, what is the percentage dissociation of NH_4OH at this dilution?
(a) 0.392 (b) 39.2 (c) 3.92 (d) 0.039

21. Through molten $AlCl_3$, a charge equal to the charge of 1 mole N^{3-} was passed. Volume of Cl_2 evolved at anode will be:
(a) 22.4 litre (b) 67.2 litre (c) 33.6 litre (d) 11.2 litre

22. The rate constant of a reaction will be equal to pre-exponential factor when:
(a) temperature in centigrade is zero
(b) absolute temperature is zero
(c) absolute temperature is infinity
(d) no suitable answer

23. The energy levels of A, B and C of certain atoms correspond to increasing values of energy, *i.e.*,

$$E_A < E_B < E_C$$

If λ_1, λ_2 and λ_3 are wavelengths C to B, B to A and C to A respectively; which of the following relation is correct?
(a) $\lambda_3 = \lambda_1 + \lambda_2$ (b) $\lambda_3 = \lambda_1\lambda_2/(\lambda_1 + \lambda_2)$
(c) $\lambda_1 + \lambda_2 + \lambda_3 = 0$ (d) $\lambda_3^2 = \lambda_1^2 + \lambda_2^2$

24. A stationary hydrogen atom emits a photon corresponding to the first line of Lyman series. What velocity does the atom acquire?
(a) 3.25 m/sec (b) 2.35 m/sec
(c) 3.52 m/sec (d) 5.23 m/sec

25. Which of the following transitions is not allowed in the normal electronic spectrum of an atom?
(a) $2p \rightarrow 1s$ (b) $3d \rightarrow 2p$ (c) $5p \rightarrow 3s$ (d) $2s \rightarrow 1s$

26. How many spectral lines can be observed when an excited electron returns from 7th to 2nd shell?
(a) 10 (b) 15 (c) 20 (d) 14

27. Two lines of Balmer series of hydrogen are 486.1 and 410.2 nm. If the difference of wave numbers of these lines corresponds to the wave number of a line in the series, to which of following series does the line belong?
(a) Brackett (b) Paschen (c) Pfund (d) Humphrey

28. For a third order reaction, half life is given as:
(a) $t_{1/2} \propto \frac{1}{a}$ (b) $t_{1/2} \propto \frac{1}{a^2}$ (c) $t_{1/2} \propto a^2$ (d) $t_{1/2} \propto a$

29. What specific name can be given to the following sequence of steps?

$$Hg + h\nu \longrightarrow Hg^*$$
$$Hg^* + H_2 \longrightarrow Hg + H_2^*$$
$$H_2^* \longrightarrow 2H$$

(a) Photosensitization (b) Photosorption
(c) Phosphorescence (d) Chemiluminescence

30. If the tetrahedral sites in a ccp array of negative ions (B) were half filled with cations (A), the empirical formula of the compound will be:
(a) A_2B_3 (b) A_2B (c) AB_2 (d) AB

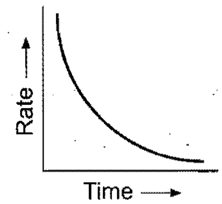
31. An electron in the p-orbital has an orbital angular momentum of:
(a) $\sqrt{2}\ h$ (b) $\frac{\sqrt{2}h}{2\pi}$ (c) $\frac{h}{\pi}$ (d) $\frac{h}{2\pi}$

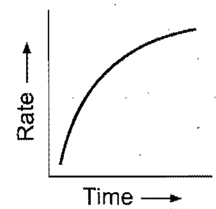
32. An electron of velocity 'v' is found to have a certain value of de Broglie wavelength. The velocity to be possessed by a neutron to have the same de Broglie wavelength is:
(a) $1840v$ (b) $v/1840$ (c) v (d) $1840/v$

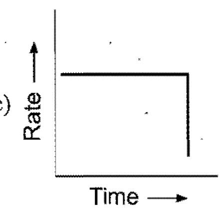
33. van't Hoff factor for a dilute aqueous solution of HCN is 1.00002. The percentage degree of dissociation of the acid is:
(a) 2×10^{-5} (b) 1×10^{-5} (c) 2×10^{-3} (d) 1×10^{-3}

34. The average life of a radioactive element is 10 minute. In 10 minute what percentage of a radioactive element will decay?
(a) 50% (b) 63.21% (c) 75% (d) 100%

35. Which of the following corresponds to zero order reaction?

(a) 

(b) 

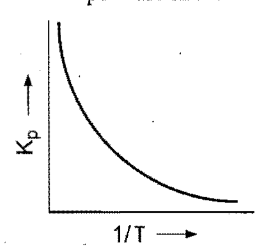
(c) 

(d) None of these

36. The equilibrium constant K_p for the reaction,

$$X(g) + Y(g) \rightleftharpoons Z(g)$$

is found to vary with temperature in the diagram as shown:



(a) The reaction is exothermic in forward reaction
(b) The equilibrium mixture contains a high proportion of Z at higher pressure
(c) The equilibrium mixture contains a high proportion of Z at high temperature
(d) The equilibrium is unaffected by addition of inert gas

37. Helium was discovered in sun's atmosphere by analysing:
(a) Mayer hoff bands (b) Fraunhofer lines
(c) spectrum (d) spectrometer

38. For an ideal solution of miscible components:

$$\Delta S_{mix} = -R\ \Sigma\ n_2 \log x_1$$

(a) ΔS_{mix} is a negative quantity
(b) ΔS_{mix} is a positive quantity
(c) ΔS_{mix} is zero
(d) ΔS_{mix} is sometimes negative and sometimes positive

39. Specific conductance of a conductivity solution:
(a) increases with dilution
(b) decreases with dilution

(c) is independent of concentration
(d) depends upon the cell constant

40. In the oxide of a compound 'A', oxide ions are arranged in hexagonal close packing and A^{3+} ions occupy two-thirds of the octahedral voids. What is the formula of corundum?
(a) AO (b) A_2O (c) A_2O_3 (d) AO_2

41. Spinel structure is shown by:
(a) $MgAl_2O_4$ (b) $ZnAl_2O_4$ (c) $MgFe_2O_4$ (d) all of these

42. Which of the following atomic orbitals does not have the four lobes lying symmetrically between the axial directions?
(a) $3d_{xy}$ (b) $3d_{xz}$ (c) $3d_{yz}$ (d) $3d_{x^2-y^2}$

43. The degree of dissociation (α) of a weak electrolyte A_xB_y is related to van't Hoff factor 'i' by expression:
(a) $\alpha = \dfrac{i-1}{x+y-1}$ (b) $\alpha = \dfrac{i-1}{x+y+1}$
(c) $\alpha = \dfrac{x+y-1}{i-1}$ (d) $\alpha = \dfrac{x+y+1}{i-1}$

44. The solubility of mercurous chloride in water will be given as:
(a) $S = K_{sp}$ (b) $S = K_{sp}/4$
(c) $S = (K_{sp}/4)^{1/2}$ (d) $S = (K_{sp}/4)^{1/3}$

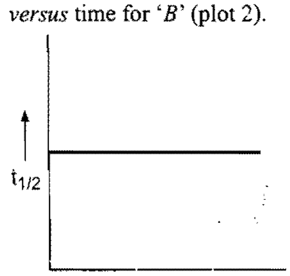
45. The activation energies of two reactions are E_{a_1} and E_{a_2}. If the temperature of the reacting systems is increased from T_1 to T_2, predict which of the following alternatives is correct?
(a) $\dfrac{k_1'}{k_1} = \dfrac{k_2'}{k_2}$ (b) $\dfrac{k_1'}{k_1} > \dfrac{k_2'}{k_2}$
(c) $\dfrac{k_1'}{k_1} < \dfrac{k_2'}{k_2}$ (d) $\dfrac{k_1'}{k_1} < 2\dfrac{k_2'}{k_2}$
where, k_1' and k_2' are rate constants at higher temperature.

46. In a cubic unit cell, seven of the eight corners are occupied by atoms 'A' and centres of faces are occupied by atoms 'B'. The general formula of the compound is:
(a) A_7B_6 (b) A_7B_{12} (c) A_7B_{24} (d) $A_{24}B_7$

47. The rate law of a reaction of 'A' and 'B',

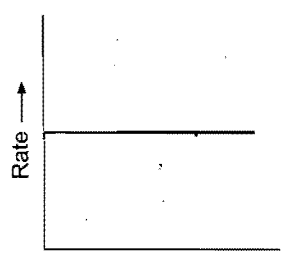
$$\text{rate} = k\,[A]^n[B]^m$$

may be determined by plotting $t_{1/2}$ *versus* $[A]_0$ (plot 1) and rate *versus* time for 'B' (plot 2).



$[A]_0 \longrightarrow$

(plot 1)



Time $\longrightarrow$

(plot 2)

The rate law superscripts, 'n' and 'm' are:
(a) 0, 0 (b) 0, 1 (c) 1, 0 (d) 1, 1

48. For 1s-orbital of hydrogen, the radial electron probability has a maximum value at:
(a) 0.1 Å (b) 0.40 Å (c) 0.53 Å (d) 2.1 Å

49. Which of the following expressions correctly represents the relationship between average kinetic energy of CO and N_2 molecules at the same temperature?
(a) $E_{CO} > E_{N_2}$
(b) $E_{CO} < E_{N_2}$
(c) $E_{CO} = E_{N_2}$
(d) Cannot be predicted unless volumes of the gases are given

50. On the basis of Hardy-Schulze rule, which of the following sequences represents the coagulating power of cations?
(a) $Ba^{2+} > Al^{3+} > Na^+$ (b) $Ba^{2+} > Na^+ > Al^{3+}$
(c) $Al^{3+} > Na^+ > Ba^{2+}$ (d) $Al^{3+} > Ba^{2+} > Na^+$

51. Adiabatic expansion of an ideal gas is accompanied by:
(a) increase in temperature
(b) decrease in ΔS
(c) decrease in ΔE
(d) no change in any one of the above properties

52. For a cyclic process, which of the following is not true?
(a) $W = 0$ (b) $\Delta E = 0$ (c) $\Delta H = 0$ (d) $\Delta G = 0$

53. Radius of nucleus is related to the mass number 'A' by:
(a) $R = R_0A^{1/2}$ (b) $R = R_0A$
(c) $R = R_0A^2$ (d) $R = R_0A^{1/3}$

54. A catalyst:
(a) increases the average kinetic energy of molecules
(b) increases the activation energy
(c) alters the reaction mechanism
(d) increases the frequency of collisions of reacting species

55. A chemist wishes to prepare a buffer solution of pH = 3.85 that efficiently resists changes in pH yet contains only small concentration of the buffering agents. Which one of the following weak acids together with its sodium salt would be best to use?
(a) *m*-chlorobenzoic acid ($pK_a = 3.98$)
(b) *p*-chlorocinnamic acid ($pK_a = 4.41$)
(c) 2,5-hydroxybenzoic acid ($pK_a = 2.97$)
(d) Aceto-acetic acid ($pK_a = 3.58$)

56. For coordination number 4, the geometry that is not possible is:
(a) trigonal planar (b) tetrahedral
(c) irregular tetrahedral (d) trigonal pyramidal

57. The rate constant, the activation energy and the Arrhenius parameter of a chemical reaction at 25°C are $3 \times 10^{-4}\ \text{sec}^{-1}$, 104.4 kJ mol^{-1} and $6 \times 10^{14}\ \text{sec}^{-1}$ respectively. The value of rate constant as $T \to \infty$ is:
(a) $2 \times 10^{18}\ s^{-1}$ (b) $6 \times 10^{14}\ s^{-1}$
(c) infinity (d) $3.6 \times 10^{30}\ s^{-1}$

58. Emission of one 'α' and two 'β' particles successively from an element forms:
(a) isotope of parent element (b) isobar of parent element
(c) isotone of parent element (d) isomer of parent element

59. Fraction of the total volume occupied by atoms in a simple cube is:
(a) $\dfrac{\pi}{2}$ (b) $\dfrac{\sqrt{3}\pi}{8}$ (c) $\dfrac{\sqrt{2}\pi}{6}$ (d) $\dfrac{\pi}{6}$

60. Which of the following statements is wrong?
(a) Crystalline solids are optically anisotropic
(b) Glass is amorphous solid
(c) There are 14 Bravais lattices
(d) There are only 10 crystal symmetries

61. Which of the following pairs is correctly matched?

Experimental observation	Phenomenon
(a) X-ray spectra	Charge on the nucleus
(b) α-particle scattering	Quantized electron orbit
(c) Emission spectra	Quantization of energy
(d) The photoelectric effect	The nuclear atom

62. Arrangement of the following group of orbitals in which they fill with electrons:

$$(5f, 6p, 4p, 6s, 4d, 4f)$$

(a) $4p, 4d, 6s, 4f, 6p, 5f$ (b) $6s, 4d, 4f, 5f, 4p, 6p$
(c) $6s, 4p, 4d, 4f, 5f, 6p$ (d) $4d, 4p, 4f, 5f, 6s, 6p$

63. π° meson is exchanged between:
(a) proton and neutron
(b) proton and proton
(c) neutron and neutron
(d) may be between two protons or two neutrons

64. If nucleons in an excited state fall to a lower energy level, energy is emitted as:
(a) α-rays (b) β-rays (c) γ-rays (d) X-rays

65. Minimum amount of energy required to remove a proton is approximately:
(a) 2 MeV (b) 4 MeV (c) 6 MeV (d) 8 MeV

66. Mark the incorrect statement:
(a) Semiconductors are basically insulator
(b) In metal crystal conduction occurs because molecular orbitals extend over the whole crystal and there is no energy gap between filled and unfilled molecular orbital
(c) Mobile electrons account for high thermal and electrical conduction of metals
(d) When a metal is heated with a non-metal, the resulting compound is never an ionic compound

67. Given:
(i) $NH_3(g) + 3Cl_2(g) \longrightarrow NCl_3(g) + 3HCl(g)$; ΔH_1
(ii) $N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$; ΔH_2
(iii) $H_2(g) + Cl_2(g) \longrightarrow 2HCl(g)$; ΔH_3

Express the enthalpy of formation of $NCl_3(g)$ (ΔH_f) in terms of ΔH_1, ΔH_2 and ΔH_3:

(a) $\Delta H_f = \Delta H_1 - \frac{\Delta H_2}{2} + \frac{3}{2}\Delta H_3$

(b) $\Delta H_f = \Delta H_1 + \frac{1}{2}\Delta H_2 - \frac{3}{2}\Delta H_3$

(c) $\Delta H_f = \Delta H_1 - \frac{1}{2}\Delta H_2 - \frac{3}{2}\Delta H_3$

(d) $\Delta H_f = \Delta H_1 + \frac{1}{2}\Delta H_2 + \frac{3}{2}\Delta H_3$

68. A spontaneous process may be defined as:
(a) a process which is exothermic and evolves a lot of heat
(b) a process which is slow and reversible
(c) a process which takes place only in presence of a catalyst
(d) a process that occurs without any input from the surroundings

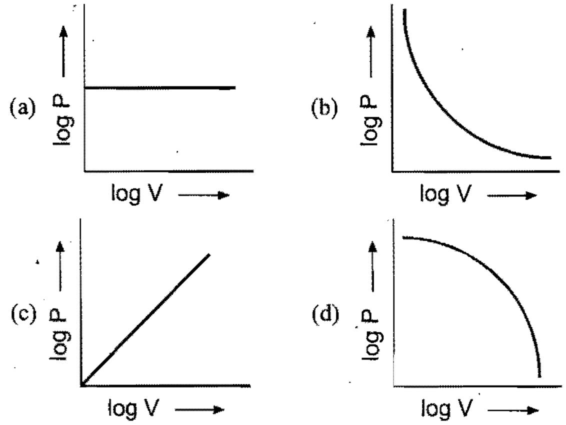
69. In the sequence of reaction,

$$L \xrightarrow{k_1} M \xrightarrow{k_2} N \xrightarrow{k_3} O$$

$$k_3 > k_2 > k_1$$

The rate determining step of the reaction is:
(a) $L \longrightarrow M$ (b) $M \longrightarrow N$ (c) $N \longrightarrow O$ (d) $L \longrightarrow O$

70. The plot of log V against log P at constant temperature for a fixed mass of gas is:



71. When mercuric iodide is added to aqueous solution of KI:
(a) freezing point is raised
(b) freezing point does not change
(c) freezing point is lowered
(d) boiling point does not change

72. The van der Waals' constant 'b' for water vapour is 0.03 litre mol^{-1}. The radius of water vapour molecule is:
(a) 1.448 cm (b) 1.448 Å (c) 1.448 pm (d) 1.448 nm

73. For a reaction $A \begin{smallmatrix} \xrightarrow{k_1} C \\ \xrightarrow[k_2]{} B \end{smallmatrix}$, the overall rate constant is related to individual rate constants by:
(a) $k = k_1 - k_2$ (b) k_1/k_2 (c) k_1k_2 (d) $k_1 + k_2$

74. N_2O_5 decomposes to N_2O_4 and O_2 as:

$$N_2O_5 \longrightarrow N_2O_4 + \frac{1}{2}O_2$$

The pressure P_t at any stage is related to p_0 and 'x', the fraction of dissociation, as:

(a) p_0 (b) $(1 + \frac{1}{2}x)\,p_0$

(c) $1 - \frac{3}{2}p_0$ (d) $\frac{3}{2}xp_0$

SECTION III

MULTIPLE CHOICE QUESTIONS (For IIT, AIIMS and BHU Medical Entrance)

This section includes those questions in which two or more options may be correct. Few of them have single correct choice.

75. An ideal gas:
(a) has no intermolecular attraction
(b) molecules do not collide with each other
(c) the product of P and V is constant at a fixed temperature for definite mass
(d) can be liquefied easily

76. Extensive properties among the following is/are:
(a) refractive index (b) volume
(c) density (d) mass

77. Which of the following statements regarding equilibrium is /are true?
(a) Equilibrium constant varies with temperature
(b) Equilibrium constant varies with catalyst
(c) The reaction stops when the equilibrium is reached
(d) The equilibrium constant depends on the concentration of reactants

78. When mercuric iodide is added to aqueous KI solution:
(a) freezing point is raised (b) osmotic pressure is raised
(c) boiling point is elevated (d) vapour pressure is raised

79. The correct statements are:
(a) Smoke is carbon dispersed in air
(b) Butter is water dispersed in fat
(c) Greater is the valency of ion more will be its coagulating power
(d) More is the gold number of a lyophobic sol, more is protecting power

80. Select the correct statements among the following:
(a) Order can be zero.
(b) Order cannot have fractional value.
(c) Order is a theoretical quantity.
(d) Order is equal to molecularity for decomposition of N_2O_5 giving N_2O_4 and O_2.

81. Rate law for a chemical reaction is:

$$\text{Rate} = k[A]^{1/2}[B]^1$$

Choose the correct options among the following:
(a) Order of the reaction is 3/2.
(b) Unit of its rate constant is litre$^{1/2}$ mol$^{-1/2}$ sec^{-1}.
(c) Unit of rate is mol litre^{-1} sec^{-1}.
(d) Its molecularity is always 3.

82. Liquid benzene burns in oxygen according to:

$$2C_6H_6 + 15O_2 \longrightarrow 12CO_2 + 6H_2O$$

If density of liquid benzene is 0.88 g/cc, what volume of O_2 at STP is needed to complete the combustion of 39 cc of liquid benzene?
(a) 11.2 litre (b) 74 litre (c) 0.074 m^3 (d) 37 dm^3

83. For the reaction;

$$N_2H_4(l) + 2H_2O_2(l) \longrightarrow N_2(g) + 4H_2O(g)$$

heats of formation of N_2H_4, H_2O_2, H_2O are 12, – 45 and –57.8 kcal mol^{-1}. Internal energy change for this reaction is/are at 298 K:
(a) –153.2 kcal mol^{-1} (b) – 641.142 kJ mol^{-1}
(c) –24.8 kcal mol^{-1} (d) –309 kcal mol^{-1}

84. Which of the following electrolytes have same osmotic pressure as that of 0.1 *M* KCl?
(a) 0.1 *M* HCl (b) 0.1 *M* NaCl
(c) 0.1 *M* CsCl (d) None of these

85. Select the correct statements about the following reaction:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g); \quad \Delta H = -22.4 \text{ kcal mol}^{-1}$$

(a) Increase in pressure will favour forward reaction.
(b) Addition of inert gas forms more NH_3.
(c) At low temperature, there is forward shift.
(d) Catalyst will increase the amount of NH_3.

86. Which among the following is/are correct about penetrating power?
(a) α-rays are less penetrating than β-rays.
(b) β-rays are less penetrating than γ-rays.
(c) α, β, γ rays have equal penetrating power.
(d) γ-rays are most penetrating.

87. Select the natural series among the following:
(a) $(4n + 1)$ (b) $(4n + 2)$ (c) $4n$ (d) $(4n + 3)$

88. Select the correct conclusion(s) about average life:
(a) Average life = $1/\lambda$
(b) Average life = $1.44 \times t_{1/2}$
(c) The time in which 63.2% element decays is called average life
(d) None of the above

89. Which of the following statements are correct?
(a) 1 faraday is the charge of 1 mole electron.
(b) 1 faraday is used to deposit 1 g equivalent of a substance.
(c) 5.6 litre O_2 will be evolved at STP by 1 faraday charge.
(d) 11.2 litre Cl_2 will be evolved at STP by 1 faraday charge.

90. Select the species having zero oxidation state at the underlined elements:
(a) $(CH_3)_2\underline{S}O$ (b) $\underline{C}_{12}H_{22}O_{11}$ (c) $H_2\underline{S}_2O_3$ (d) $\underline{N}_2H_4$

91.
$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

'α' is the degree of dissociation of PCl_5 at equilibrium pressure 'P'. Which among the following is the correct expression for degree of dissociation of 'α'?
(a) $\alpha = \sqrt{\dfrac{K_p}{P + K_p}}$ (b) $\alpha = \sqrt{\dfrac{P + K_p}{K_p}}$
(c) $\alpha = \sqrt{K_p P}$ (d) $\alpha = \sqrt{P/K_p}$

92. In Wilson Cloud Chamber, the track is formed by:
(a) α-rays (b) β-rays (c) γ-rays (d) all of these

93. Select the correct relation:
(a) $N_0 = N \cdot 10^{\lambda t/2.303}$ (b) $N_0 = Ne^{\lambda t}$
(c) $N_0 = N \dfrac{\lambda}{10^{2.303t}}$ (d) $N = N_0 e^{-\lambda t}$

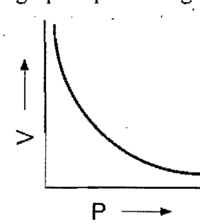
94. For the first order reaction, $t_{99\%} = x \times t_{90\%}$, the value of '$x$' will be:
(a) 10 (b) 6 (c) 3 (d) 2

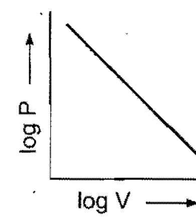
95. Which among the following has same kinetic energy as O_2 gas at NTP?
(a) H_2 (b) N_2 (c) CO_2 (d) None of these

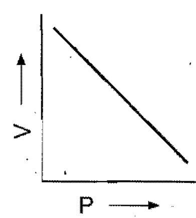
96. Which among the following is correct about γ-rays?
(a) High energy electrons
(b) Low energy electrons
(c) High energy electromagnetic waves
(d) High energy positrons

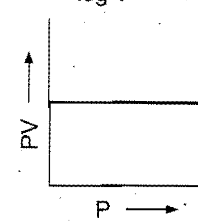
97. The RMS speed at NTP of a gas can be calculated from the expression:
(a) $\sqrt{3P/d}$ (b) $\sqrt{3PV/M}$ (c) $\sqrt{3RT/M}$ (d) $\sqrt{3d/P}$

98. The graph representing Boyle's law is(are):

(a)


(b)


(c)


(d)


99. For diatomic molecules; the correct relation is/are:
(a) $C_P = \frac{7}{2}R$ (b) $C_V = \frac{5}{2}R$ (c) $\gamma = 1.4$ (d) $C_P = \frac{3}{2}R$

100. Which of the following aqueous solutions produce the same osmotic pressure?
(a) 0.1 M NaCl solution
(b) 0.1 M glucose solution
(c) 0.6 g urea in 100 mL solution
(d) 1.0 g of a non-electrolyte solute in 50 mL solution (Molar mass = 200)

Answers with Hints for Selected Questions

SECTION I

1. (b) 2. (b) 3. (b) 4. (b) 5. (c)
6. (d) Degree of freedom $= 3n$
where, n = no. of atoms in the molecule.
7. (b) At high temperature, $T\Delta S > \Delta H$
$\therefore \quad \Delta G = \Delta H - T\Delta S = -\text{ve}$
and process will be spontaneous.
8. (a)
9. (c) Binding energy has no role in emission of α-particle. n/p ratio determines the mode of emission.
$$4[{}_1H^1] \longrightarrow {}_2He^4 + 2[{}_{+1}e^0] + \text{Energy}$$
10. (c) Packing fraction (fcc) = 74%
Packing fraction (bcc) = 67.9%

SECTION II

11. (c)
12. (c) Rate $= k[A]^1$ (for first order)
$$t_{1/2} = \frac{0.693}{k} = \text{constant}$$
13. (b) Lower the value of $(n + l)$, lesser is the energy of orbital.
14. (c) No. of lines $= \frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$
n_2 = higher shell
n_1 = lower shell
15. (d) $p_A = x_A \times p = \frac{1}{2} \times 1 = 0.5$ atm, $x_A = \frac{1}{2}$ = mole fraction of O_2.
16. (c)
17. (b) Greater is the intermolecular force on mixing, more negative will be the deviation $p < p_A^0 x_A + p_B^0 x_B$
Experimental vapour pressure will be less than calculated vapour pressure.
18. (c) Non-ideal solutions form low or high boiling azeotrope, hence, maxima and minima in the curve are obtained.
19. (a)
20. (c) $\Lambda_m^\infty NH_4OH = \Lambda_m^\infty NH_4Cl + \Lambda_m^\infty NaOH - \Lambda_m^\infty NaCl$
$= 129.8 + 217.4 - 108.9$
$= 238.3 \text{ ohm}^{-1}\text{ cm}^2\text{ mol}^{-1}$
$$\alpha = \frac{\Lambda_m}{\Lambda_m^\infty} = \frac{9.33}{238.3} = 0.03915$$
% Ionization = 3.92
21. (c)
22. (c) $k = Ae^{-E_a/RT}$ When $T = \infty$, $k = Ae^0 = A$
23. (b) $\frac{hc}{\lambda_3} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2}$
$$\frac{1}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$$
$$\lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_1 + \lambda_2}$$
24. (a) 25. (d)
26. (b) $n_2 = 7$, $n_1 = 2$
No. of lines $= \frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$
$= \frac{(7-2)(7-2+1)}{2}$
$= \frac{5 \times 6}{2} = 15$
27. (c) The difference fall in far infrared series.
28. (b) $t_{1/2} \propto \frac{1}{a^{n-1}}$, where, n = order of reaction.
29. (a)
30. (d) Number of 'B' atoms $= n$
Number of tetrahedral void $= 2n$
Number of 'A' atoms $= \frac{2n}{2} = n$
$A : B = n : n = 1 : 1$
Formula $= AB$
31. (b) Orbital angular momentum $= \sqrt{l(l+1)}\,\frac{h}{2\pi}$
$l = 1$ for 'p' subshell.
32. (b)
33. (c) $\alpha = \frac{i-1}{n-1}$, $n = 2$ for HCN
$$\alpha = \frac{1.00002 - 1}{2 - 1} = 0.00002$$
% dissociation = 0.002
34. (b)
35. (c) Rate of zero order reaction is constant.
36. (b) 37. (b) (b)
39. (b) Number of ion per unit volume decreases on dilution
40. (c)
41. (d) AB_2O_4 has spinel structure.
42. (d) 43. (a)
44. (d) $\underset{S}{Hg_2Cl_2} \longrightarrow \underset{S}{Hg_2^{2+}} + \underset{2S}{2Cl^-}$
$$K_{sp} = [Hg_2^{2+}][Cl^-]^2 = [S][2S]^2 = 4S^3$$
45. (b) Use the relation,
$$\log_{10}\left(\frac{k_2}{k_1}\right) = \frac{E_a}{2.303R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$
When $E_{a_1} > E_{a_2}$
$$\frac{k_2}{k_1} > \frac{k_2'}{k_1'} \quad \text{or} \quad \frac{k_1'}{k_1} \quad \frac{k_2'}{k_2}$$
46. (c)
47. (c) $t_{1/2}$ of first order reaction is constant (plot 1).
$$t_{1/2} = \frac{0.693}{R}$$

Rate of zero order reaction is constant (plot 2).

$$\text{Rate} = k\,[A]^0$$

48. (c) **49.** (c) **50.** (d)

51. (c) Adiabatic expansion results into decrease in internal energy and temperature of system.

52. (d) **53.** (d)

54. (c) Catalyst forms new intermediate of either low or high activation energy.

55. (a)

56. (a) Either square planar or tetrahedral geometry is possible.

57. (b) **58.** (a) **59.** (d) **60.** (d)

61. (c) In emission spectra quantum of electromagnetic radiations are released.

62. (a) **63.** (d)

64. (c) γ-rays are evolved due to secondary effect of α, β emission.

65. (a) **66.** (d) **67.** (b) **68.** (d)

69. (a) Slowest step is $L \xrightarrow{k_1} M$; it will be rate determining.

70. (b)

71. (a) $HgI_2 + 2KI \longrightarrow K_2[HgI_4]$

Nessler's reagent $K_2[HgI_4]$ is formed which lowers the overall number of particles in the solution. Thus, on mixing the two components freezing point will be raised.

72. (b) $b = 4NV' = 4N\left(\frac{4}{3}\pi r^3\right)$

V' = volume occupied by single molecule.

73. (d)

74. (b)

$$\begin{array}{llll} & N_2O_5(g) & \longrightarrow N_2O_4(g) & + (1/2)\,O_2(g) \\ t=0 & p_0 & 0 & 0 \\ \text{At } t & p_0(1-x) & p_0x & p_0x/2 \end{array}$$

$$P_t = p_0(1-x) + p_0\,x + \frac{p_0\,x}{2} = p_0\left(1 + \frac{x}{2}\right)$$

SECTION III

75. (a, c) **76.** (b, d) **77.** (a, b)

78. (a, d) KI reacts with HgI_2 to form Nessler's reagent. Number of particles are lowered.

$$2KI + HgI_2 \longrightarrow K_2[HgI_4]$$

79. (a, b, c) **80.** (a, d) **81.** (a, b, c) **82.** (b, c)

83. (a, b)

84. (a, b, c) van't Hoff factor will be same for the given electrolytes.

85. (a, b, c) **86.** (a, b, d) **87.** (b, c, d) **88.** (a, b, c)

89. (a, b, c, d) **90.** (a, b) **91.** (a) **92.** (a, b)

93. (a, b, d) **94.** (d) **95.** (a, b. [illegible] **96.** [illegible]

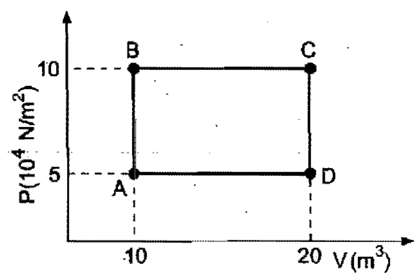
97. (a, b, c) **98.** (a, b, d) **99.** (a, b, c) **100.** (b, c, d)

IIT ENTRANCE TEST PAPERS

TEST SERIES II

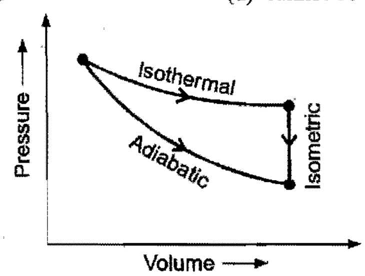
(Graphical Aptitude)

1. A sample of 2 kg of helium (assumed ideal) is taken through the process ABC and another sample of 2 kg of the same gas is taken through the process ADC. Then the temperature of the states A and B are: (Given, $R = 8.3$ joules/mol K)

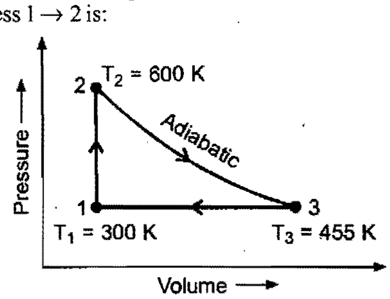


(a) $T_A = 120.5\ K, T_B = 120.5\ K$
(b) $T_A = 241\ K, T_B = 241\ K$
(c) $T_A = 120.5\ K, T_B = 241\ K$
(d) $T_A = 241\ K, T_B = 482\ K$

2. An ideal diatomic gas is caused to pass through a cycle shown on the $P-V$ diagram in figure, where $V_2 = 3.00\,V_1$. If P_1, V_1 and T_1 specify the state 1, then the temperature of the state 3 is:
(a) $(T_1/3)^{1.4}$ (b) $T_1/3^{1.4}$
(c) $T_1/3^{0.4}$ (d) cannot be determined

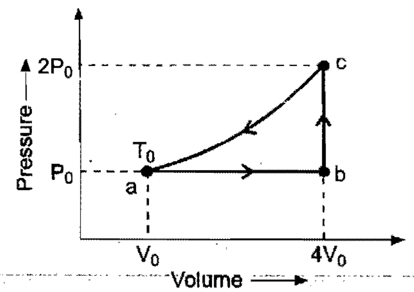


3. A heat engine carries one mole of an ideal monoatomic gas around the cycle as shown in the figure. Process $1 \to 2$ takes place at constant volume, process $2 \to 3$ is adiabatic and process $3 \to 1$ takes place at constant pressure. Then the amount of heat added in the process $1 \to 2$ is:



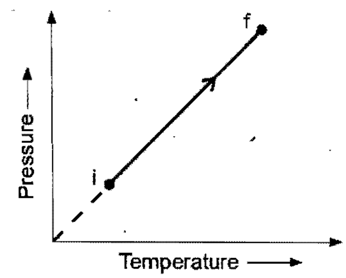
(a) 3740 J (b) –3740 J (c) 1810 J (d) 3220 J

4. One mole of an ideal monoatomic gas is caused to go through the cycle shown in figure. Then the change in the internal energy in expanding the gas from a to c along the path abc is:



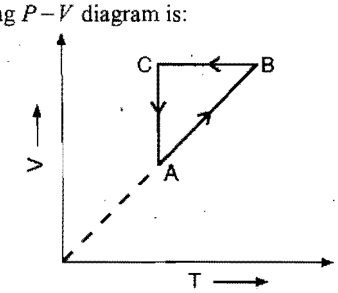
(a) $3P_0V_0$ (b) $6RT_0$ (c) $4.5RT_0$ (d) $10.5RT_0$

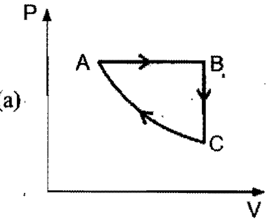
5. A thermodynamic system consists of a cylinder-piston arrangement with ideal gas in it. It goes from the state i to the state f as shown in the figure. The work done by the gas during the process:

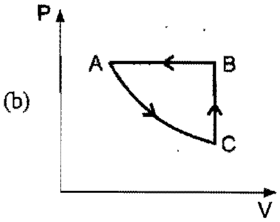


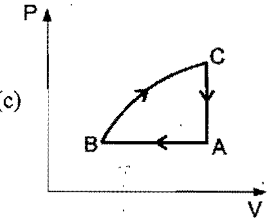
(a) is zero (b) is negative
(c) is positive (d) nothing can be predicted

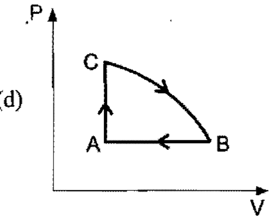
6. A cyclic process $ABCA$ is shown in a $V-T$ diagram. The corresponding $P-V$ diagram is:



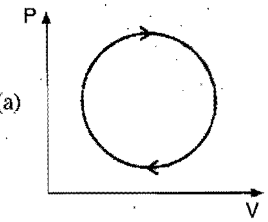
(a)


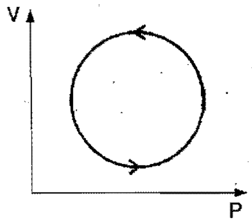
(b)


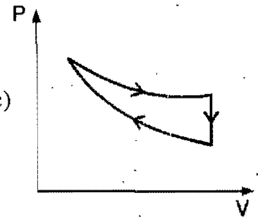
(c)


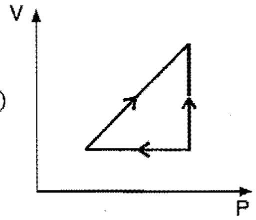
(d)


7. The following are the $P-V$ diagrams for cyclic processes for a gas. In which of these processes heat is not absorbed by the gas?

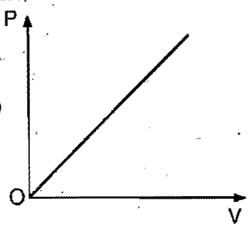
(a) 

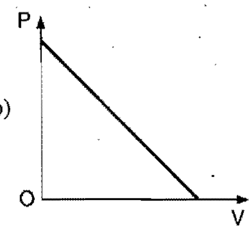
(b) 

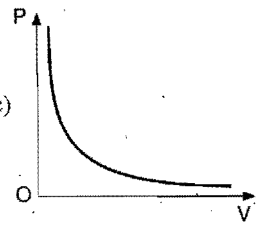
(c) 

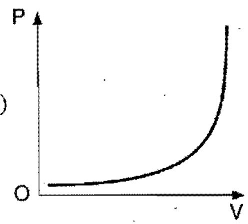
(d) 

8. The graph between P and V at constant temperature should look like:

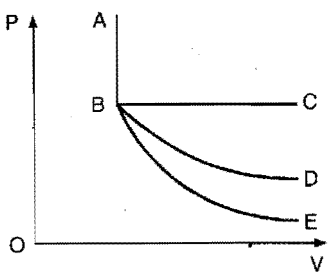
(a) 

(b) 

(c) 

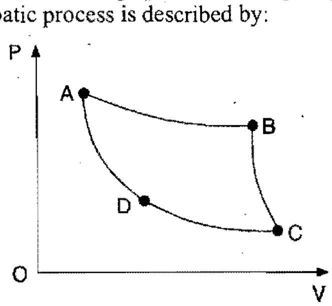
(d) 

9. In $P-V$ diagram shown below:



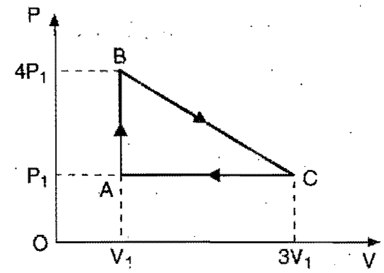
(a) AB represents adiabatic process
(b) AB represents isothermal process
(c) AB represents isobaric process
(d) AB represents isochoric process

10. The pressure-volume graph of an ideal gas cycle is shown below. The adiabatic process is described by:



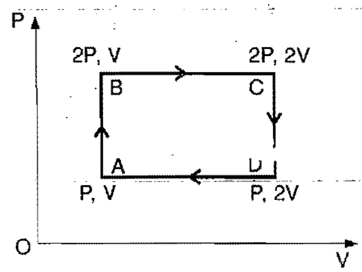
(a) AB and BC (b) AB and CD
(c) AD and BC (d) BC and CD

11. An ideal gas is taken around the cycle $ABCA$ shown in $P-V$ diagram. The net work done by the gas during the cycle is equal to: (BHU 1994)



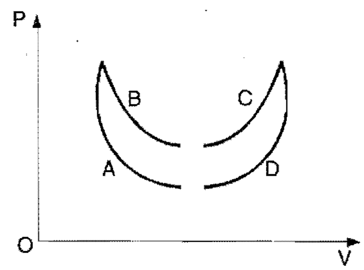
(a) $12P_1V_1$ (b) $6P_1V_1$ (c) $3P_1V_1$ (d) P_1V_1

12. An ideal monoatomic gas is taken round the cycle $ABCDA$ as shown in figure. The work done during cycle is:



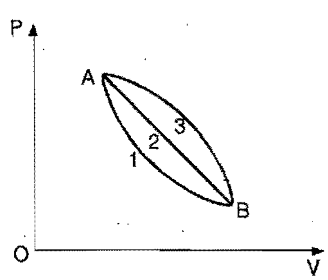
(a) PV (b) $2PV$ (c) $\frac{1}{2}PV$ (d) zero

13. Four curves A, B, C and D are drawn in figure for a given amount of gas. The curve which represents adiabatic and isothermal changes are:



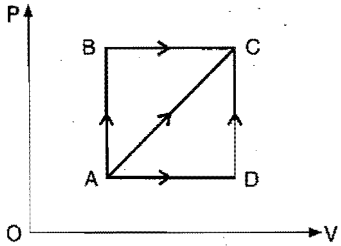
(a) C and D respectively (b) D and C respectively
(c) A and B respectively (d) B and A respectively

14. A given mass of gas expands from the state A to the state B by three paths 1, 2 and 3 as shown in the figure. If W_1, W_2 and W_3 respectively be the work done by the gas along three paths then: (CPMT 1992)



(a) $W_1 > W_2 > W_3$ (b) $W_1 < W_2 < W_3$
(c) $W_1 = W_2 = W_3$ (d) $W_1 < W_2$; $W_1 < W_3$

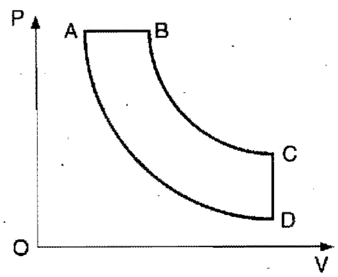
15. A thermodynamic process is shown in the following figure. The pressure and volumes corresponding to some points in the figure are:
$P_A = 3 \times 10^4 \text{Pa}, V_A = 2 \times 10^{-3}\ \text{m}^3$;
$P_B = 8 \times 10^4 \text{Pa}, V_D = 5 \times 10^{-3}\ \text{m}^3$



In process AB, 600 J of heat is added to the system and in the process BC, 200 J of heat is added to the system. The change in internal energy of the system in the process AC would be: **(CBSE 1992)**

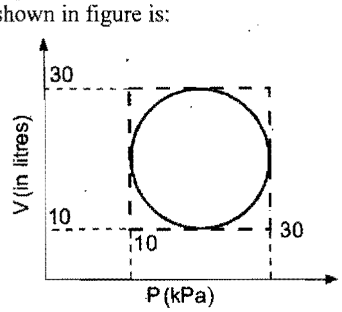
(a) 560 J (b) 800 J (c) 600 J (d) 640 J

16. In the pressure-volume diagram given below, the isochoric, isothermal, isobaric and isoentropic parts respectively are:



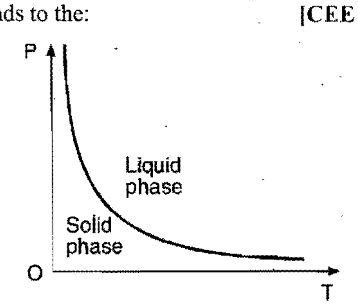
(a) BA, AD, DC, CB (b) DC, CB, BA, AD
(c) AB, BC, CD, DA (d) CD, DA, AB, BC

17. Heat energy absorbed by a system in going through a cyclic process shown in figure is: **(AIIMS 1995)**



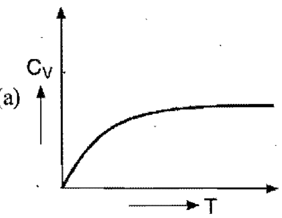
(a) $10^7\pi$ J (b) $10^4\pi$ J (c) $10^2\pi$ J (d) $10^{-3}\pi$ J

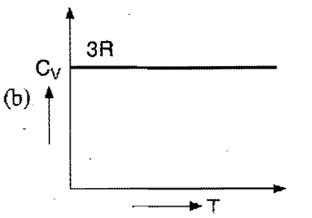
18. The pressure-temperature $(P-T)$ phase diagram shown below corresponds to the: **[CEE (Haryana) 1996]**

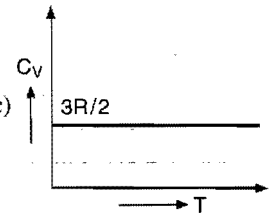


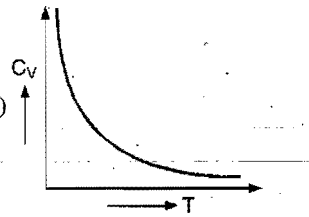
(a) Curve of fusion of solids that expand on solidification
(b) Curve of sublimation of solids that directly go over to the vapour phase
(c) Curve of fusion of solids that contract on solidification
(d) Curve of fusion of solids that do not change in volume upon solidification

19. Graph of specific heat at constant volume for a monoatomic gas is:

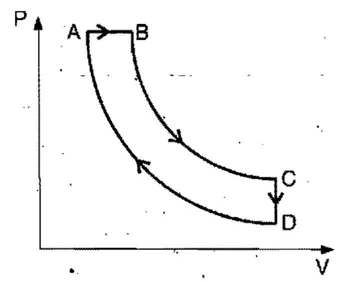
(a) 

(b) 

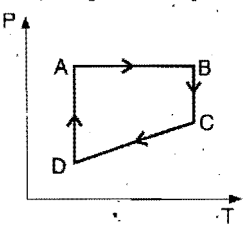
(c) 

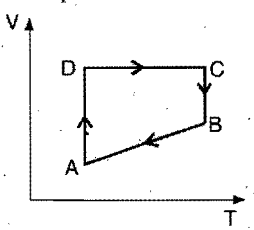
(d) 

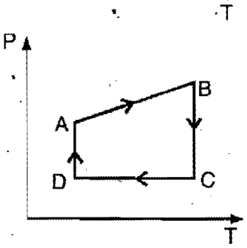
20.

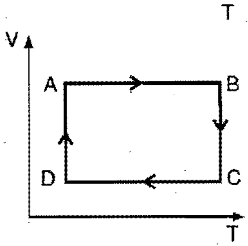


A cyclic process $ABCD$ is shown in the $P-V$ diagram. Which of the following curves represents the same process?

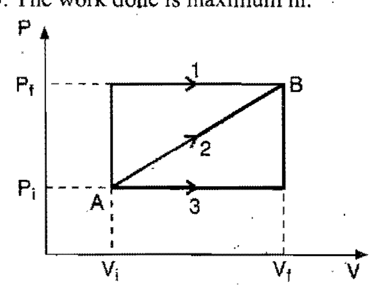
(a) 

(b) 

(c) 

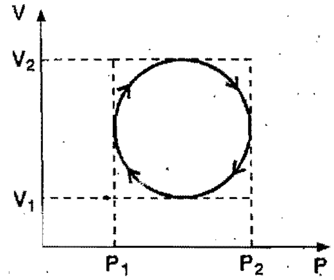
(d) 

21. A system is taken from state A to B through three different paths 1, 2 and 3. The work done is maximum in: **(CPMT 1997)**



(a) process 1 (b) process 2
(c) process 3 (d) equal in all processes

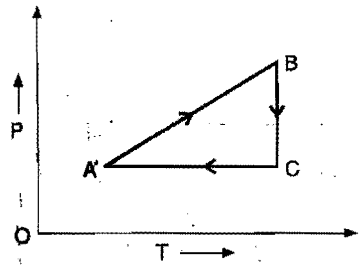
22. In the cyclic process shown on $P-V$ diagram, the magnitude of the work done is:



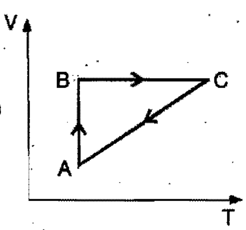
(a) $\pi\left(\frac{P_2-P_1}{2}\right)^2$ (b) $\pi\left(\frac{V_2-V_1}{2}\right)^2$

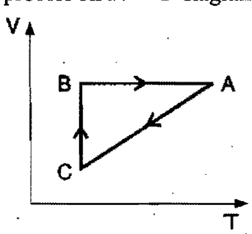
(c) $\frac{\pi}{4}(P_2-P_1)(V_2-V_1)$ (d) $\pi(P_2V_2 = P_1V_1)$

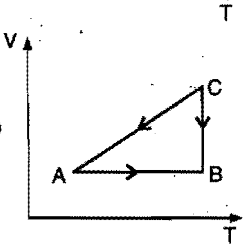
23. A cyclic process is shown in the $P-T$ diagram:

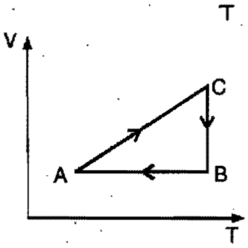


Which of the curves shows the same process on a $V-T$ diagram?

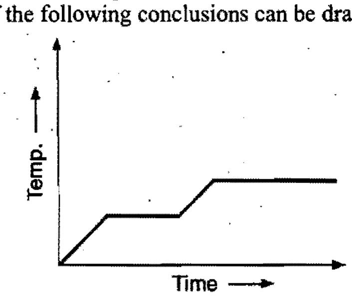
(a)


(b)


(c)


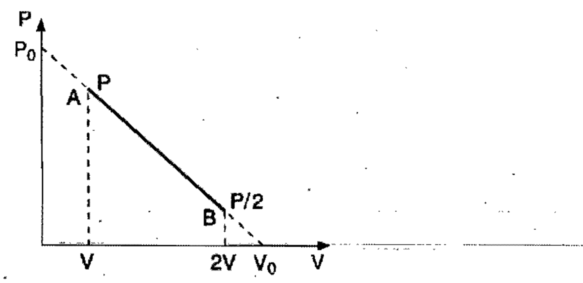
(d)


24. Heat is supplied to a certain homogeneous sample of matter, at a uniform rate. Its temperature is plotted against time, as shown. Which of the following conclusions can be drawn?



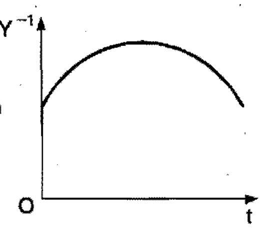
(a) Its specific heat capacity is greater in the solid state than in the liquid state.
(b) Its specific heat capacity is smaller in the solid state than in the liquid stat.
(c) Its latent heat of vaporization is greater than its latent heat of fusion.
(d) Its latent heat of vaporization is smaller than its latent heat of fusion.

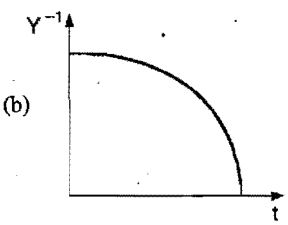
25. An ideal gas is taken from the state A (pressure P, volume V) to the state B (pressure $P/2$, volume $2V$) along a straight line path in the $P-V$ diagram. Select the wrong statement from the following:

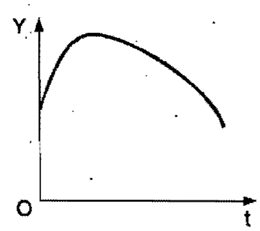


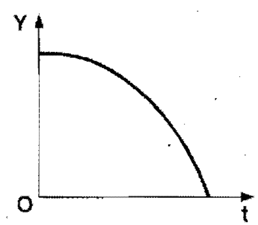
(a) The work done by the gas in the process A to B exceeds the work that would be done by it if the system were taken from A to B along the isotherm
(b) In the $T-V$ diagram, the path AB becomes a part of parabola
(c) In the $P-T$ diagram, the path AB becomes a part of hyperbola
(d) In going from A to B, the temperature T of the gas first increases to a maximum value and then decreases

26. The radioactive nucleus of an element X decays to a stable nucleus of element Y. A graph of the rate of formation of Y against time would look like:

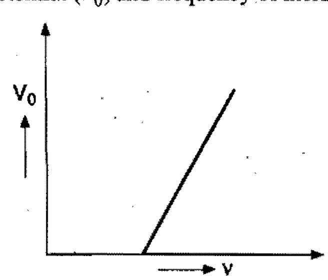
(a)


(b)


(c)


(d)


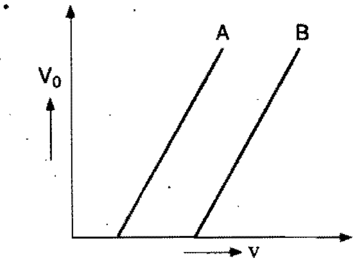
27. In photoelectric effect the slope of straight line graph between stopping potential (V_0) and frequency of incident light (ν) gives:



(a) charge on electron
(b) work function of emitter

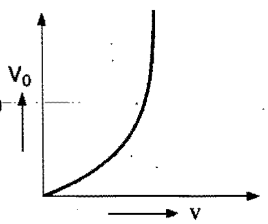
(c) Planck's constant
(d) ratio of Planck's constant to charge on electron

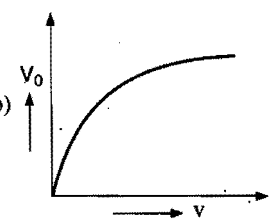
28. The sloping potential as a function of frequency of incident radiation is plotted for two different photoelectric surfaces A and B. The graphs show that the work function of A is:

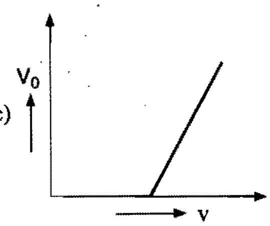


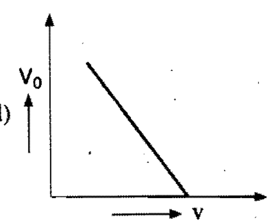
(a) greater than that of B
(b) smaller than that of B
(c) same as that of B
(d) such that no comparison can be done from given graphs

29. Which of the following is the graph between the frequency (ν) of the incident radiations and the stopping potential?

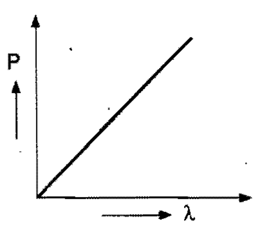
(a) 

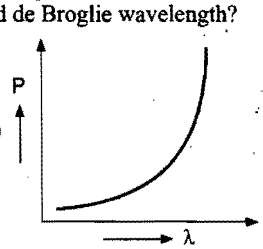
(b) 

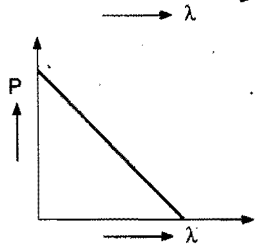
(c) 

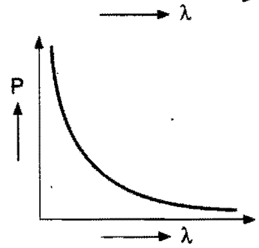
(d) 

30. Which of the following figures represents the variations of particle momentum and associated de Broglie wavelength?

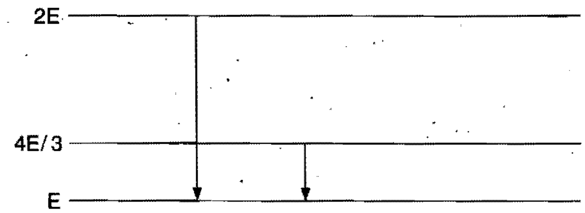
(a) 

(b) 

(c) 

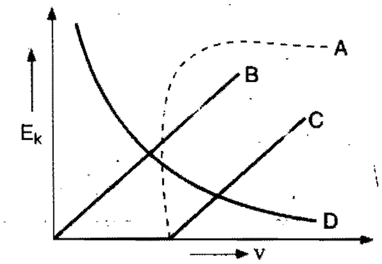
(d) 

31. The given figure indicates the energy levels of a certain atom. When the system moves from $2E$ level to E, a photon of wavelength λ is emitted. The wavelength of photon produced during the transition from level $4E/3$ to level E is:



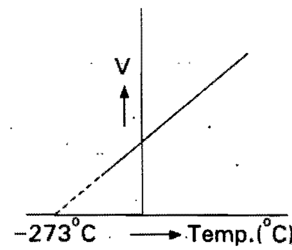
(a) $\lambda/3$ (b) $3\lambda/4$ (c) $4\lambda/3$ (d) 3λ

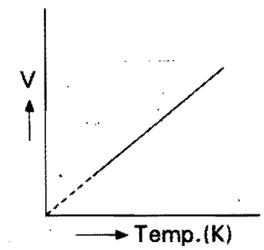
32. The maximum kinetic energy (E_k) of the photoelectron varies with frequency (ν) of the incident light as shown by the curve:



(a) A (b) B (c) C (d) D

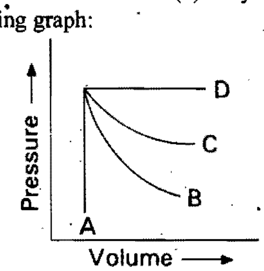
33. The following graphs illustrate:





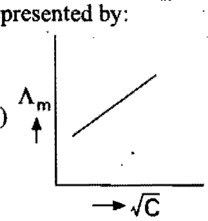
(a) Dalton's law (b) Charles' law
(c) Boyle's law (d) Gay-Lussac's law

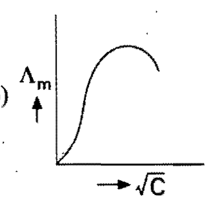
34. In the following graph:

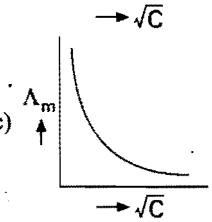


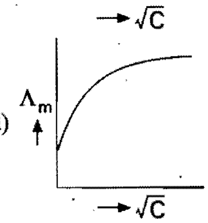
(a) 'A' represents isochoric process
(b) 'B' represents adiabatic process
(c) 'C' represents isothermal process
(d) 'D' represents isobaric process

35. The variation of Λ_m of acetic acid with concentration is correctly represented by:

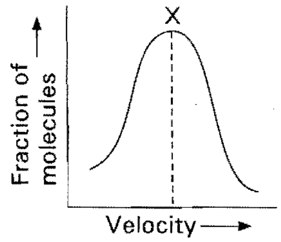
(a) 

(b) 

(c) 

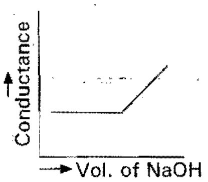
(d) 

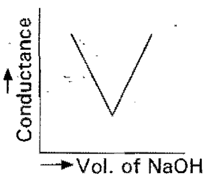
36. Distribution of fraction of molecules with velocity is represented in the figure. Velocity corresponding to X is:

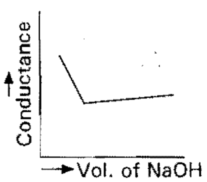


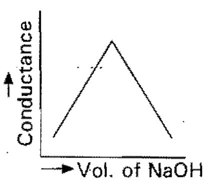
(a) $\sqrt{\frac{2RT}{M}}$ (b) $\sqrt{\frac{3RT}{M}}$ (c) $\sqrt{\frac{8RT}{\pi M}}$ (d) none of these

37. CH_3COOH is neutralized by NaOH. Conductometric titration curve will be of the type:

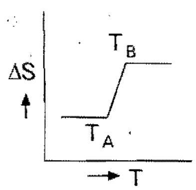
(a) 

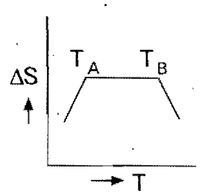
(b) 

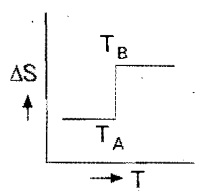
(c) 

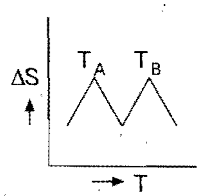
(d) 

38. If for a given substance, T_B is the m.pt. and T_A is the freezing point, then correct variation of entropy by graph between entropy change (ΔS) and temperature is:

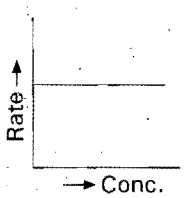
(a) 

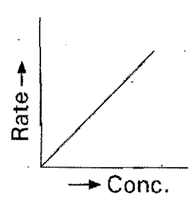
(b) 

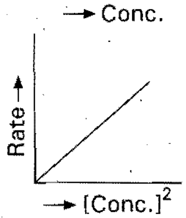
(c) 

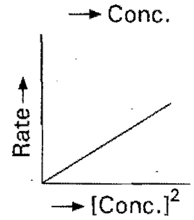
(d) 

39. Which of the following represents zero order reaction?

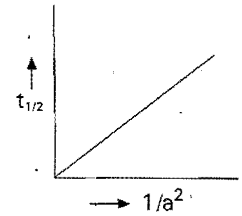
(a) 

(b) 

(c) 

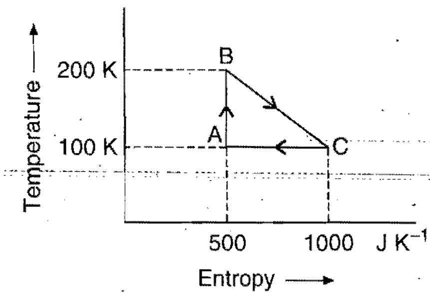
(d) 

40. This graph represents:



(a) first order reaction (b) zero order reaction
(c) second order reaction (d) third order reaction

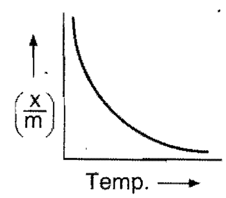
41. The efficiency of the reversible cycle shown in the given figure is:

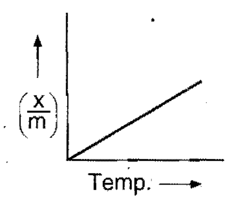


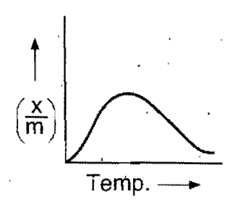
(a) 33.33% (b) 56% (c) 66% (d) 16.7%

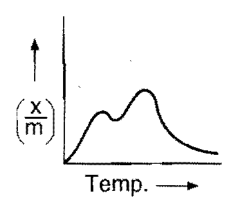
[**Hint:** Efficiency $= \frac{\text{Area bounded by the curve}}{\text{Total area under the line BC}} \times 100$]

42. Which of the following curves represents the chemical adsorption?

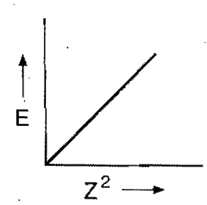
(a) 

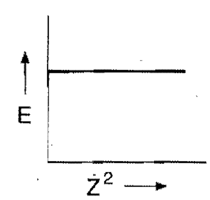
(b) 

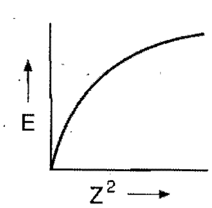
(c) 

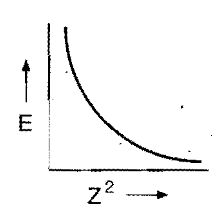
(d) 

43. Energy of electron varies with atomic number as the following curve/line:

(a) 

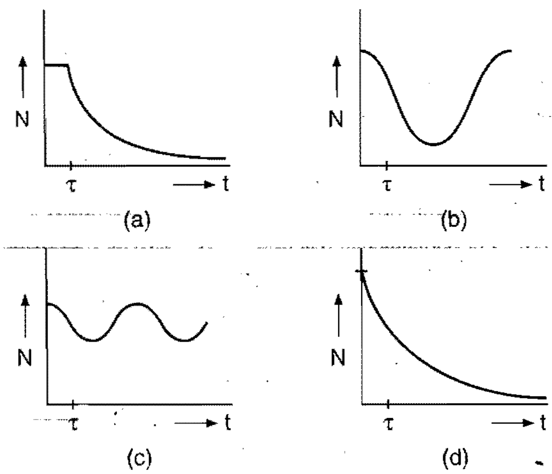
(b) 

(c) 

(d) 

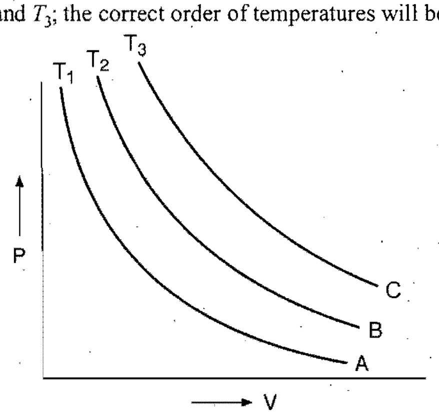
[**Hint:** $E = -\frac{Z^2}{n^2} \times 13.6 \text{ eV}, E \propto \frac{1}{Z^2}$; therefore, E will decrease exponentially with increase in Z^2.]

44. A radioactive sample consists of two distinct species having equal number of atoms initially. The mean life of one of the species τ and that of the other is 5τ. The decay products in both the cases are stable. A plot is made of total number of radioactive nuclei as the function of time. Which of the following figures best represents the form of this plot?



[**Hint:** The activity will decay spontaneously with passage of time.]

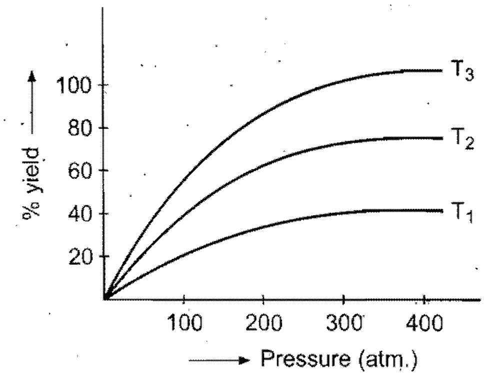
45. In following isothermal graphs A, B and C at temperatures T_1, T_2 and T_3; the correct order of temperatures will be:



(a) $T_1 > T_2 > T_3$ (b) $T_1 > T_3 > T_2$
(c) $T_3 > T_2 > T_1$ (d) $T_3 > T_1 > T_2$

46. $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$; $\Delta H° = -22.4 \text{ kJ mol}^{-1}$.
Percentage yield of the reaction against pressure is plotted at three different temperatures T_1, T_2 and T_3, then:

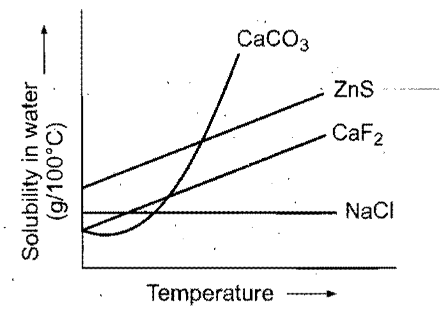
(a) $T_3 > T_2 > T_1$ (b) $T_1 > T_2 > T_3$
(c) $T_1 = T_2 = T_3$ (d) none of these



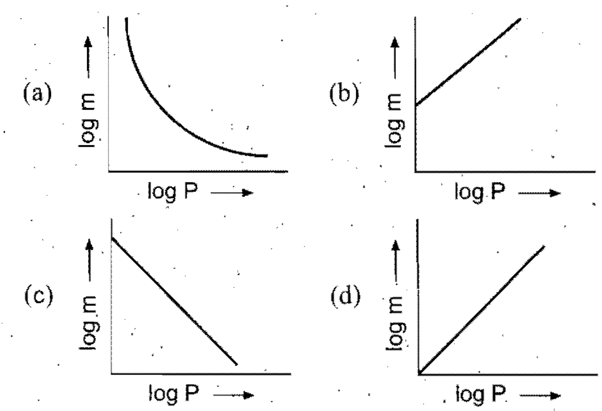
[**Hint:** Reaction is exothermic; hence, the reaction will shift in forward direction to give better yield.

$\therefore \xrightarrow[\text{Decreasing yield of reaction}]{T_1 > T_2 > T_3}$]

47. From the given graph, predict the compound which would be most easily purified by recrystallisation from aqueous solution:
(a) ZnS
(b) $CaCO_3$
(c) CaF_2
(d) NaCl



48. Which of the following curves represents the Henry's law?



Answers

1. (c)	**2.** (c)	**3.** (a)	**4.** (d)	**5.** (a)	**6.** (a)	**7.** (d)	**8.** (a)
9. (c)	**10.** (d)	**11.** (c)	**12.** (c)	**13.** (c)	**14.** (b)	**15.** (b)	**16.** (d)
17. (c)	**18.** (a)	**19.** (c)	**20.** (c)	**21.** (d)	**22.** (b)	**23.** (c)	**24.** (c)
25. (c)	**26.** (c)	**27.** (d)	**28.** (b)	**29.** (c)	**30.** (d)	**31.** (d)	**32.** (c)
33. (b)	**34.** (a, b, c, d)		**35.** (c)	**36.** (a)	**37.** (a)	**38.** (a)	**39.** (a)
40. (d)	**41.** (a)	**42.** (c)	**43.** (d)	**44.** (d)	**45.** (d)	**46.** (b)	**47.** (d)
48. (b)							

TEST OF MATCHING APTITUDE

TEST SERIES III

1. Match the List-I with List-II and pick up the correct matching from the codes given below:

List-I	List-II
A. $\left(\frac{\partial E}{\partial V}\right)_T = 0$	1. Isothermal process
B. $W = -\Delta E$	2. $-nFE°$
C. $\Delta E = 0$	3. Adiabatic reaction
D. $\Delta G°$	4. van der Waals' gas
E. $\left(\frac{\partial T}{\partial P}\right)_H \neq 0$	5. Ideal gas

Codes:

(a)	A–2	B–1	C–4	D–5	E–3
(b)	A–2	B–5	C–1	D–4	E–3
(c)	A–3	B–1	C–2	D–5	E–4
(d)	A–5	B–4	C–1	D–2	E–3
(e)	A–5	B–3	C–1	D–2	E–4

2. Match the Column-I with Column-II:

Column-I	Column-II
(I). $^{40}_{20}Ca$	1. Unstable, α-emitter
(II). $^{133}_{53}I$	2. Unstable, β-emitter
(III). $^{121}_{53}I$	3. Unstable, positron emitter
(IV). $^{232}_{90}Th$	4. Stable

Codes:

(a)	I–1	II–2	III–3	IV–4
(b)	I–4	II–3	III–2	IV–1
(c)	I–4	II–2	III–3	IV–1
(d)	I–4	II–3	III–1	IV–2

3. Match the List-I with List-II and select the correct answer using the options given below the lists:

List-I (Electrochemical parameter)	List-II (Units)
(I). Ionic mobility	1. cm^{-1}
(II). Cell constant	2. $ohm^{-1}\ cm^{-1}$
(III). Specific conductance	3. $ohm^{-1}\ cm^2\ mol^{-1}$
(IV). Molar conductance	4. $cm^2\ V^{-1}\ s^{-1}$

Codes:

(a)	I–4	II–1	III–2	IV–3
(b)	I–2	II–3	III–4	IV–1
(c)	I–3	II–1	III–2	IV–4
(d)	I–1	II–2	III–3	IV–4

4. Match the Column-I with Column-II and select the correct answer using the sequences given below:

Column-I (Compounds)	Column-II (Oxidation state of nitrogen)
A. NaN_3	1. +5
B. N_2H_4	2. +1
C. NH_2OH	3. −1/3
D. N_2O_5	4. −2

Codes:

	A	B	C	D
(a)	3	4	2	1
(b)	4	3	1	2
(c)	3	4	1	2
(d)	4	3	2	1

5. Match the Column-I with Column-II and pick up the correct alternate:

Column-I	Column-II
(I). For spontaneous reaction	A. $\Sigma(BE)_R - \Sigma(BE)_P$
(II). For endothermic reaction	B. $\Delta H = \Delta E$
(III). Bond dissociation energy	C. $\Delta G = -ve$
(IV). For solids and liquids in a thermochemical reaction	D. $\Sigma H_P > \Sigma H_R$

Codes:

(a)	I – C	II–A	III–D	IV–B
(b)	I – B	II–D	III–A	IV–C
(c)	I – C	II–D	III–B	IV–A
(d)	I – C	II–D	III–A	IV–B

6. Match the Column-I with Column-II and pick up the correct answer:

Column-I	Column-II
(I). Nickel	A. Conversion of alcohol to gasoline
(II). ZSM-5	B. Alkylation of benzene
(III). SiO_2	C. Hydrogenation of oil

Codes:

(a)	I – C	II–A	III–B
(b)	I – A	II–B	III–C
(c)	I – C	II–B	III–A
(d)	I – B	II–C	III–B

7. Match the List-I (enzymes) with List-II (metals) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Nitrogenase	1. Cu
B. Cytochrome oxidase	2. Mo
C. Cytochrome-C	3. Zn
D. Carboxypeptidase	4. Fe

Codes:

	A	B	C	D
(a)	1	2	4	3
(b)	2	1	3	4
(c)	2	1	4	3
(d)	1	2	3	4

8. Match the Column-I with Column-II and select the correct answer:

Column-I	Column-II
(I). Curie	A. 10^6 dis sec^{-1}
(II). Rutherford	B. 3.7×10^{10} dis sec^{-1}
(III). Becquerel	C. 1 dis sec^{-1}

Codes:

(a)	I–B	II–A	III–C
(b)	I–B	II–C	III–A
(c)	I–A	II–B	III–C
(d)	I–C	II–B	III–A

9. Match the List-I with List-II:

List-I	List-II
(I). $\Delta H = q_P$	1. $\Delta S^\circ = 0$
(II). Kirchhoff's equation	2. State function
(III). $H^+(aq.)$	3. Path function
(IV). Spontaneous process	4. $\Delta G > 0$
	5. $\Delta S^\circ_{\text{Total}} > 0$
	6. $\Delta H_2 - \Delta H_1 = \Delta C_p(T_2 - T_1)$

Codes:

	(I)	(II)	(III)	(IV)
(a)	1	2	4	5
(b)	5	4	3	6
(c)	2	6	1	5
(d)	6	2	5	1

10. Match the List-I with List-II:

List-I	List-II
(I). Mixing of two ideal gases	1. $\Delta G_{\text{mix}} = 0$
(II). Criterion for irreversibility	2. $1/P$
(III). Isobaric thermal coefficient of an ideal gas	3. $1/T$
(IV). Joule-Thomson effect	4. $\Delta S_{\text{Total}} > 0$
	5. $\Delta G_{\text{mix}} < 0$
	6. $\Delta H = 0$

Codes:

	(I)	(II)	(III)	(IV)
(a)	1	2	4	5
(b)	5	4	3	6
(c)	2	6	1	5
(d)	6	2	5	1

11. Match the List-I with List-II:

List-I	List-II
(I). Translational kinetic energy	1. $\frac{3}{2}P$
(II). Rotational kinetic energy of CO_2	2. 15/13
(III). Translational kinetic energy per unit volume	3. 7/5
(IV). γ for CO_2 at very high temperature	4. Function of T only
	5. RT
	6. $\frac{3}{2}RT$

Codes:

	(I)	(II)	(III)	(IV)
(a)	3	4	5	1
(b)	4	5	1	2
(c)	5	6	2	3
(d)	6	1	3	4

12. Match the Column-X with Column-Y:

Column-X (Colloids)	Column-Y (Classification)
(I). Rain cloud	A. Sol
(II). Milk of magnesia	B. Aerosol
(III). Soap suds	C. Gel
(IV). Butter	D. Foam

Codes:

	(I)	(II)	(III)	(IV)
(a)	A	B	C	D
(b)	A	C	B	D
(c)	B	A	D	C
(d)	B	A	C	D

13. Match the List-I with List-II and select the correct answer from given codes:

List-I (Spectrum)	List-II (Region)
A. Lyman	1. Ultraviolet
B. Paschen	2. Visible
C. Balmer	3. Near infrared
D. Pfund	4. Far infrared

Codes:

	A	B	C	D
(a)	1	3	2	4
(b)	1	2	3	4
(c)	4	3	2	1
(d)	1	2	4	3

14. Match the List-I with List-II and select the correct answer:

List-I	List-II
A. Critical temperature	1. a/Rb
B. Boyle temperature	2. $2a/Rb$
C. Inversion temperature	3. T/T_c
D. Reduced temperature	4. $8a/27Rb$

Codes:

	A	B	C	D
(a)	4	1	2	3
(b)	2	1	4	3
(c)	4	3	2	1
(d)	2	3	1	4

15. Match the List-I, List-II and List-III and select the answer from the given codes:

List-I (Order)	List-II (Unit of rate constant)	List-III (Relation between half life and initial concentration)
A. Zero	(i) $L^2\ mol^{-2}\ s^{-1}$	1. $t_{1/2}$ = Constant
B. First	(ii) $L\ mol^{-1}\ s^{-1}$	2. $t_{1/2} \propto \frac{1}{a}$
C. Second	(iii) s^{-1}	3. $t_{1/2} \propto a$
D. Third	(iv) $mol\ L^{-1}\ s^{-1}$	4. $t_{1/2} \propto \frac{1}{a^2}$

Codes:

	A	B	C	D
(a)	i–2	ii–4	iii–3	iv–1
(b)	i–4	iv–3	ii–2	iii–1
(c)	iv–3	iii–1	ii–2	i–4
(d)	ii–2	i–1	iii–3	iv–4

16. Match the List-I (solutions of salts) with List-II (pH of the solutions) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Weak acid and strong base	1. $\frac{1}{2} pK_w$
B. Strong acid and weak base	2. $\frac{1}{2}[pK_w - pK_b + pK_a]$
C. Weak acid and weak base	3. $\frac{1}{2}[pK_w - pK_b - \log c]$
D. Strong acid and strong base	4. $\frac{1}{2}[pK_w + pK_a + \log c]$

Codes:

	A	B	C	D
(a)	4	3	2	1
(b)	1	2	3	4
(c)	2	3	4	1
(d)	3	2	1	4

17. Match the List-I with List-II and choose the correct answer from the codes:

List-I (Electrolyte)	List-II (Solubility product)
A. Bi_2S_3	1. $4s^3$
B. $Al(OH)_3$	2. $27s^4$
C. CdS	3. $108s^5$
D. CaF_2	4. s^2

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	2	3	1	4
(c)	4	3	2	1
(d)	3	2	4	1

18. Match the following combinations of electrical units with their terms as single unit:

Electrical unit	Single unit
(I). ampere-second	A. coulomb
(II). volt-ampere	B. ohm
(III). volt-ampere^{-1}	C. ampere
(IV). watt/ampere ohm	D. watt
(V). joule /ampere second	E. volt

Codes:

	A	B	C	D	E
(a)	I	III	IV	II	V
(b)	I	II	III	IV	V
(c)	V	IV	III	II	I
(d)	I	V	IV	II	III

19. Match the List-I with List-II and select the correct answer from the given codes:

List-I (Thermodynamic properties)	List-II (Relation)
A. Free energy change of a reaction (ΔG)	1. $-RT \log K$
B. Standard enthalpy change (ΔH°) of a reaction	2. $RT^2\left(\frac{d \ln K}{dT}\right)_P$
C. Standard entropy change (ΔS°)	3. $-nFE$
D. Standard free energy change (ΔG°)	4. $-\left(\frac{d\,\Delta G}{dT}\right)_P$

Codes:

	A	B	C	D
(a)	3	2	4	1
(b)	1	2	3	4
(c)	4	3	2	1
(d)	2	3	1	4

20. Match the List-I, List-II and List-III:

List-I	List-II	List-III
A. $\Delta G > 0$	X. $\Delta S > 0$	1. Non-spontaneous
B. $\Delta G < 0$	Y. $\Delta S < 0$	2. Spontaneous
C. $\Delta G = 0$	Z. $\Delta S = 0$	3. Equilibrium

Select the correct answer from the following codes:

	A	B	C
(a)	(Y, 1)	(X, 2)	(Z, 3)
(b)	(X, 2)	(Y, 3)	(Z, 1)
(c)	(X, 3)	(Y, 1)	(Z, 2)
(d)	(Y, 1)	(X, 3)	(Z, 2)

21. Match the Column-I with Column-II:

Column-I	Column-II
(a) Spontaneous process	(p) $\Delta H = -$ ve
(b) Heat flow from high temperature of system towards low temperature of surroundings	(q) $\Delta G = +$ ve
(c) Exergonic process	(r) $\Delta S_{Total} = +$ ve
(d) Increase in the randomness of system by heating	(s) $\Delta G = -$ ve

(a)	p	q	r	s
(b)	p	q	r	s
(c)	p	q	r	s
(d)	p	q	r	s

22. Match the items of Column-I with the items of Column-II:

Column-I (Metal)	Column-II (Packing/coordination number)
(a) Na	(p) ccp
(b) Cu	(q) bcc
(c) Au	(r) 12
(d) K	(s) 8

23. Match the Column-I with Column-II and Column-III:
l = Edge length of unit cell;
r = Radius of spherical constituent unit

Column-I	Column-II	Column-III
(a) Simple cubic unit cell	(p) $l\sqrt{3} = 4r$	(u) 74% occupied space
(b) Face-centred cubic unit cell	(q) $l = 2r$	(v) 67.98% occupied space
(c) Body-centred cubic unit cell	(r) $l\sqrt{2} = 4r$	(w) 52.33% occupied space

24. Match the List-I with List-II:

List-I	List-II
(a) Silicon doped with phosphorus	(p) Acceptor level above valence bond
(b) Metal excess non-stoichiometry in NaCl	(q) n-type semiconductor
(c) Ge doped with Ga	(r) Donor level just below the conduction band
(d) Anion vacancy with trapped electron	(s) F-centre

25. Match the solids in List-I with their properties in List-II:

List-I	List-II
(a) MnO	(p) Ferromagnetic solid
(b) ZnO	(q) Antiferromagnetic solid
(c) CrO_2	(r) Zero magnetic moment
(d) TiO	(s) Attracted in magnetic field

26. Match the List-I with List-II:

List-I	List-II
(a) The highest temperature at which liquid CO_2 exists	(p) $\frac{V_{real}}{V_{ideal}}$
(b) $8a/27Rb$	(q) Critical temperature
(c) Compressibility factor $Z = 3/8$ at	(r) Ideal gas
(d) Compressibility factor $Z = 1$ for	(s) 30.98° C

27. Match the physical properties of Column-I with their values in Column-II:

Column-I	Column-II
(a) SATP	(p) 1 bar/1 atm
(b) Temperature in STP	(q) 99.6° C
(c) Pressure in NTP	(r) 273.15 K
(d) Standard boiling point of water	(s) 298.15 K

SATP $\longrightarrow$ Standard ambient temperature and pressure
STP $\longrightarrow$ Standard temperature and pressure
NTP $\longrightarrow$ Normal temperature and pressure

28. Match the quantities in Column-I with their units in Column-II:

Column-I	Column-II
(a) Coefficient of viscosity	(p) $L\ mol^{-1}$
(b) van der Waals' constant 'b'	(q) $N\ s\ m^{-2}$
(c) Molar volume of gas at STP = 22.4 ...	(r) Pas
(d) van der Waals' constant 'a'	(s) $L^2\ atm\ mol^{-2}$

29. Match the temperature in List-I with its value in List-II:

List-I	List-II
(a) Critical temperature	(p) a/Rb
(b) Boyle's temperature	(q) θ
(c) 1/2 [Inversion temperature]	(r) T/T_c
(d) Reduced temperature	(s) $8a/27Rb$

30. Match the items of Column-I with its proportional term in the items of Column-II:

Column-I	Column-II
(a) Kinetic energy	(p) Mole fraction
(b) Partial pressure of a gas	(q) Density
(c) Rate of diffusion	(r) Molar mass
(d) Vapour pressure of a liquid	(s) Absolute temperature

31. Match the List-I with List-II and List-III:

List-I (Solids)	List-II (Unit cell)	List-III (Coordination number)
(a) Rock salt	(p) Face-centred cubic, anion in tetrahedral void	(w) 6
(b) Fluorite	(q) Face-centred cubic, cation in octahedral void	(x) Cation (8), anion (4)
(c) AgI, ZnS	(r) Face-centred cubic, cation in alternate tetrahedral void	(y) Cation (4), anion (8)
(d) Na_2O	(s) Face-centred cubic, cation in tetrahedral void	(z) Cation (4), anion (4)

Answers

1. (e) **2.** (c) **3.** (a) **4.** (a) **5.** (d) **6.** (a) **7.** (b) **8.** (a)
9. (c) **10.** (b) **11.** (d) **12.** (c) **13.** (a) **14.** (a) **15.** (c) **16.** (a)
17. (d) **18.** (a) **19.** (a) **20.** (a) **21.** (a-r,s) (b-p,r,s) (c-q) (d-q,r)
22. (a-q,s) (b-p,r) (c-p,r) (d-q,s) **23.** (a-q-w) (b-r-u) (c-p-v)
24. (a-q,r) (b-s) (c-p) (d-s) **25.** (a-q,r) (b-r) (c-p,s) (d-s) **26.** (a-q,s) (b-q) (c-p,q) (d-r) **27.** (a-p,s) (b-r) (c-p) (d-q)
28. (a-q,r) (b-p) (c-p) (d-s) **29.** (a-s) (b-p) (c-p) (d-q,r) **30.** (a-s) (b-p,s) (c-q,r) (d-p,s)
31. (a-q-w) (b-p-x) (c-r-z) (d-s-y)

TEST OF REASONING APTITUDE

TEST SERIES IV

REASON AND ASSERTION

(For IIT & AIIMS Aspirants)

In each of the following questions, a statement of **Assertion (A)** is given followed by corresponding statement of **Reason (R)** just below it. Mark the correct answer as:

(a) Both (R) and (A) are true and reason is the correct explanation of assertion.
(b) Both (R) and (A) are true but reason is not correct explanation of assertion.
(c) Assertion (A) is true but reason (R) is false.
(d) Assertion (A) and reason (R) both are false.
(e) Assertion (A) is false but reason (R) is true.

1. (A) CH_4 and CO_2 have the value of Z (compressibility factor) less than one.
(R) $Z < 1$ is due to repulsive forces among the molecules.

2. (A) More is the value of van der Waals' constant 'a', greater is the tendency of liquefaction.
(R) 'a' measures the magnitude of force of attraction among the molecules.

3. (A) Crystalline solids are anisotropic.
(R) Crystalline solids are not as closely packed as amorphous solids.

4. (A) Antiferromagnetic substances possess zero magnetic moment.
(R) MnO is an antiferromagnetic substance.

5. (A) Isotonic solutions do not show osmosis.
(R) Isotonic solutions have equal osmotic pressure.

6. (A) In a gaseous reaction, K_c is unitless when $\Delta n = 0$.
(R) Unit of $K_c = (\text{mol L}^{-1})^{\Delta n}$.

7. (A) Strength of acidic character of oxyacids lies in the following sequence:
$$HClO_4 > HBrO_4 > HIO_4$$
(R) Greater is the oxidation state of a halogen, more is the acidic character of its oxyacid.

8. (A) The molecularity of the following reaction is 2
$$H_2 + Br_2 \longrightarrow 2HBr$$
(R) The order of reaction is 3/2.

9. (A) Half-life of a first order reaction is independent of the initial concentration of reactant.
(R) $t_{1/2}$ (first order) $= \dfrac{\tau}{1.44}$
where, τ = average life.

10. (A) For the reaction,
$$2NH_3(g) \longrightarrow N_2(g) + 3H_2(g)$$
$\Delta H > \Delta U$.
(R) The enthalpy change is always greater than internal energy change.

11. (A) $^{20}N_e$ and $^{22}N_e$ are isotones.
(R) Noble gases do not exist as isotopes as they are not reactive.

12. (A) $3d_{z^2}$ orbital is spherically symmetrical.
(R) $3d_{z^2}$ orbital is the only d-orbital which is spherical in shape.

13. (A) The kinetic energy of the photoelectron ejected increases with increase in intensity of incident radiation.
(R) Increase in intensity of incident light increases the rate of emission.

14. (A) $^{133}_{56}Be + e^- \longrightarrow {}^{133}_{55}Cs + X$-ray
It is a process of K-electron capture.
(R) The atomic number decreases by one unit as a result of K-capture.

15. (A) Vapour pressure is a colligative property.
(R) Colligative property depends on the number of solute particles dissolved in the solution.

16. (A) Entropy decreases when an egg is boiled.
(R) It is solidified due to denaturation of albumin.

17. (A) 1 faraday = 96,500 coulomb.
It is a charge of 1 mole electrons.
(R) 1 faraday charge liberates one gram equivalent of substance at an electrode.

18. (A) The electrical resistance of a column of 0.05 M NaOH solution of diameter 1 cm and length 50 cm is 5.55×10^3 ohm.
(R) Its resistivity is equal to 76.234 ohm-cm.

19. (A) If water is heated to 350 K, then pOH will increase to 8.
(R) K_w increases with increase in temperature.

20. (A) Magnetic quantum number can have the value $0, \ldots, (n-1)$.
(R) Magnetic quantum number specifies the number of orbitals.

Answers

1. (a)	**2.** (a)	**3.** (c)	**4.** (b)	**5.** (a)	**6.** (a)	**7.** (b)	**8.** (b)
9. (a)	**10.** (c)	**11.** (d)	**12.** (d)	**13.** (e)	**14.** (b)	**15.** (e)	**16.** (a)
17. (b)	**18.** (c)	**19.** (e)	**20.** (e)				