(ix) *For the redox reaction :*

$$Cr_2O_7^{2-} + H^+ + Ni \longrightarrow Cr^{3+} + Ni^{2+} + H_2O$$

the correct coefficients of the reactants for the balanced reaction are :

	$Cr_2O_7^{2-}$	Ni	H^+
(A)	1	3	14
(B)	2	3	14
(C)	1	1	16
(D)	3	3	12

ANALYSIS BASED ON MOLE CONCEPT — Section - 2

Let us now solve some numerical problems based on the analysis of redox reactions. In such type of applications based problems, first we have to create a chemical equation and then balance it. And then proceed as per the given problem, using Mole concept.

Illustration - 12 *Find the amount of Iron pyrites (FeS_2) which is sufficient to produce enough SO_2 on roasting (heating in excess of O_2) such that it (SO_2) completely decolourises a 1L solution of $KMnO_4$ containing 15.8 g/L of it.*

The equations are : $FeS_2 + O_2 \longrightarrow Fe_2O_3 + SO_2$ *and* $KMnO_4 + SO_2 \longrightarrow MnSO_4 + H_2SO_4 + K_2SO_4$

SOLUTION :

First calculate the amount of SO_2 required to decolourise 15.8 g/L of $KMnO_4$ solution. For this you need to balance the following chemical reaction.

$$KMnO_4 + SO_2 \longrightarrow MnSO_4 + H_2SO_4 + K_2SO_4$$

Proceeding in the manner as given in above illustrations, we have the balanced equation as :

$$2\,KMnO_4 + 5\,SO_2 + 2H_2O \longrightarrow 2\,MnSO_4 + 2H_2SO_4 + K_2SO_4$$

Now, using our understanding to solve a typical stoichiometric problems, we can solve this problem as follows :

From stoichiometry of balanced equation, we have:

$$2 \text{ moles of } KMnO_4 \equiv 5 \text{ moles of } SO_2$$

Calculate moles in 15.8 g/L of $KMnO_4$:

Using : Strength (g/L) = M M_0

$$\text{Molarity} = \frac{15.8}{158} = 0.1\text{ M}$$

$\Rightarrow$ 1.0 L of $KMnO_4$ contains 0.1 moles

Hence moles of SO_2 required $= \frac{5}{2}(0.1) = 0.25$

To calculate the amount of pyrites, we have to balance the reaction :

$$FeS_2 + O_2 \longrightarrow Fe_2O_3 + SO_2$$

Balancing the reaction (using Hit and Trial Method) we have

$$4\,FeS_2 + 11\,O_2 \longrightarrow 2\,Fe_2O_3 + 8\,SO_2$$

From stoichiometry of roasting, we have :

$$8 \text{ moles of } SO_2 \equiv 4 \text{ moles of } FeS_2$$

$$0.25 \text{ moles of } SO_2 \equiv \frac{4}{8}(0.25) \text{ moles of } FeS_2$$

$$= 0.125 \text{ moles of } FeS_2$$

$\Rightarrow$ Mass of $FeS_2 = 0.125 \times 120 = 15$ gm

Illustration - 13 *20 mL of a solution containing 0.2 gm of impure sample of H_2O_2 reacts with 0.316 gm of $KMnO_4$ in presence of H_2SO_4 as per following reaction.*

$$KMnO_4 + H_2O_2 + H_2SO_4 \longrightarrow MnSO_4 + O_2 + H_2O$$

(*a*) *Find the purity of H_2O_2 solution* (*b*) *Calculate the volume of dry oxygen evolved at 27°C and at 760 mm Hg.*

SOLUTION :

First write a complete balanced the reaction :

$$2\,KMnO_4 + 5\,H_2O_2 + 3H_2SO_4 \longrightarrow 2\,MnSO_4 + K_2SO_4 + 5\,O_2 + 8\,H_2O$$

From the balanced reaction, we have :

5 moles of $H_2O_2 \equiv 2$ moles of $KMnO_4$

Moles of $KMnO_4 = \dfrac{0.316}{158}$

$\Rightarrow$ Moles of H_2O_2 required $= \dfrac{5}{2} \times \dfrac{0.316}{158}$

$\Rightarrow$ Grams of $H_2O_2 = \dfrac{5}{2} \times \dfrac{0.316}{158} \times 34 = 0.17$ gm

$\Rightarrow$ % age purity of $H_2O_2 = \dfrac{0.17}{0.2} \times 100 = 85\ \%$

Now : 2 moles of $KMnO_4 \equiv 5$ moles of O_2

Moles of O_2 produced $= \dfrac{5}{2} \times \dfrac{0.316}{158} = 5 \times 10^{-3}$

Using PV = nRT we have :

$$V = \frac{nRT}{P} = \frac{5 \times 10^{-3} \times 0.0821 \times 300}{760/760}$$

$\Rightarrow$ $V = 0.123\ L = 123\ mL$

Illustration - 14 *Calculate the amount of SeO_3^{2-} in a solution on the basis of given analysis. 20 mL of M/60 $KBrO_3$ was added to a sample of SeO_3^{2-}. The bromine evolved was removed and the excess of $KBrO_3$ was titrated with 5.1 mL of M/25 solution of $NaAsO_2$. The reactions involved are :* $[A_{Se} = 79\ gm/mol]$

$$SeO_3^{2-} + BrO_3^- + H^+ \longrightarrow SeO_4^{2-} + Br_2 + H_2O \quad \text{and} \quad BrO_3^- + AsO_2^- + H_2O \longrightarrow Br^- + AsO_4^{3-} + H^+$$

SOLUTION :

In this problem, find the exact amount of $KBrO_3$ used for SeO_3^{2-} (in the first equation) by calculating the excess of $KBrO_3$ with the help of second equation.

Balancing the two equations

(i) $$5\,SeO_3^{2-} + 2BrO_3^- + 2H^+ \longrightarrow 5\,SeO_4^{2-} + Br_2 + H_2O$$

(ii) $$BrO_3^- + 3AsO_2^- + 3H_2O \longrightarrow Br^- + 3AsO_4^{3-} + 6H^+$$

From the equation (ii) :

3 m.moles of $AsO_2^- \equiv 1$ m.moles of excess of $KBrO_3$

$\Rightarrow$ $\dfrac{1}{25} \times 5.1$ m.moles of AsO_2^-

$\equiv \dfrac{1}{3} \times \dfrac{5.1}{25}$ (= 0.068) m.moles of excess of $KBrO_3$

m.moles of $KBrO_3$ used in equation (i)

$$= \left(\frac{1}{60} \times 20\right) - 0.068 = 0.265 \text{ m.moles}$$

From equation (i) :

2 m.moles of $KBrO_3 \equiv 5$ m.moles of SeO_3^{2-}

0.265 m.moles of $KBrO_3 \equiv 5/2\,(0.265)$ m.moles

$\equiv 5/2\,(0.265) \times 127$ mg

Mass of $SeO_3^{2-} = 84.13$ mg $= 0.08413$ g

Illustration - 15 *1.0 gms of $AgNO_3$ is dissolved in 50 mL of water. It is titrated with 50 mL of KI solution. The AgI precipitated is filtered off. The excess of KI in the filtrate is titrated with M/10 KIO_3 in presence of 6 M HCl till all I^- is converted to ICl. It requires 50 ml of M/10 KIO_3 solution. 20 mL of same KI solution requires 30 mL of M/10 KIO_3 under same conditions. Determine the percentage of $AgNO_3$ in the sample.*

The reaction involved is : $KIO_3 + KI + HCl \longrightarrow ICl + KCl + H_2O$

SOLUTION :

The problem considers three experiments :

(i) 1.0 gm $AgNO_3$ (50 mL) + 50 mL of KI (M = ?)

$$AgNO_3 + KI \longrightarrow AgI + KNO_3$$

(ii) Excess of KI + 50 mL of M/10 KIO_3 in 6M HCl

$$KI + KIO_3 + HCl \longrightarrow ICl + KCl + H_2O.$$

(iii) To determine the molarity of KI (say M)

20 mL KI (original) + 30 mL of M/10 KIO_3

First of all you must balance the equation involved in experiments 2 and 3. (Note that the reaction is same in both cases)

$$I^- \longrightarrow I^+ + 2e^-$$

$$IO_3^- + 6H^+ + 4e^- \longrightarrow I^+ + 3H_2O$$

$\Rightarrow$ The overall balanced equation is :

$$\mathbf{2I^- + IO_3^-} + 6H^+ \longrightarrow 3I^+ + 3H_2O$$

$\Rightarrow$ 2 m.moles of KI $\equiv$ 1 m.moles of KIO_3

Using the above stoichiometry, first find the excess of KI and then molarity of KI

- m.moles of KIO_3 used = $1/10 \times 50 = 5$

  1 m mole of $KIO_3 \equiv$ 2 m. moles of KI

$\Rightarrow$ 5 m.moles of $KIO_3 \equiv$ 10 m.moles of KI (excess)

- m.moles of KIO_3 used for titrating 20 mL KI $= 1/10 \times 30 = 3$

$\Rightarrow$ m.moles of KI = 6 = M $\times$ 20 $\Rightarrow$ M = 6/20

This gives us initial m.moles of KI in 50 mL volume taken initially.

- Initial m.moles of KI = (6/20) $\times$ 50 = 15

$\Rightarrow$ m.moles of KI used for $AgNO_3$ = 15 − 10 = 5

Now, 1 m.mole of KI $\equiv$ 1 m.mole of $AgNO_3$

$\Rightarrow$ m.moles of $AgNO_3$ = 5

$\Rightarrow$ $\frac{g}{170} \times 1000 = 5 \Rightarrow g = 0.85$ gram

or % $AgNO_3$ = 85% (mass of sample = 1 gm)

IMP. Note that n-factor of $KBrO_3$ in illustration-14 and that of KI in illustration-15 is different in two redox reactions. It is advised to use concept of moles in such cases as done above

IN-CHAPTER EXERCISE - B

1. $C_2O_4^{2-}$ can be oxidised to CO_2 by MnO_4^- in acidic as well as in basic medium. What is ratio of moles of MnO_4^- used per mol of $C_2O_4^{2-}$ in acidic medium (Mn^{2+}) to strong basic medium (MnO_4^{2-}) ?

2. Calculate number of moles of MnO_4^- required to oxidise 1 mol of $Fe(HC_2O_4)_2$ in acidic medium. How many moles of $Ca(OH)_2$ are required to react with 1 mol of $Fe(HC_2O_4)_2$?

3. If 10 g V_2O_5 is dissolved in acid and reduced to V^{2+} by treatment with zinc metal, how many moles of I_2 could be reduced by the resulting V^{2+} solution, as it is oxidised to V^{4+} ? ($V = 51$)

$$V_2O_5 + 10H^+ + 6e^- \longrightarrow 2V^{2+} + 5H_2O$$

4. If 94 gm of potassium dichromate react with 3.584 gm of HI, find : $Cr_2O_7^{2-} + HI \longrightarrow CrI_3 + KI + I_2$

(i) % age (by mass) of $K_2Cr_2O_7$ left un-reacted (if any),

(ii) volume of I_2 (g) evolved , if I_2(s) obtained is heated to 546 K and 1.0 atm pressure

5. What volume of 0.02 M $KMnO_4$ solution is required to oxidise 40.0 mL of 0.1 M $FeSO_4$ in presence of H_2SO_4. Also give the complete balanced chemical reaction.

$$KMnO_4 + FeSO_4 + H_2SO_4 \longrightarrow MnSO_4 + K_2SO_4 + Fe_2(SO_4)_3 + H_2O$$

6. MnO_4^- can oxidise NO_2^- to NO_3^- in dilute basic medium. How many moles of NO_2^- are oxidised by 1 mol of MnO_4^- ?

7. Exactly 40.0 ml of potassium permanganate solution react with 0.8 g of $Na_2C_2O_4.2H_2O$ in the acidic medium according to the reaction : $16H^+ (aq) + 2MnO_4^- (aq) + 5C_2O_4^{2-} (aq) \longrightarrow 2Mn^{2+} (aq) + 10\,CO_2 (g) + 8H_2O$

(i) Calculate the normality of permanganate solution. **(ii)** Calculate the strength of the solution ?

8. Alcohol levels in the blood can be determined by a redox titration with dichromate solutions in acidic medium according to the balanced equation.

$$C_2H_5OH(aq) + 2Cr_2O_7^{2-}(aq) + 16H^+(aq) \longrightarrow 2CO_2(g) + 4Cr^{3+}(aq) + 11H_2O(l)$$

What is the blood alcohol level in mass per cent if 8.76 mL of 0.05 M solution is required for titration of a 10.00 g sample of blood ?

9. **Choose the correct option for each of the following questions. Only one option is correct.**

(i) $NaIO_3$ reacts with $NaHSO_3$ according to equation : $IO_3^- + 3HSO_3^- \longrightarrow I^- + 3H^+ + 3SO_4^{2-}$

The weight of $NaHSO_3$ required to react with 100 ml of solution containing 0.66 gm of $NaIO_3$ is :

(A) 5.2 **(B)** 4.57 gm **(C)** 2.3 gm **(D)** 1.04 gm

(ii) $4I^- + Hg^{2+} \longrightarrow HgI_4^{2-}$, 1 mol each of Hg^{2+} and I^- will form ____ HgI_4^{2-} :

(A) 1 mol **(B)** 0.5 mol **(C)** 0.25 mol **(D)** 2 mol