G.C.E (A.L.) Support Seminar – 2016
Chemistry - Paper I
Answer Guide

Question No.	Answer	Question No.	Answer
(1)	3	(26)	3
(2)	1	(27)	2
(3)	3	(28)	4
(4)	5	(29)	5
(5)	2	(30)	1
(6)	1	(31)	4
(7)	4	(32)	4
(8)	2	(33)	2
(9)	5	(34)	1
(10)	1	(35)	2
(11)	3	(36)	3
(12)	2	(37)	2
(13)	3	(38)	5
(14)	4	(39)	5
(15)	3	(40)	2
(16)	5	(41)	2
(17)	2	(42)	4
(18)	4	(43)	4
(19)	2	(44)	4
(20)	5	(45)	3
(21)	4	(46)	1
(22)	4	(47)	5
(23)	2	(48)	2
(24)	2	(49)	1
(25)	4	(50)	3

(50 marks with one mark for each question)

G.C.E (A.L.) Support Seminar – 2016
Chemistry - Paper II
Answer Guide

Part A

1. **(a)** (i) V

(ii) Tetrahedral

(iii) Fe^{2+} / $C_2O_4^{2-}$ / I^-
or
ferrous/ iron(II) /oxalate/ iodide

(iv) + 6 / VI

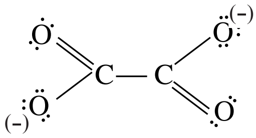
(v) Ba^{2+} / Sr^{2+} or barium/ strontium

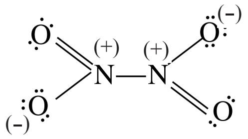
(vi) Cl_2O_7

(vii) greater/ higher

(viii) acidic (3 × 8 = 24)

(b) (i)





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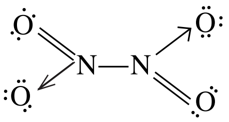


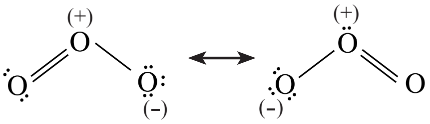
(5 × 2 = 10)

(ii) In N_2O_4 molecule each N atom carries a positive charge, so there is repulsion between them. There is no such repulsion between the C atoms in the oxalate ion. (3 × 3 = 09)

(c) (i) J - O / oxygen
K - S / sulphur / sulfur (3 × 2 = 06)

(ii) angular / ''V'' shaped (03)

(iii)



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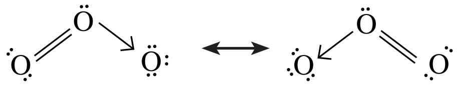
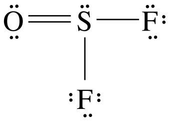


(6 × 2 = 12)

(iv) I.

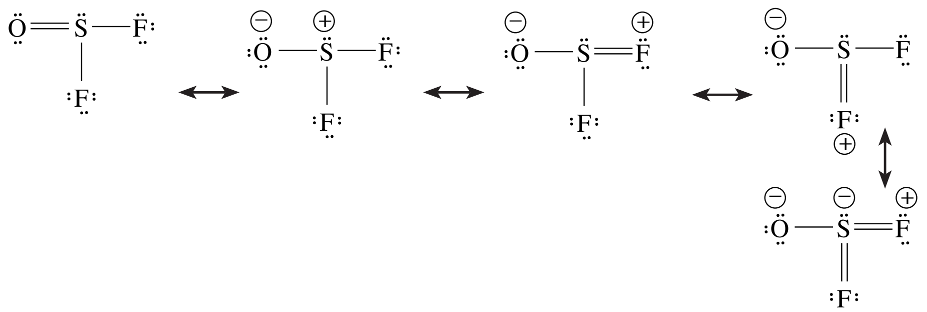


(06)

II. tetrahedral (03)

III. triangular pyramidal / trigonal pyramid (03)

IV.



(for any four 3 × 4 = 12)

(d) (i) $BaF_2 < BaCl_2 < CaCl_2 < MgBr_2$ (06)

(ii) $Al(OH)_3 < Ca(OH)_2 < Ba(OH)_2 < NaOH$ (06)

(total marks 100**)**

2. (a) (i) H_2O_2 (04)

(ii) $2\,H_2O_2 \xrightarrow{\Delta} 2\,H_2O + O_2$ (06)

(iii) $H_2O_2 + 2\,H^+ + 2\,e^- \longrightarrow 2\,H_2O$ (06)

$H_2O_2 + 2\,e^- \longrightarrow 2\,OH^-$ (06)

(iv) I. $H_2O_2 + Ag_2O \longrightarrow O_2 + 2\,Ag + H_2O$ or

$H_2O_2 + 2\,Ag^+ \longrightarrow O_2 + 2\,Ag + 2H^+$ (06)

II. $2\,Cr^{3+} + 10\,OH^- + 3\,H_2O_2 \longrightarrow 2\,CrO_4^{2-} + 8H_2O$ (06)

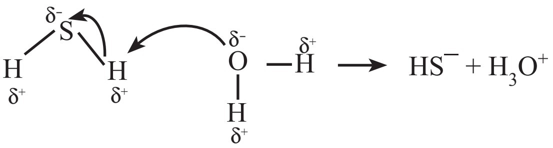
(b) (i) I. The reactivity of alkali metals depends on the ability of forming positive ions by removing electrons whereas the reactivity of halogens depends on the ability of forming negative ions by gaining electrons. Descending a group the atomic radius increases. Therefore, in alkali metals, the tendency to form cations increases down the group. But in the halogens, the ability to form anions decreases down the group. (06)

II. In C the electron configuration of the valence shell is of the type ns^2np^2 whereas in ‘‘N’’ it is of the type ns^2np^3. Thus carbon has an ability to gain another electron. But in ‘‘N’’ the outer p orbitals are half-filled and stable. So, it has a little tendency to accept another electron for which enegry has to be supplied. (06)

III. In aqueous solution LiH is basic because it forms OH^- ions as follows.

$Li-H + H-O-H \longrightarrow Li^+ + OH^- + H_2$

In aqueous solution H_2S is acidic because it forms H_3O^+ ions as follows.



(06)

IV. "Na" and V are metals. The atomic/metallic radius of V is smaller than that of "Na". When forming the metallic bond, in "Na" only the "s" electrons are delocalised whereas in V both "s" electrons and "d" electrons get delocalised. Therefore, the strength of the metallic bond in V is much greater than that in "Na". Thus the melting point is relatively higher in V. (06)

(ii) I. (A) yellow (B) green (C) black

II. (D) violet (E) colourless (F) green (12)

III. A - As_2S_3

B - Ni^{2+} or $[Ni(H_2O)_6]^{2+}$

C - NiS

D - I_2

F - Fe^{2+} or $[Fe(H_2O)_6]^{2+}$ (10)

(c) $P_4O_{10} + 6\,H_2O \longrightarrow 4\,H_3PO_4$

$SiCl_4 + 3H_2O \longrightarrow H_2SiO_3 + 4\,HCl$

$SbCl_3 + H_2O \rightleftharpoons SbOCl + 2\,HCl$

$AlN + 3H_2O \longrightarrow Al(OH)_3 + NH_3$ (5 × 4 = 20)

(Total marks 100)

3. (a) (i) $\Delta G^{\emptyset} = \sum G^{\emptyset}\text{(products)} - \sum G^{\emptyset}\text{(reactants)}$

$= (-137-229)\text{ kJ mol}^{-1} - (-394-0)\text{ kJ mol}^{-1}$

$= 28\text{ kJ mol}^{-1}$ (4 × 3 = 12)

(ii) $\Delta S^{\emptyset} = \sum S^{\emptyset}\text{(products)} - \sum S^{\emptyset}\text{(reactants)}$

$= (197.5 + 188.7)\text{ J mol}^{-1}\text{K}^{-1} - (213.7 + 130.6)\text{ J mol}^{-1}\text{K}^{-1}$

$= 41.9\text{ J K}^{-1}\text{ mol}^{-1}$ (4 × 3 = 12)

(iii) $\Delta G^{\emptyset} = \Delta H^{\emptyset} - T\Delta S^{\emptyset}$

$\Delta H^{\emptyset} = 28\text{ kJ mol}^{-1} + T\Delta S^{\emptyset}$

$\Delta H^{\emptyset} = 28\text{ kJ mol}^{-1} + 298\text{ K} \times \dfrac{41.9}{10^3}\text{ kJ K}^{-1}\text{ mol}^{-1}$

$= 40.48\text{ kJ mol}^{-1}$

$= 40.5\text{ kJ mol}^{-1}$ (4 × 3 = 12)

(iv) Since $\Delta G^{\emptyset} > 0$, the reaction doesn't take place in the given directions spontaneously. For it to be spontaneous it is required that $\Delta G^{\emptyset} < 0$.

$\Delta H^{\emptyset} - T\Delta S^{\emptyset} < 0$

$$T > \frac{\Delta H^{\emptyset}}{\Delta S^{\emptyset}} = \frac{40.5\text{ kJ mol}^{-1}}{41.9 \times 10^{-3}\text{ kJ mol}^{-1}\text{K}^{-1}}$$

$= 967\text{ K}$

$= 693\ °\text{C}$ (4 × 3 = 12)

(v) $G_1^{\emptyset} = -394\text{ kJ mol}^{-1}$

$G_2^{\emptyset} = -137 - 229$

$= -366\text{ kJ mol}^{-1}$ (04)

(vi) When the system is in dynamic equilibrium, $\Delta G_r = 0$.

$0 = \Delta G^{\emptyset} + 2.303\,RT \log K$

$\Delta G^{\emptyset} = -2.303\,RT \log K$ (08)

(vii) $28\ \text{kJ mol}^{-1} = -\ 2.303 \times 8.314\ \text{J K}^{-1}\ \text{mol}^{-1} \times 298\ \text{K} \times \log K$

$\log K = -\ 4.9$

$K = 1.25 \times 10^{-5}$ (10)

(viii) Yes.

According to $\Delta G^{\varnothing} = -2.303\ RT \log K$

$\log K > 0$ for $\Delta G^{\varnothing} < 0$.

$\therefore\ K > 1.$ (10)

(ix) At the composition *x* the system is in dynamic equilibrium.

$CO_2(g) + H_2(g) \rightleftharpoons CO(g) + H_2O(g)$

$$K = \frac{[CO(g)][H_2O(g)]}{[CO_2(g)][H_2(g)]}$$

[CO(g)] = $(H_2O(g)]$. As equal amounts of CO_2 and H_2 are mixed and the stoichiometry of the reaction is 1 : 1,

$[CO_2(g)] = [H_2(g)]$.

$$\therefore\quad K = \frac{[CO(g)]^2}{[CO_2(g)]^2}$$

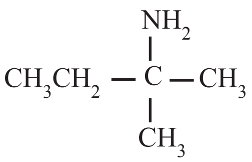
$$\frac{[CO(g)]}{[CO_2(g)]} = \sqrt{K}$$

$= (\ 1.25 \times 10^{-5})^{1/2}$

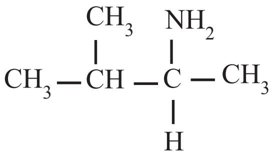
$= 3.5 \times 10^{-3}$ (20)

(Total makrs 100)

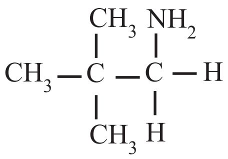
4. (a)


$CH_3CH_2-C(NH_2)(CH_3)-CH_3$

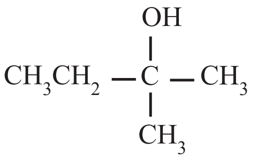
A


$CH_3-CH(CH_3)-CH(NH_2)-CH_3$

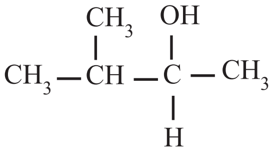
B


$CH_3-C(CH_3)_2-CH_2-NH_2$

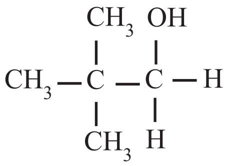
C


$CH_3CH_2-C(OH)(CH_3)-CH_3$

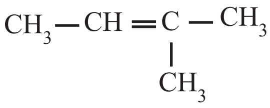
D


$CH_3-CH(CH_3)-CH(OH)-CH_3$

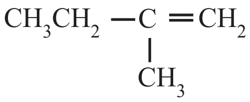
E


$CH_3-C(CH_3)_2-CH_2-OH$

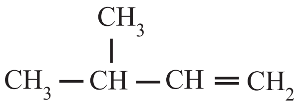
F


$CH_3-CH=C(CH_3)-CH_3$

G


$CH_3CH_2-C(CH_3)=CH_2$

H


$CH_3-CH(CH_3)-CH=CH_2$

I

(4 × 9 = 36)

(b) (i) H - Zn(Hg) / conc. HCl

I - $LiAlH_4$ or $NaBH_4$

J - $LiAlH_4$

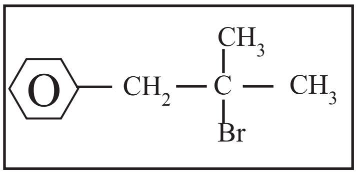
K - CH_3CH_2MgBr

L - Cl_2 / diffuse light or Cl_2 / diffuse sunlight or Cl_2 / uv

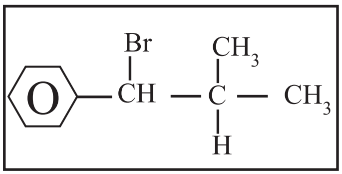
M - $Cl_2 / AlCl_3$ or $Cl_2 / ZnCl_2$ or $Cl_2 / FeCl_3$ or Cl_2 / Fe

(4 × 6 = 24)

(c) (i)

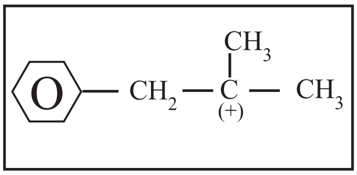


(A)

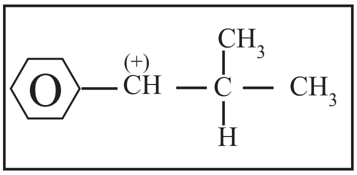


(B)

(ii)



(X)

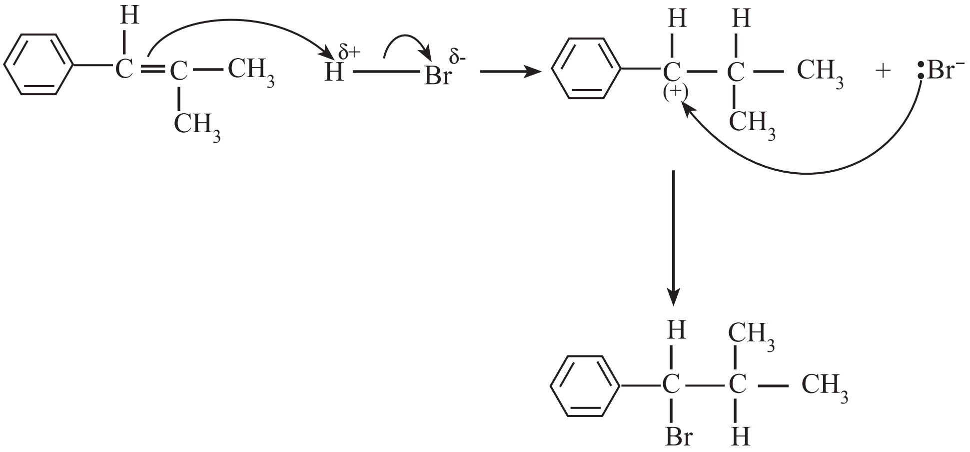


(Y)

(iii) Y or its structure

(iv) B (5 × 6 = 30)

(iv)



(10)

(Total marks 100)

Part B - Essay

05. (a) (i) Applying

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \text{ for gas A}$$

$$P = 3.6 \times 10^5 \text{ Pa} \times \frac{500 \text{ K}}{300 \text{ K}}$$

$$= 6 \times 10^5 \text{ Pa}$$

(06)

(ii)

$$A(g) \rightleftharpoons B(g) + C(g) \longrightarrow \text{I}$$

$$6 \times 10^5 \text{ Pa} - P_1 \qquad P_1 - 2P_2 \qquad P_1$$

$$2B(g) \rightleftharpoons P(g) + Q(g) \longrightarrow \text{II}$$

$$P_1 - 2P_2 \qquad P_2 \qquad P_2$$

Considering reaction II,

$$K_p = \frac{P_p \times P_Q}{P_B^2}$$

$$0.25 = \frac{P_2^2}{(P_1 - 2P_2)^2}$$

$$0.5 = \frac{P_2}{P_1 - 2P_2}$$

$$0.5 P_1 - P_2 = P_2$$

$$P_1 = 4P_2$$

$$P_T = P_A + P_B + P_C + P_P + P_Q$$

$$1 \times 10^6 \text{ Pa} = (6 \times 10^5 \text{ Pa} - P_1) + (P_1 - 2P_2) + P_1 + 2P_2$$

$$4 \times 10^5 \text{ Pa} = P_1$$

$$P_2 = \frac{1}{4} \times 4 \times 10^5 \text{ Pa} = 1 \times 10^5 \text{ Pa}$$

$$P_A = 2 \times 10^5 \text{ Pa} \qquad P_B = 2 \times 10^5 \text{ Pa}$$

$$P_C = 4 \times 10^5 \text{ Pa} \qquad P_P = P_Q = 1 \times 10^5 \text{ Pa}$$

(20)

(iii) Applying $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ for P

$$P_P = 1 \times 10^5 \text{ Pa} \times \frac{400 \text{ K}}{500 \text{ K}}$$

$$= 8 \times 10^4 \text{ Pa}$$

(06)

(iv)

$$P_A = 2 \times 10^5 \times \frac{4}{5} \text{ Pa} = 1.6 \times 10^5 \text{ Pa}$$

$$P_B = 1.6 \times 10^5 \text{ Pa}$$

$$P_C = 4 \times 10^5 \text{ Pa} \times \frac{4}{5} = 3.2 \times 10^5 \text{ Pa}$$

(12)

(v)

	A(g) $\rightleftharpoons$	B(g) +	C(g)
Initial pressure /Pa	1.6×10^5	1.6×10^5	3.2×10^5
Eqm. pressure/ Pa	$1.6 \times 10^5 + P_3$	$(1.6 \times 10^5 - P_3)$	$(3.2 \times 10^5 - P_3)$

$P_T = P_A + P_B + P_C + P_P + P_Q$

7.4×10^5 Pa $= (1.6 \times 10^5 + P_3) + (1.6 \times 10^5 - P_3) + (3.2 \times 10^5 - P_3) + 0.8 \times 10^5 \times 2$

$7.4 \times 10^5 = 8 \times 10^5 - P_3$

$P_3 = 0.6 \times 10^5$ Pa

$P_A = 2.2 \times 10^5$ Pa $\qquad P_B = 1.0 \times 10^5$ Pa $\qquad P_C = 2.6 \times 10^5$ Pa

(20)

(vi) $K_p = \dfrac{P_B \times P_C}{P_A}$

$= \dfrac{1.0 \times 10^5 \text{ Pa} \times 2.6 \times 10^5 \text{ Pa}}{2.2 \times 10^5 \text{ Pa}}$

$= 1.2 \times 10^5$ Pa

(06)

(vii) $K_p(127\ °C) < K_p(227\ °C)$

Decrease in temperature favours the backward reaction. That means a backward reaction is exothermic and the forward reaction is endothermic. So, ΔH is possitive ($\Delta H > o$). (05)

(b) (i) During electrolysis, the amount/ mass of a substance discharged at an electrode is directly proportional to the amount of electricity passed through the circuit.

The mass of an element discharged by a given amount of electricity is proportional to its equivalent mass. (equivalent mass = atomic mass of the element/ charge of the ion discharged) (10)

(ii)

Electrochemical cell	Electrolytic cell
1. converts chemical energy into electrical energy	converts electrical energy into chemical energy
2. electricity is produced by the changes in matter	electricity brings about changes in matter
3. a spontaneous process	not a spontaneous process

(06)

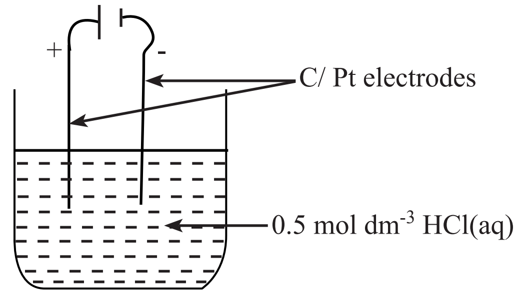
(iii) I. anodic reaction $\quad 2Cl^-(aq) \longrightarrow Cl_2(g) + 2e$

cathodic reaction $\quad 2H^+(aq) + 2e \longrightarrow H_2(g)$

overall reaction $\quad 2Cl^-(aq) + 2H^+(aq) \longrightarrow H_2(g) + Cl_2(g)$

(15)

II.



(08)

III. At the (+) terminal a light green gas/ a gas with a suffocating odour (Cl_2) is evolved.
At the (-) terminal colourless gas bubbles (H_2) are liberated. (04)

(iv) $Q = 10\text{ A} \times 3600\text{ s}$
$= 36\ 000\text{ C}$

$\therefore$ Amount of electrons = $36\ 000\text{ C}/\ 96\ 500\text{ C mol}^{-1} = 0.35\text{ mol}$

Initial pH = $-\log[H^+(aq)] = -\log[0.50]$
= $\underline{0.35}$

Moles of H^+ lost : moles of electrones = 1 : 1

Amount of H^+ remaining = (0.50 - 0.35) mol = 0.15 mol

$\therefore$ Final pH of the solution= $-\log[0.15]$
= 0.82

$\therefore$ Difference in pH = 0.82 - 0.35
= $\underline{0.47}$

Assumptions : (1) The volume remains unchanged.
(2) The temperature doesn't change. (18)

(v) The entropy increases due to the conversion
liquid $\longrightarrow$ gas (H_2, Cl_2) (02)

(vi) The amount of HCl remaining = 0.15 mol

After the reaction with NaOH

	HCl	+	$NaOH$	$\longrightarrow$	$NaCl$	+	H_2O
Amount/ mol	0.15		0.4		-		
Remaining amount/ mol	-		0.25		0.15		

$\therefore$ OH^-, Cl^-, H^+ can discharge in the solution.

$\therefore$ plausible reactions at the anode :

$4\,OH^-(aq) \longrightarrow O_2(g) + 2H_2O(l) + 4e$

$2Cl^-(aq) \longrightarrow Cl_2(g) + 2e$

at the cathode : $2H^{+}(aq) + 2e \longrightarrow H_2(g)$ (12)

(Total marks 150)

06. (a) (i) As the stoichiometry of the reaction between $FeCl_3$ and KI_3 is 2 : 1, ④

$R^{/} = 2\,R$ ④ (08)

(ii) to find $R^{/}$ in (i) above

$R^{/} = 2\,R = 2 \times 0.08\ \text{mol dm}^{-3}\ \text{s}^{-1} = 0.16\ \text{mol dm}^{-3}\ \text{s}^{-1}$ ④ (04)

(iii) Rate equation of the reaction

$R = k\,[FeCl_3(aq)]^x\ [KI_3(aq)]^y$ ④

★ Determining order with respect to $FeCl_3$

from experiment (1) : $0.08\ \text{mol dm}^{-3}\text{s}^{-1} = k\,[0.01\ \text{mol dm}^{-3}]^x\,[0.02\ \text{mol dm}^{-3}]^y$ ----- (1) ④

from experiment (2) : $0.16\ \text{mol dm}^{-3}\text{s}^{-1} = k\,[0.01\ \text{mol dm}^{-3}]^x\,[0.04\ \text{mol dm}^{-3}]^y$ ----- (2) ④

(1) / (2) $2 = 2^y$ $y = 1$ ④

★ Determining order with respect to KI

from experiment (1) : $0.08\ \text{mol dm}^{-3}\text{s}^{-1} = k\,[0.01\ \text{mol dm}^{-3}]^x\,[0.02\ \text{mol dm}^{-3}]^y$ ----- (1)

from experiment (3) : $0.16\ \text{mol dm}^{-3}\text{s}^{-1} = k\,[0.2\ \text{mol dm}^{-3}]^x\,[0.02\ \text{mol dm}^{-3}]^y$ ----- (3) ④

(3) / (1) $2 = 2^x$ $x = 1$ ④

$\therefore$ overall order of the reaction $= x + y = 1 + 1 = \underline{2}$ ④ (28)

(iv) substituting in (1)

$0.08\ \text{mol dm}^{-3}\text{s}^{-1} = k\,[0.01\ \text{mol dm}^{-3}]\ [0.02\ \text{mol dm}^{-3}]$ ④

$$k = \frac{0.08\ \text{mol dm}^{-3}\text{s}^{-1}}{2 \times 10^{-4}\ \text{mol}^2\ \text{dm}^{-6}} = 4 \times 10^2\ \text{mol}^{-1}\ \text{dm}^3\ \text{s}^{-1}$$ ④ (08)

(v)
- Adding a constant amount of $Na_2S_2O_3$ and the starch solution to the reaction mixture to measure a constant amount of KI_3. ②
- Preparing two reaction mixtures by separately mixing KI solution with $Na_2S_2O_3$ solution ① and $FeCl_3$ solution with starch solution ①
- Mixing the two mixtures and measuring the time for the appearance of blue colour ②

(06)

(b) (i) $R = k\,[S_2]^x\,[B]^y$ (04)

(ii) second step (04)

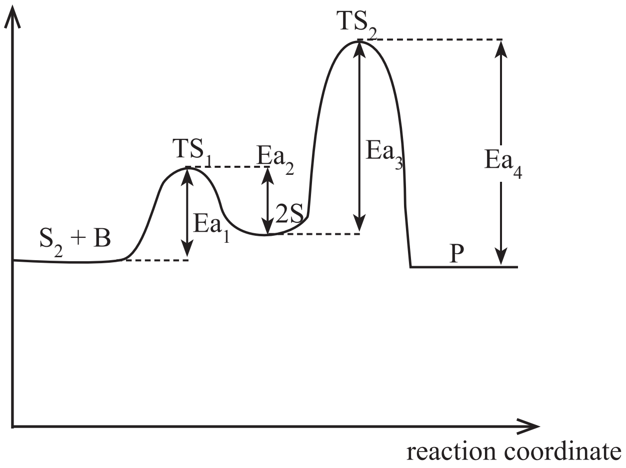
(iii) $R \,\alpha\, [S]^2[B]$

$$K_c = \frac{[S]^2}{[S_2]} \Rightarrow [S]^2 = K_c \times [S_2]$$

$\therefore\ R \,\alpha\, [S_2][B]$

$\therefore$ order with respect to $S_2 = 1$ (04)

(iv) potential energy



(09)

(c) (i) $HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)$

$$K_c = \frac{[H_3O^+(aq)]\,[A^-(aq)]}{[HA(aq)][H_2O(l)]}$$

$$\underbrace{K_c \times [H_2O(l)]} = \frac{[H_3O^+(aq)]\,[A^-(aq)]}{[HA(aq)]}$$

As $[H_2O(l)]$ is a constant at constant temperature,

$$K_a = \frac{[H_3O^+(aq)]\,[A^-(aq)]}{[HA(aq)]} \qquad \text{———— (1)}$$

(10)

(ii) $A^-(aq) + H_2O(l) \rightleftharpoons HA(aq) + OH^-(aq)$

$$K_b = \frac{[HA(aq)]\,[OH^-(aq)]}{[A^-(aq)]} \qquad \text{———— (2)}$$

(05)

(iii) $2\,H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$

$K_w = [H_3O^+(aq)][OH^-(aq)]$

$(1) \times (2) = K_a \times K_b = [H_3O^+(aq)][OH^-(aq)]$

$K_a \times K_b = K_w$

(10)

(iv) $CH_3COONa(aq) + HCl(aq) \rightarrow CH_3COOH(aq) + NaCl(aq)$

A. When $V_{HCl} = 0$

$CH_3COONa(aq) \rightarrow CH_3COO^-(aq) + Na^+(aq)$

$CH_3COO^-(aq) + H_2O(l) \rightleftharpoons CH_3COOH(aq) + OH^-(aq)$

$[CH_3COOH(aq)] = [OH^-(aq)]$

As the degrees off hydrolysis of CH_3COO^- is very small,

$$K_b = \frac{K_w}{K_a} = \frac{[OH^-(aq)]^2}{[CH_3COO^-(aq)]} \Rightarrow \therefore [OH^-(aq)]^2 = \frac{10^{-14} \times 0.18}{1.8 \times 10^{-5}} \text{ mol dm}^{-3}$$

$[OH^-(aq)]^2 = 10^{-10}$ mol^2 dm^{-6}

$[OH^-(aq)] = 10^{-5}$ mol dm^{-3}

pOH = $-\log_{10} [OH^-(aq)]$

pOH = 5

pH + pOH = 14

pH = 14 - 5

pH = 9 (10)

B $CH_3COONa(aq) + HCl(aq) \longrightarrow CH_3COOH(aq) + NaCl(aq)$

When $V_{HCl} = 12.50$ cm^3 half equivalence point is obtained. Then,

$[CH_3COONa(aq)] = [CH_3COOH(aq)]$

Neglecting the ionisation of CH_3COOH which is small,

$[H_3O^+(aq)] = K_a$

$= 1.8 \times 10^{-5}$ mol dm^{-3}

pH $= -\log_{10} [1.8 \times 10^{-5}]$

pH = 4.74 (10)

C When $V_{HCl} = 25.00$ cm^3

$$[CH_3COOH(aq)] \text{ in the medium} = \frac{0.18}{1000} \times \frac{25}{50} \times 1000 \text{ mol dm}^{-3}$$

$= 0.09$ mol dm^{-3}

$CH_3COOH(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CH_3COOH(aq)$

As CH_3COOH is a weak acid its degree of dissociation is negligibly small.

$$K_a = \frac{[H_3O^+(aq)]^2}{[CH_3COOH(aq)]} \longrightarrow [H_3O^+(aq)] = \sqrt{K_a \times 0.09} \text{ mol dm}^{-3}$$

$$= \sqrt{1.8 \times 10^{-5} \times 9 \times 10^{-2}} \text{ mol dm}^{-3}$$

$= 1.27 \times 10^{-3}$ mol dm^{-3}

pH $= -\log_{10} (1.27 \times 10^{-3})$

pH = 2.89 or pH = 2.9 (10)

D When $V_{HCl} = 50.00 \text{ cm}^3$

$$[\text{HCl(aq)}] \text{ in the medium } = \frac{0.18}{1000} \times \frac{50}{75} \times 1000 \text{ mol dm}^{-3}$$

$$= 0.12 \text{ mol dm}^{-3}$$

As the [H+] given by the dissociation of CH_3COOH is negligible compared to that provided by HCl,

$$\text{pH} = -\log_{10}(1.2 \times 10^{-1})$$

$$\text{pH} = 0.92$$

(10)

(v) Q < P < R < S

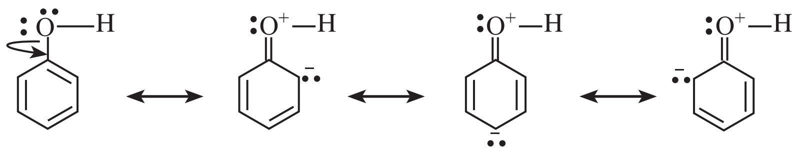
Solution Q corresponds to point B in the graph. Since this is a buffer solution the changed in pH is minimum on addition of a little amount of HCl acid.

Solution R corresponds to point C in the graph. It is an equimolar mixture of CH_3COOH and HCl. As indicated by the graph, at point C, a large change in pH occurs for a small change in V_{HCl}. (10)

(Total marks 150)

07. (a) (i) I. Nucleophilic substitution reaction (S_N) (04)

II. In phenol, the long pair of electrons on oxygen gets delocalised in the ring. Hence the C-O bond assumes a double bond character becoming shorter and stronger. This makes it difficult to break. Therefor, phenol does not undergo nucleophilic substitution reactions.



(15)

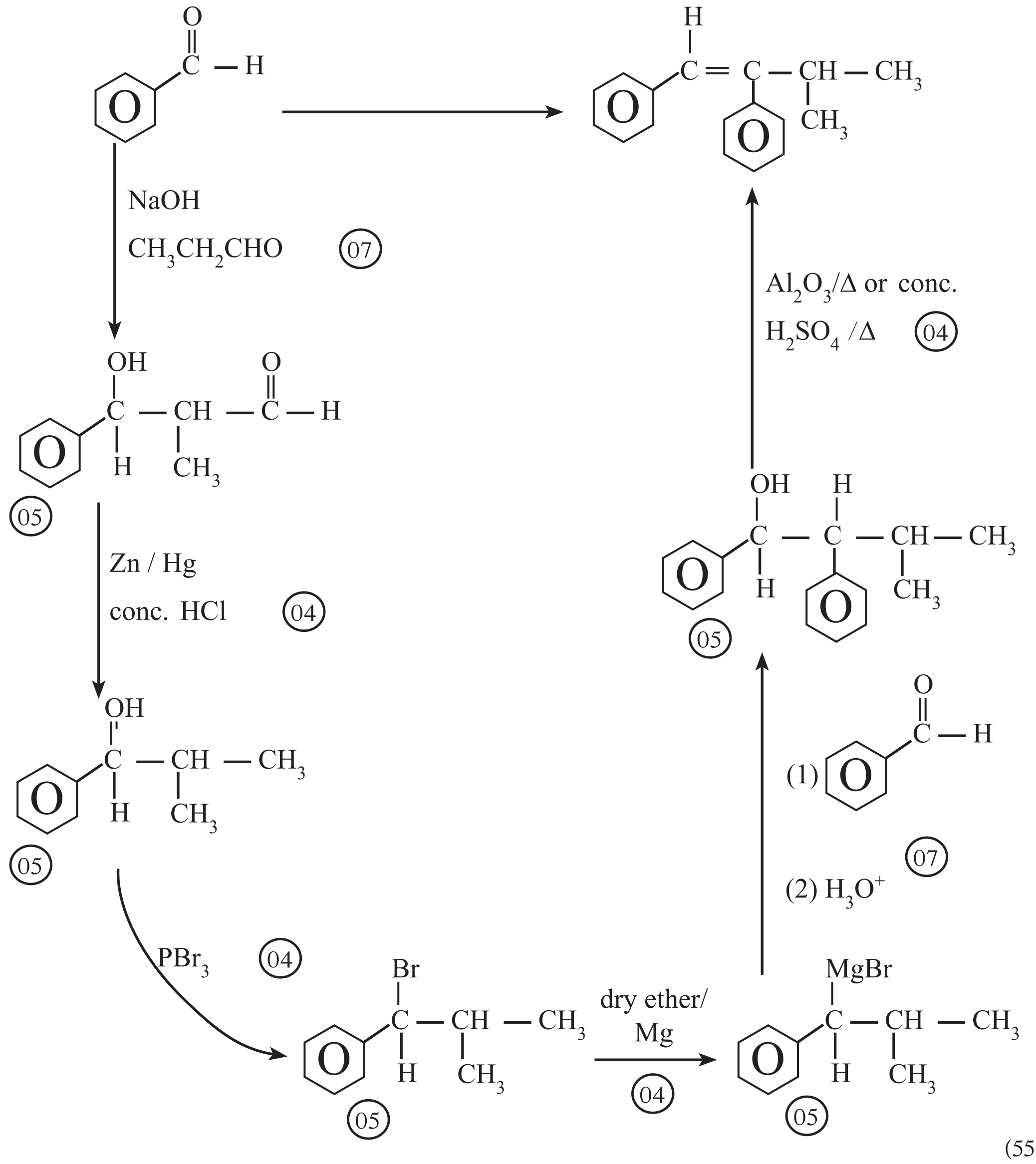
(ii) Basicity

$CH_3CH_2NHCH_2CH_3 > CH_3CH_2NH_2 > NH_3 > C_6H_5NH_2$

(1) (2) (3) (4) (06)

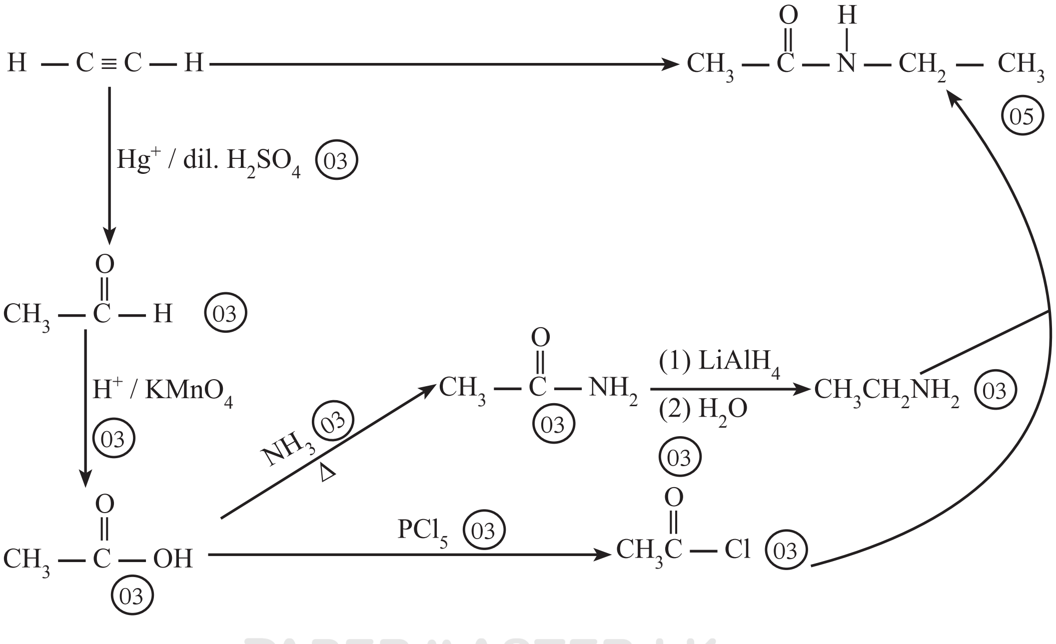
In $CH_3CH_2NHCH_2CH_3$ both CH_3CH_2 - groups repel electrons whereas in $CH_3CH_2NH_2$ only one CH_3CH_2 - group repels electrons. This enables $CH_3CH_2NHCH_2CH_3$ to donate its lone pair on the "N" atom more than that in $CH_3CH_2NH_2$.Thus (1) is the most basic. As NH_3 lacks alkyl groups the basicity of (3) is less than the basicity of (2). In (4), the lone pair on the "N" atom gets delocalised in the ring making it less available for proton coordination. Therefore, (4) is the least basic. (15)

(b)

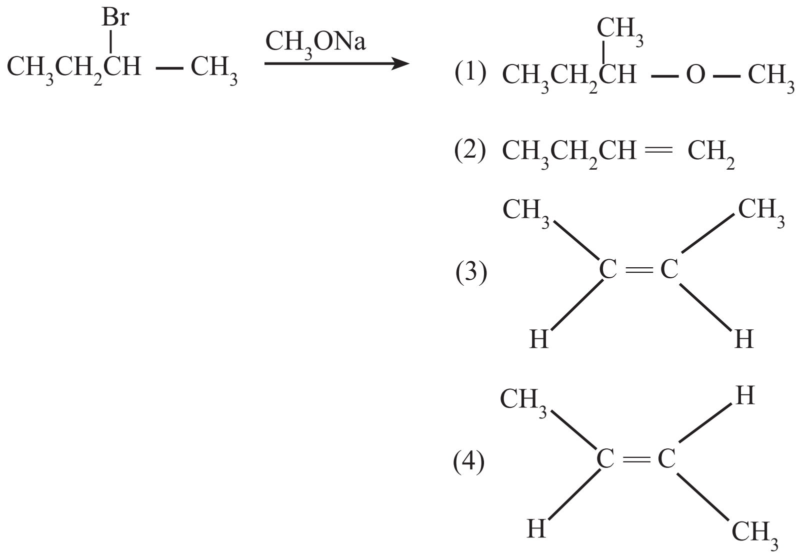

NaOH
CH_3CH_2CHO
07
05
Zn / Hg
conc. HCl
04
05
PBr_3
04
05
dry ether/
Mg
04
05
(1)
(2) H_3O^+
07
05
Al_2O_3/Δ or conc.
H_2SO_4 /Δ
04

(55)

(c)


H — C ≡ C — H
$CH_3-\overset{O}{C}-\overset{H}{N}-CH_2-CH_3$
05
Hg^+ / dil. H_2SO_4
03
$CH_3-\overset{O}{C}-H$
03
$H^+ / KMnO_4$
03
$CH_3-\overset{O}{C}-OH$
03
NH_3
03
Δ
$CH_3-\overset{O}{C}-NH_2$
03
(1) $LiAlH_4$
(2) H_2O
03
$CH_3CH_2NH_2$
03
PCl_5
03
$CH_3\overset{O}{C}-Cl$
03

(35)

(d) 

$CH_3CH_2\overset{Br}{CH}-CH_3 \xrightarrow{CH_3ONa}$

(1) $CH_3CH_2\overset{CH_3}{CH}-O-CH_3$ (05)

(2) $CH_3CH_2CH=CH_2$ (05)

(3) (05)

(4) (05)

(20)

(Total marks 150)

Part C - Essay

8. **(a)** (i)

A - CuS

B - $CuCl_2$ / $[CuCl_4]^{2-}$

C - H_2S

D - S

E - $CrCl_3$ / Cr^{3+}

F - Na_2S / $Na_2S_2O_3$

G - $Na_2S_2O_3$ / Na_2S

H - SO_2 / H_2S

I - $Cu(OH)_2$

J - $[Cu(NH_3)_4]^{2+}$ (4 × 10 = 40)

(ii) $4S + 6NaOH \longrightarrow 2Na_2S + Na_2S_2O_3 + 3H_2O$ (5)

(iii) $3H_2S + 8H^+ + Cr_2O_7^{2-} \longrightarrow 2Cr^{3+} + 3S + 7H_2O$ (5)

(50)

(b) (i) $Q = KMnO_4$ (9)

(ii) $2KMnO_4 \longrightarrow K_2MnO_4 + MnO_2 + O_2$ (5)

(iii) $3MnO_4^{2-} + 2H_2O \longrightarrow 2MnO_4^- + MnO_2 + 4OH^-$ (5)

The green solution turns purple.
A brown precipitate is formed. } (4)

(iv) $MnO_2 + 2NaBr + 2H_2SO_4 \longrightarrow MnSO_4 + Br_2 + Na_2SO_4 + 2H_2O$ (5)

A brown coloured solution is formed/ or a gas is evolved. (2)

(c) (i)

$$2Fe^{2+} + 2H^+ + H_2O_2 \longrightarrow 2Fe^{3+} + 2H_2O$$

$$SO_3^{2-} + H_2O_2 \longrightarrow SO_4^{2-} + H_2O$$

$$2Fe^{3+} + 2I^- \longrightarrow 2Fe^{2+} + I_2$$

$$2H^+ + H_2O_2 + 2I^- \longrightarrow I_2 + 2H_2O$$

$$I_2 + 2S_2O_3^{2-} \longrightarrow S_4O_6^{2-} + 2I^-$$

$$Ba^{2+} + SO_4^{2-} \longrightarrow BaSO_4$$

(4 × 6 = 24)

(ii) $BaSO_4 = \dfrac{0.5825\text{ g}}{233\text{ g mol}^{-1}} = 0.0025\text{ mol} = 2.5 \times 10^{-3}\text{ mol}$ (4)

$x + y = 2.5 \times 10^{-3} \times 2$ mol (2)

$x + y = 5.0 \times 10^{-3}$ mol ----------------- (1) (2)

(iii) Initial amount of $H_2O_2 = \dfrac{0.2}{1000} \times 50\text{ mol} = 0.01\text{ mol}$ (3)

Amount of H_2O_2 reacted with $Fe^{2+} = \dfrac{x+y}{2}$ (2)

Amount of H_2O_2 reacted with $SO_3^{2-} = x$ (2)

Amount of H_2O_2 left in T $= 0.01 - \left(\dfrac{x+y}{2} + x\right)$ mol
(in 100 cm^3)

$= 0.01 - \left(\dfrac{3x+y}{2}\right)$ mol (4)

(iv) for 50 cm^3 of the solution

Amount of $S_2O_3^{2-}$ reacted $= 2 \times$ amount of I_2 (2)

$= 2$(amount of I_2 liberated by Fe^{3+} + amount of I_2 liberated by H_2O_2 left) (5)

$$\frac{0.4}{1000} \times 20 \quad = 2\left\{\frac{(x+y)}{2} \times \frac{1}{2} + \left(\frac{0.01}{2}\right) - \left(\frac{3x+y}{2}\right)\frac{1}{2}\right\}$$

$$8 \times 10^{-3} = 0.01 - x$$

$$x = 2 \times 10^{-3} \text{ mol}$$

from (1) $y = 3 \times 10^{-3}$ mol (10)

(v) Concentration of $FeSO_3$ $= \dfrac{2 \times 10^{-3}}{50} \times 1000$ mol dm^{-3} $= 0.04$ mol dm^{-3} (5)

Concentration of $FeSO_4$ $= \dfrac{3 \times 10^{-3}}{50} \times 1000$ mol dm^{-3} $= 0.06$ mol dm^{-3} (5)

(Total marks 150)

9. (a) (i) A = HCl / H_2SO_4 / HNO_3 or their names or any other suitable acid.

(e.g. : acetic acid)

B = name or formula of any carbonate or a bicabonate (2 × 2 = 04)

(ii) common salt / sodium chloride/ NaCl

ammonia (solution) / ammonium hydroxide / NH_3 / NH_4OH (2 × 2 = 04)

(iii) In Solvey process limestone is thermally decomposed / heated.

Acids are not used. (2 × 2 = 04)

(iv) sodium bicarbonate / sodium hydrogencarbonate / $NaHCO_3$ (03)

(v) $NH_3 + H_3O^+ \rightleftharpoons NH_4^+ + OH^-$

$OH^- + CO_2 \rightleftharpoons HCO_3^-$

$Na^+ + HCO_3^- \rightarrow NaHCO_3$ (4 × 3 = 12)

(vi) I. The solution is divided into small droplets.

Therefore, the surface area of the solution increases.

This makes the absoption of carbon dioxide gas more efficient. (2 × 3 = 06)

II. The solution almost about to be saturated with the gas meets the new gas front.
This makes the dissolving of the gas/ CO_2 efficient. (2 × 2 = 04)

III. The reactions (1) and (2) in (v) are exothermic.

Under low temperature their equilibrium points shift to the right.

Therefore, the yield of those reactions increases.

As the solubility of $NaHCO_3$ is low at low temperatures it crystallises/ separates easily.

(2 × 4 = 08)

(vii) $2NaHCO_3 \longrightarrow Na_2CO_3 + H_2O + CO_2$ (04)

(viii) Used as washing soda/ softning hard water/production of soap/ glass/ detergents/ paper
Removal of Ca^{2+} / Mg^{2+} ions in sea water during the production of NaOH (any 2 × 2 = 04)

(ix) $$\frac{M(Na_2CO_3)}{M(CaCO_3) + 2M(NaCl)} \times 100$$

$$\frac{106}{100 + (2 \times 58.5)} \times 100$$

$= 48.85\%$ (2 × 3 = 06)

(x) It is an indicator of the fraction converted to the desired product from the raw meterials.
It indirectly indicates the amount of unwanted products added to the environment.
It inspires to seek alternative methods with higher cost effectiveness in an industry. (any 2 × 2 = 04)

(xi)

Species	Pollutant	Unfavourable effect
(b) Solid	$CaCl_2$	making water hard
	Na_2CO_3	making soil/ water/ alkaline/ retarding plant growth/ destroying soil/ aquatic organisms
Gaseous	CO_2	increasing global warming
	NH_3	making soil/ water/ alkaline/ destroying soil/ aquatic organisms/ respiratory diseases
Non material	heat	climatic changes

(2 × 6 = 12)

(b) (i)

N_2	O_2	Ar	CO_2	
				(2 × 4 = 8)
78.09	20.99	0.94	0.03	
78	21	0.9	0.03	(2 × 4 = 8)

(ii)

CO_2	respiration combustion photosynthesis
CO	incomplete combustion anaerobic degradation of organic substances oxidation of CH_4
SO_2	combustion of fossil fuels eruption of volcanoes biological decay of organic substances containing sulphur reduction of sulphates isolational of metals from metallic sulphides
SO_3	oxidation of SO_2
NO_x	ligthning and thunderbolts from internal combustion engines
H_2S	microbial digestion of organic substances containing sulphur reduction of sulphate ions

(1 x 5 + 1 x 5 = 10)

(iii) global warming, acid rains, photochemical smog, depletion of ozone layer

(2 x 4 = 08)

(iv) acid rains (04)

$\boxed{SO_2}$ $2SO_2 + 2H_2O + O_2 \rightarrow 2H_2SO_4$

$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$

$\boxed{NO_2}$ $4\,NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$

$HNO_3 \rightarrow H^+ + NO_3^-$

marble buildings $CaCO_3 + H^+ \rightarrow Ca^{2+} + HCO_3^-$

$MgCO_3 + H^+ \rightarrow Mg^{2+} + HCO_3^-$

metal structures $\underset{\text{(metal)}}{M} \xrightarrow{H^+} \underset{\text{(cation)}}{M^{n+}}$

(21)

(v) Increasing hardness of water

Addition of heavy metal cations to soil (08)

(vi) I. SO_2

Scrubbing acidic gases using limestone and a slurry containing lime

Using the products formed here again to produce H_2SO_4

II. NO / NO_2

Converting the above gas/gases to N_2 and O_2 using catalytic converters

Using the products formed here again to produce HNO_3 (08)

(Total marks 150)

10. (a) (i) Cobalt / Co (04)

(ii) $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^7, 4s^2$

or

$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^7$ (04)

(iii) +2, +3 / II, III (06)

(iv) $[Co(H_2O)_6]^{2+} + 4\,Cl^- \rightleftharpoons [CoCl_4]^{2-} + 6H_2O$

or

$[Co(H_2O)_6]^{2+} + 4\,Cl^- \rightleftharpoons [CoCl_4(H_2O)_2]^{2-} + 4H_2O$ (05)

(v) I. A - diamminetetraaquacobalt(II) chloride

B - diamminediaquadichloridocobalt(III) chloride

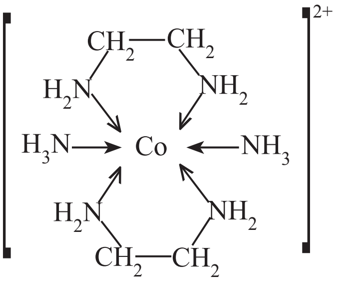
or

diamminediaquadichlorocobalt(III) chloride (5 × 2 = 10)

II. Octahedral (05)

III.
- Taking equal volumes of solutions A and B (to identical test tubes)
- Adding equal volumes of the silver nitrate solution in excess to the above test tubes separately
- Comparing the height/ mass of the (silver chloride) precipitate formed
- The compound giving more precipitate is A / The compound giving less precipitate is B/ The amount of precipitate given by A is twice the amount of precipitate given by B. (4 × 4 = 16)

(vi)



(award full marks even if the central atom is M)

(10)

(vii)
- Dissolve a sample of the alloy in (a minimum quantity of) nitric acid.
- Acidify the solution with dil. HCl and pass H_2S gas
- Filter the precipitate and boil the filtrate.
- Add a metal like Mg / Zn to the filtrate (or electrolyse).
- Filter, wash and dry the precipitate formed.

(Subjecting the above filtrate to reactions such as those given below is also acceptable.)

$$\text{Filtrate} \xrightarrow{NaOH} Co(OH)_2 \xrightarrow{\Delta} CoO \xrightarrow[\Delta]{H_2/C} Co$$

The following alternative answers are also acceptable.

- Dissolve a sample of the alloy in (a minimum quantity of) dil. HCl/ H_2SO_4 and filter.
- Add Mg / Zn / a named metal above cobalt in the electrochemical series to the filtrate.
- Filter, wash and dry the precipitate formed.

or

- Dissolve a sample of the alloy in dil. HCl/ H_2SO_4 and filter.
- Electrolyse the filtrate using inert electrodes. (15)

(b) (i) Finding $[Na^+]$

mass of Na_2SO_4 = 1.42 g

molar mass of Na_2SO_4 = 142 g mol^{-1}

amount of Na_2SO_4 $= \dfrac{1.42}{142}$ mol

= 0.01 mol

mass of NaI $= 1.50\ \text{g}$

molar mass of NaI $= 15.0\ \text{g mol}^{-1}$

amount of NaI $= \dfrac{1.50}{150}\ \text{mol}$

$= 0.01\ \text{mol}$

total amount of Na^+ $= 0.01\ \text{mol} + 2 \times 0.01\ \text{mol}$

$= 0.03\ \text{mol}$

$[Na^+(aq)]$ $= \dfrac{0.03}{2.5} \times 1\ \text{mol dm}^{-3}$

$= 0.012\ \text{mol dm}^{-3}$

- Finding $[I^-(aq)]$

$[I^-(aq)]$ $= \dfrac{0.01}{2.5} \times 1\ \text{mol dm}^{-3}$

$= 0.004\ \text{mol dm}^{-3}$

- Finding $[SO_4^{2-}(aq)]$

$[SO_4^{2-}(aq)]$ $= \dfrac{0.01}{2.5} \times 1\ \text{mol dm}^{-3}$

$= 0.004\ \text{mol dm}^{-3}$ (4 × 3 = 12)

(ii) Reactions :

$$Pb(NO_3)_2(s) \longrightarrow Pb^{2+}(aq) + 2\,NO_3^-(aq)$$

$$PbSO_4(s) \rightleftharpoons Pb^{2+}(aq) + SO_4^{2-}(aq)$$

$$PbI_2(s) \rightleftharpoons Pb^{2+}(aq) + 2\,I^-(aq)$$

Since $K_{sp}\ (PbSO_4) = 1.6 \times 10^{-8}\ \text{mol}^2\ \text{dm}^{-6}$

Calculating the minimum $[Pb^{2+}]$ to precipitate $PbSO_4$:

$K_{sp}\ (PbSO_4) = [Pb^{2+}(aq)]\,[SO_4^{2-}(aq)]$

$$[Pb^{2+}(aq)] = \frac{K_{sp}\ (PbSO_4)}{[SO_4^{2-}(aq)]} = \frac{1.6 \times 10^{-8}\ \text{mol}^2\ \text{dm}^{-6}}{4 \times 10^{-3}\ \text{mol dm}^{-3}}$$

$$= 4 \times 10^{-6}\ \text{mol dm}^{-3}$$

- Calculating the minimum $[Pb^{2+}]$ to precipitate PbI_2 :

  $K_{sp}\,[PbI_2(s)] = [Pb^{2+}(aq)]\,[I^-(aq)]^2$

$$[Pb^{2+}(aq)] = \frac{K_{sp}\,[PbI_2(s)]}{[I^-(aq)]^2} = \frac{1.6 \times 10^{-9}\ \text{mol}^3\ \text{dm}^{-9}}{(4 \times 10^{-3})^2\ \text{mol}^2\ \text{dm}^{-6}}$$

$$= 1.0 \times 10^{-4}\ \text{mol dm}^{-3}$$

$\therefore$ $PbSO_4$ which needs minimum $[Pb^{2+}(aq)]$ precipitates first. (15)

(iii) To find the mass of $Pb(NO_3)_2$ for the precipitation of $PbSO_4$:

As the total volume of the solution is 2.5 dm^3,

Amount of Pb^{2+} it should contain $= 4 \times 10^{-6} \times 2.5$ mol

$= 1 \times 10^{-5}$ mol

$\therefore$ Amount of $Pb(NO_3)_2$ to be added $= 1 \times 10^{-5}$ mol

Molar mass of $Pb(NO_3)_2$ $= 331$ g mol^{-1}

Minimum mass of $Pb(NO_3)_2$ to be added $= 1 \times 10^{-5} \times 331$ g

$= 3.31 \times 10^{-3}$ g $= 3.31$ mg (15)

(iv) $\therefore$ new $[Pb^{2+}(aq)]$ $= \dfrac{2 \times 10^{-5}}{2.5} \times 1$

$= 8 \times 10^{-6}$ mol dm^{-3}

As the $[Pb^{2+}(aq)]$ required to precipitate PbI_2 (1.0×10^{-4} mol dm^{-3}) is not available here too, PbI_2 doesn't precipitate.

To find the mass of $PbSO_4$ precipitating :

$[SO_4^{2-}(aq)]$ in the solution $= \dfrac{0.004}{2}$ mol dm^{-3}

$= 0.002$ mol dm^{-3}

$\therefore$ $[SO_4^{2-}(aq)]$ remaining $= 0.002$ mol dm^{-3}

Amount of $PbSO_4$ formed $= 0.002 \times 2.5$ mol

Mass of $PbSO_4$ formed $= 0.002 \times 2.5 \times 303$ g

$= 1.52$ g (15)

(v) To find the mass of $Pb(NO_3)_2$ to precipitate all the ions :

Amount of $Pb(NO_3)_2$ required to precipitate PbI_2 $= 1.0 \times 10^{-4}$ mol $= 2.5 \times 10^{-4}$ mol

Mass of $Pb(NO_3)_2$ $= 2.5 \times 10^{-4} \times 331$g

$= 8.2754 \times 10^{-2}$ g

$= 82.75$ mg

Minimum mass of $Pb(NO_3)_2$ required to precipitate both $PbSO_4$ and PbI_2

$= (82.75 + 3.31)$ mg

$= 86.06$ mg / 8.6×10^{-2} g (14)

(vi) The temperature and volume of the solution remain unchanged. (04)

(Total marks 150)