G.C.E. (A/L) Examination
Chemistry - 2008

M.C.Q. Answers

(1) - 2
(2) - 5
(3) - 3
(4) - 3
(5) - 4
(6) - 3
(7) - all
(8) - 5
(9) - 3
(10) - 4
(11) - 4
(12) - 5
(13) - 2
(14) - 1
(15) - 5

(16) - 1
(17) - 2
(18) - 2
(19) - 4
(20) - 1
(21) - 2
(22) - 3
(23) - 5
(24) - 4
(25) - 3
(26) - 3
(27) - 1
(28) - 3
(29) - 5
(30) - 1

(31) - 5
(32) - 4
(33) - 4
(34) - all
(35) - 5
(36) - 5
(37) - 3
(38) - 1
(39) - 1
(40) - 5
(41) - 4
(42) - 3
(43) - 2
(44) - 4
(45) - 1

(46) - 5
(47) - 4
(48) - 4
(49) - 2
(50) - 1
(51) - 3
(52) - 3
(53) - 5
(54) - 2
(55) - 2
(56) - 1
(57) - 2
(58) - 2
(59) - 1
(60) - 4

PART A - STRUCTURED ESSAY

Answer all four questions. Each question carries **10 marks**

1. (a)

(i) Mn/ Manganese (10)

(ii) $1s^2 2S^2 2P^6 3S^2 3p^6 4S^2 3d^5$ or......$3d^5 4S^2$ (6)

(iii) MnO_2 Black (or Brown) (3+3)

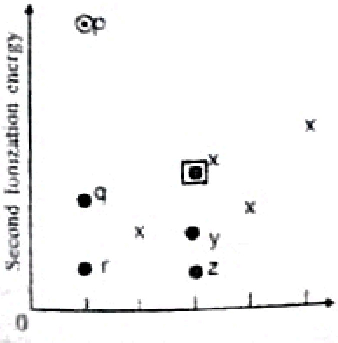
22 marks

(b)

Material	A Type of Material	B Particles Occupying Lattice Positions	C Interactions between particles	D Electrical properties
Diamond	Giant covalent lattice	atoms	covalent bonds	non-conduct
KF (s)	Ionic lattice	+8 - ions	Electrostatic	non-conduct
Ice	Molecular Lattice	molecules	H bonds	non-conduct
Li (s)	Metallic Lattice	+ive ions	metalic bonds	Conductor

(3) x 16 = 48

(c)



(15) x 2 = 30

Total marks = 100

2 (a) Concentration of Cl^- in solution No. 3

$$= \frac{4.0 \times 10^{-4}}{10} \times 3 \text{ mol dm}^{-3} \quad (13+2)$$

$$= 1.2 \times 10^{-4} \text{ mol dm}^{-3}$$

Molar mass of Nacl $= 23.0 + 35.5 \text{ g mol}^{-1}$
$= 58.5 \text{ g mol}^{-1}$ (3+2)

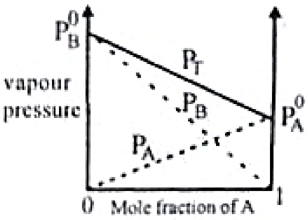
∴ The mass of Nacl in 1.0 dm^3 of solution
$= 1.2 \times 10^{-4} \times 58.5 \text{ g}$ (8+2)

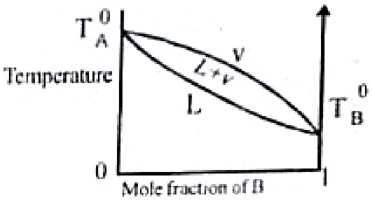
The mass of sample in $1.0 \text{ dm}^{-3} = 4.00 \text{ g}$ (3+2)

$$\% \text{ of Nacl in the sample} = \frac{1.2 \times 10^{-4} \times 58.5 \text{ g} \times 100}{4.00 \text{ g}} \quad (8+2)$$

$= 0.1755$ (5)

Part (a) = 50 marks





Labelling 02 x 10 = (20)
3 lines + 2 curves
3 x 5 = 15

(b) (v) $P_X = P_i^0 \times X_{(solu)}$ (2) $P_{Total} = P_A + P_B$ (2)

$P_A = P^0_A \times 0.5$ (2) $0.5P^0_A + 0.5P^0_B$ (2)

$P_B = P^0_B \times 0.5$ (2)

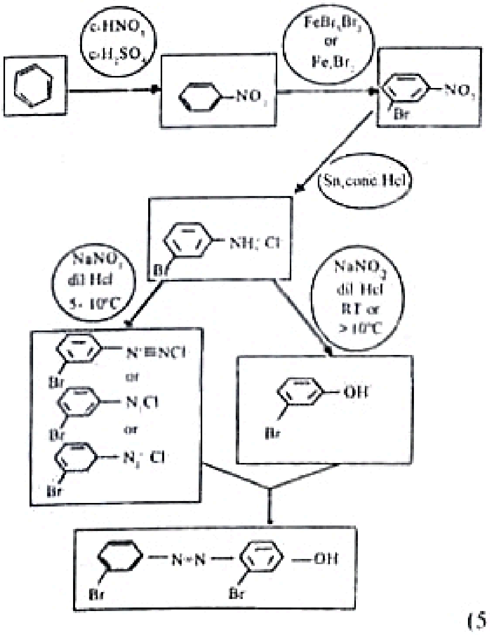
$$X_A(\text{vapour}) = \frac{P_A}{P_{Total}} = \frac{0.5P^0_A}{0.5(P^0_A + P^0_B)} = \frac{P^0_A}{P^0_A + P^0_B}$$

(2) (3)

(vi) 50 marks for all condidates

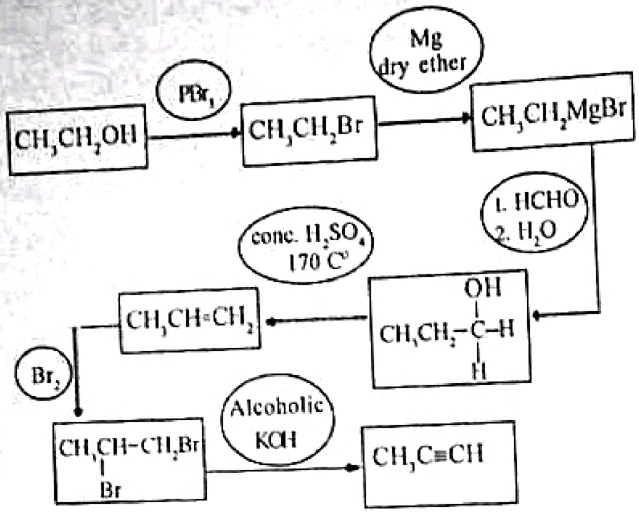
Total marks (100)

3. (i) Scheme A



(5) x 10 = 50

(i) Scheme B



Five compounds (boxes) 5 x 5 = 25
Six reagents (circles) 4 x 6 = 24
+1 mark if all correct

(ii) = 50 marks
(3) total marks =100

4. (a) (i)

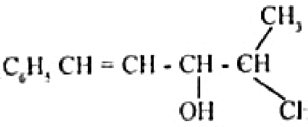
Test	Observation/s
Br_2/CCl_4 (03)	Decolorisation (03)
OR	OR
Br_2 water + shaking (02) (01)	Brown ⟶ Colourless

(ii) (i) C_6H_5 CH = CH - CH_2OH
OR C_6H_5-CH_2-CH_2CH_2OH (06)

(ii) Reduction or Nucleophilic addition (04)

(iii) (i) dry ether or (THF) (06)

(ii) Grignard reagent reacts with H_2O (05)

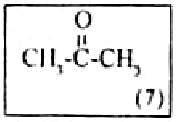
(iii)  (10)

$C_6H_5\,CH=CH-\underset{OH}{\underset{|}{CH}}-CH(CH_3)_2$

(iv)

C_6H_5CHO (7)	CH_3-CHO (7)

(a) = 50 marks

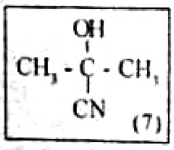
(b) (i) 

$CH_3-\overset{O}{\overset{\|}{C}}-CH_3$ (7)

A

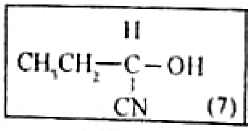
CH_3CH_2CHO (7)

B

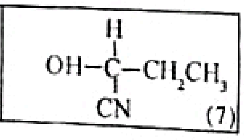


$CH_3-\overset{OH}{\overset{|}{\underset{CN}{\underset{|}{C}}}}-CH_3$ (7)

C



$CH_3CH_2-\overset{H}{\overset{|}{\underset{CN}{\underset{|}{C}}}}-OH$ (7)



$OH-\overset{H}{\overset{|}{\underset{CN}{\underset{|}{C}}}}-CH_2CH_3$ (7)

(ii) Optical isomerism

(iii) Rotation of the plane of (plane) polarised

(iv) Rotate the plane & polarised light in oppo
directions

(4) Total marks

5. (a) (i) $NH_4SH(s) \rightleftharpoons NH_3(g) \cdot H_2S(g)$

$K_p = Kc\,(RT)^{\Delta n}$

$\Delta n = 2$

$K_p = 1.44 \times 10^2\, mol^2\, m^{-6} \times (2500\, J\, mol^{-1})^2$

$= 9.0 \times 10^8\, J^2m^{-6}$ (or N^2m^{-4} or pa^2)

(ii) Method I

$Kc = [NH_3(g)] \times [H_2s(g)]$

$[NH_3(g)] = [H_2S(g)] = \sqrt{K_c}$

$= \sqrt{1.44 \times 10^2\, mol^2m^{-6}}$

$= 12\ mol\ m^{-3}$

The number of moles that must be present in $1.0 \times 10^{-2} m^3$ (volume of vessel)

$= 12\ mol\ m^{-3} \times 1.0 \times 10^{-2} m^3$

$= 0.12$ mol

Since 1 mol of $NH_3(g)$[or $H_2s(g)$] is formed from of $NH_4SH(s)$, the minimum mass of NH_4SH must be placed in the vessel is,

$= 0.12\ mol \times 51\ g\ mol^{-1}$ (3-

$= 6.12$ g (3-

Method II (Alternative method)

$Kp = P_{NH_3(g)} \times P_{H_2S(g)}$ (5)

Since both $NH_3(g)$ and $H_2S(g)$ are produced from $NH_4SH(s)$ in equal stoichiometric amounts

$\therefore P_{NH_{3(g)}} = P_{H_2S(g)} = \sqrt{K_p} = \sqrt{9 \times 10^8\, N^2m^{-4}} = 3.0 \times 10^4$

(5) + (5) + (8 + 2)

Applying PV = nRT, to calculate the number of moles of $NH_3(g)$ {or $H_2S(g)$} that must be present in the volume of $1.0 \times 10^{-2} m^3$ at 27°C to give a pressure of $3.0 \times 10^4\ Nm^{-2}$

PV = nRT (5) where RT = 2.5 KJ mol^{-1} at 27°C

$3.0 \times 10^4 Nm^{-2} \times 1.0 \times 10^{-2} m^3 = n \times 2500\ J\ mol^{-1}$ (3+2)

$n = \dfrac{3.0 \times 10^2\ Nm}{2500 Jmol^{-1}}$

$= 0.12$ mol (3+2)

Since 1 mol of $NH_3(g)$ {or $H_2S(g)$} is formed 1 mol of NH_4HSe (s), the minimum mass of that must be placed in the vessel is,

$= 0.12\ mol \times 51 g\ mol^{-1}$

$= 6.12$ g

5 (a)

(b) (i) $B < C < D < E < A$ **(10) (No part marks)**

(ii) No (3)

Ratio of the concentrations of CH_3COO^- and CH_3COOH does not change with dilution (3)

$\therefore$ pH is not changed.

(iii) E (3)

Concentration of CH_3COO^- in E > Concentration of CH_3COO^- in F (3)

(iv) Presence of CH_3COOH does not affect the amount of H^+ formed from HCl (or The $[H^+]$ due to CH_3COOH is negligible compared to that due to HCl) (4)

Concentration of $H^+ = \dfrac{50.0 cm^3 \times 0.20 mol dm^{-3}}{100.0 cm^3}$ (3+2)

$= 0.10 mol dm^{-3}$

pH $= -\log(0.10)$ (3)

$= 1.0$ (2)

(v) pH decreases (3)

Dissolution of atmospheric CO_2 decreases the pH of water. (3)

(vi) $CH_3COOH (aq) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$ (2+1)

$HCOOH (aq) \rightleftharpoons HCOO^-(aq) + H^+(aq)$ (2+1)

$H^+(aq)$ is the total $[H^+]$ at equilibrium in the mixture. (3)

$[CH_3COO^-_{(aq)}] + [HCOO^-_{(aq)}] = [H^+_{aq}]$ (2+1)

$K_1 = [CH_3COO^-]_{(aq)} [H^+_{(aq)}] / [CH_3COOH_{(aq)}]$ (2+1)

$\therefore [CH_3COO^-_{(aq)}] = K_1 [CH_3COOH_{(aq)}] / [H^+_{(aq)}]$ — Ⓐ

$K_2 = [HCOO^-_{(aq)}] [H^+_{(aq)}] / [HCOOH_{(aq)}]$ (2+1)

$\therefore [HCOO^-_{(aq)}] = K_2 [HCOOH_{(aq)}] / [H^+_{(aq)}]$ — Ⓑ

Ⓐ+Ⓑ $[H^+_{(aq)}] = K_1 [CH_3COOH_{(aq)}] / [H^+_{(aq)}] + K_2 [HCOOH_{(aq)}] / [H^+_{(aq)}]$ (2+1)

Multiplying by $[H^+_{(aq)}]$

$[H^+_{(aq)}]^2 = K_1 [CH_3COOH_{(aq)}] + K_2 [HCOOH_{(aq)}]$ (2+1)

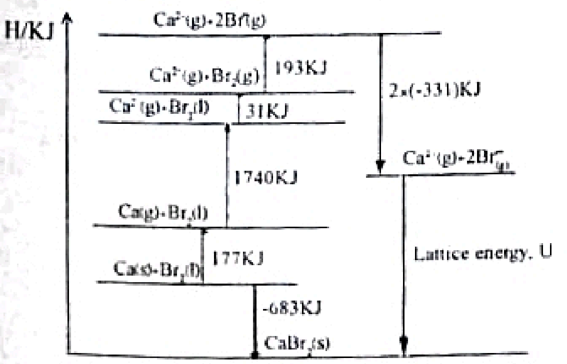
$[H^+_{(aq)}] = \sqrt{K_1 [CH_3COOH_{(aq)}] + K_2 [HCOOH_{(aq)}]}$ (2+1)

Assuming that the dissociation of these acids occurs only to a small extent (3)

$[H^+ a)] = \sqrt{K_1 C_1 + K_2 C_2}$ (3)

5 (b) = 75 marks

6. **(a)** Enthalpy level diagram of $CaBr_2(s)$



7 steps x (2 +2 +2) marks

Note : **2 for substances with correct physical states.**
2 for correct arrows and 2 for values or symbols of corresponding enthalpy.
06 marks for either H/KJ in the y- axis or H in the y-axis with unit KJ in all places. Units in $KJ mol^{-1}$ may be acceptable if the process involves 1 mol of the substance of interest.

$177KJ + 1740KJ + 31KJ + 193KJ + 2x(-331KJ) + U = -683KJ$ (4+2)

$U = -2162 KJ$

Lattice energy of $CaBr_2(s)$ $= -2162 KJ mol^{-1}$ (4+2)

6 (a) = 60 marks

(b) (i) Molar mass of CaC_2O_4 $= (40+2\times12+4\times16) g mol^{-1}$

$= 128 g mol^{-1}$ (3+2)

Mass of CaC_2O_4 $= 256 mg$

Amount of CaC_2O_4 $= \dfrac{0.256}{128 g mol^{-1}} = 0.0020 mol$ (3+2)

Amount of CaC_2O_4 in ammonium oxalate solution

$= 0.100 dm^3 \times 0.0500 mol dm^{-3}$ (3+2)

$= 0.0050 mol$

Amount of CaC_2O_4 in solution (filterate)

$= 0.0.0050 - 0.0020 mol$

$= 0.0030 mol$ (3+2)

Concentration of $C_2O_4^{2-}$ $= 0.0030mol / 0.150dm^3$

$= 0.0200 mol dm^{-3}$ (3+2)

$CaC_2O_4(s) \rightleftharpoons Ca^{2+}(aq) + C_2O_4^{2-}(aq)$ (3+2)

Initially .... 0.0200 moldm^{-3}

At equilibrium S 0.0200 moldm^{-3}(3+2)

$K_{sp} = [Ca^{2+}(aq)] [C_2O_4^{2-}(aq)]$ (5)

$= (s) (0.0200) mol^2dm^{-6}$ (3+2)

Assumption : All Ca^{2+} in the clay is exchange by K^+ (5)

$S(0.0200) mol^2dm^{-6} = 2.3 \times 10^{-9} mol^2 dm^{-6}$ (3+2)

$S = 1.15 \times 10^{-7}$

Concentration of Ca^{2+} in the filterate $= 1.15 \times 10^{-7} mol dm^{-3}$ (3+2)

(i) Quantity of Ca in clay

$$=0.002mol\ CaC_2O_4 \times \frac{1mol\ Ca}{1mol\ CaC_2O_4} \times \frac{40\ g\ ca}{1mol\ ca} \times \frac{1000mg}{1g} \times \frac{1}{0.020kg} \times \frac{100cm^3}{50cm^3}$$

(3+2) (3+2) (3+2) (3+2) (3+2)

$= 8000 mg / kg$ (3+2)

6 (b) = 90 marks

7. (a) (i) Initial colour of solution Clourless (5)

(ii) I. Anode half - reaction

$2 I^-(aq) \rightarrow I_2(s) + 2e$

or $I^-(aq) \rightarrow 1/2\ I_2(s) + e$ (5)

II. Cathode half - reaction

$2H_2O(l) + 2e \rightarrow 2OH^-(aq) + H_2(g)$

or $H^+(aq) + e \rightarrow 1/2\ H_2(g)$ (5)

II. Cell reaction

$2I^-(aq) + 2H_2O(l) \rightarrow I_2(s) + H_2(g) + 2OH^-(aq)$

or $2I^-(aq) + 2H^+(aq) \rightarrow I_2(s) + H_2(g)$ (5)

(iii) Colour changes : Near anode : Light yellow/ brown solution/ brown deposit on electrode (5)

Near cathode . Solution turning pink (5)

(iv) Remove the electrodes, extract dissolved iodine or determine the amount of dissolved iodine using thiosulphate, add excess of an oxidizing agent ($K_2Cr_2O_7$, K_2CrO_4, Fe^{3+} etc) (5) and titrate liberated I_2 with $S_2O_3^{2-}$ (5). If the volume of the solution used for electrolysis is known, the fraction of I^- remaining can be calculated. (5)

OR

If the current passed and the duration are measured (5), the amount of I_2 liberated can be calculated (5) and if the volume of the solution used for electrolysis is known the fraction of I^- remaining can be determined. (5)

(v) yes. (different) (5)

Since the amount of electricity passed is the same (5), the same amount of I_2 is liberated (5).
But since the initial amount of I^- is lager when 0.5 mol dm^{-3} KI is used (5), the fraction remaining will be different.

(vi) i. On cathode : Deposition of Cu (5)

$Cu^{2+}(aq) + 2e \rightarrow Cu\,(s)$ (5)

On anode : Evolution of gas bubbles (O_2) (5)

$2H_2O(l) \rightarrow 4H^+(aq) + O_2(g) + 4e$

or $4OH^-(aq) \rightarrow O_2(g) + 2H_2O(l) + 4e$ (5)

ii. In solution
The blue colour of the solution decreases (5)

7. (b) (i) For an elementary (single step) reacion, the rate expression contains concentration terms of reactants raised to their stoichoimetric numbers. (10) Many chemical reactions are non-elementary and may take place via several elementary steps (in their mechanisms). The rate of overall reaction is determined by the rate of the slowest (rate-determining) elementary step. (10) Substances in the rate-determining step may not have the same stoichiometric numbers as those appeering in the overall reaction. (10)

(ii) Initial concetration of Fe (III) = $\frac{0.0360 \text{ mol dm}^{-3}}{2}$ (4+2)

Change in [Fe (III)] in 4 minutes

$$= \frac{0.0360 \text{ mol dm}^{-3}}{2} \times \frac{24}{100}$$ (4+2)

The average rate of reduction of Fe (III)

$$= \frac{0.0360 \text{ mol dm}^{-3}}{2} \times \frac{24}{100} \times \frac{1}{4\text{min}}$$

$= 0.00108$ mol $dm^{-3}min^{-1}$ (4+2)

Since 2 mol of Fe (III) react with 1 mol of Sn (II) the rate of oxidation of Sn(II) is half that of reduction of Fe(III) (6)

Rate of oxidation of Sn(II)

$$= \frac{0.00108 \text{ mol dm}^{-3}\text{min}^{-1}}{2}$$

$= 0.00054$ mol $dm^{-3}min^{-1}$ (4+2)

7 (b) for 60 marks

8. (a) (i) $X_2Y = H_2S$ and $YZ_2 = SO_2$ (20+20)

(ii) $2H_2S + SO_2 \rightarrow 3S + 2H_2O$ (5)

$CuSO_4 + H_2S \rightarrow CuS + H_2SO_4$ (5)

$SO_2 + 2H_2O + 2Cu^{2+} \rightarrow 2Cu^+ + H_2SO_4 + 2H^+$ (10)

(iii) **Industrial uses of SO_2**

For bleaching, manufacture of H_2SO_4

As a preservative

(any two industrial uses)

(iv) H_2S and SO_2

Pass the gases through a metal ion solution
Hg^{2+}, Pb^{2+}, Ag^+, Cd^{2+} etc)
Which can be precipitated as the sulphide
does not with SO_2
SO_2 which comes out can be tested with acidified
mate which turns green

$M^{2+} + H_2S \rightarrow MS\downarrow + 2H^+$

$Cr_2O_7^{2-} + 3SO_2 + 8H^+ \rightarrow 2Cr^{3+} + 3SO_4 + 4H_2O$

Total marks 8 (a

8. (b) $C_2O_4^{2-} \rightarrow 2CO_2 + 2e$

$MnO_4^- + 8H^+ + 5e \rightarrow Mn^{2+} + 4H_2O$

$5C_2O_4^{2-} \equiv 2MnO_4^-$

Amount of MnO_4^- reacted with $C_2O_4^{2-}$

$$= \frac{0.05 \times 20.00}{1000} = 1.0 \times 10^{-3} \text{ mol}$$

Amount of $C_2O_4^{2-}$ in the precipitate

$$= \frac{1.0 \times 10^{-3} \times 5}{2} = 2.5 \times 10^{-3} \text{mol}$$

∴ The conc. of $C_2O_4^{2-}$ in solution B

$$= \frac{2.5 \times 10^{-3} \times 1000}{25.00}$$

$= 0.10$ mol dm^{-3}

The relative formula unit mass of CaC_2O_4 = 128

The mass of CaC_2O_4 in the precipitate

$= 2.50 \times 10^{-3}$mol x 128 g mol^{-1} = 0.320g

∴ The mass of $CaCO_3$ in the ppt.

= (0.820 - 0.320) g = 0.500 g

The relative formula unit mass of $CaCO_3$ = 100

The number of mol of $CaCO_3$ $= \frac{0.500 \text{ g}}{100}$

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

∴ Number of moles of CO_3^{2-} in 25.00 cm^3 of solution B = 5×10^{-3} mol

∴ The conc. of CO_3^{2-} in solution B

$$= \frac{5.0 \times 10^{-3} \times 1000}{25} \text{ mol dm}^{-3}$$ (5)

$= 0.2$ mol dm^{-3} (3+2)

Total marks for 8 (b

9. (a) (i) Mass of Na_2Co_3 in 1.00 cm^3 of solution

= 1.0212g - 1.000g

= 0.0212 g

Mass of Na_2Co_3 in 1.000 dm^3 of solution

= 0.0212 g x 1000

= 21.20 g

Molar mass of Na_2Co_3 = 106 g mol^{-1}

∴ The conc. of Na_2Co_3 solution $= \frac{21.20}{106}$ mol dm^{-3}

= 0.20 mol dm^{-3}

(ii) **When Na_2CO_3 solution is added from burette to the H_2SO_4 solution in the flask the end point is obtained when Na_2CO_3 is completely neutralized.**

OR

$Na_2Co_3 + H_2SO_4 \rightarrow Na_2So_4 + CO_2 + H_2O$ (5)

$\therefore$ 1 mol of $Na_2Co_3 \equiv$ 1 mol of H_2SO_4 (5)

Amount of Na_2Co_3 in 12.50 cm^3 of solution

$= \frac{0.2 \times 12.50}{1000} = 2.5 \times 10^{-3}$ mol (5)

Amount of H_2SO_4 reacted with Na_2Co_3

$= 2.5 \times 10^{-3}$ mol (5)

$\therefore$ The conc. of H_2SO_4 solution

$= \frac{2.5 \times 10^{-3} \times 1000}{25.0}$ mol dm $^{-3}$ (5)

$= 0.10$ mol dm $^{-3}$ (3+2)

(iii) yes. 12.5 cm^3 (5 + 5)

9 (a) for 60 marks

(b) (i) Fe (Iron) (15)

(ii) +2 and +3 (5+5)

(iii) Potassium ferricyanide gives a blue ppt. with Fe^{2+} (or potassium Ferrocyanide gives blue ppt. with Fe^{3+}) or any other suitable test (eg. SCN^- gives a red coloration with Fe^{3+})

Test + observation (5 +5)

(iv) Take a measured volume (5) of solution and titrate with a standard solution of $KMnO_4$ (05). This gives the amount of Fe^{2+} (5)

Take another portion and pass SO_2 to convert Fe^{3+} to Fe^{2+} (05)

Boil off excess SO_2 and titrate with $KMnO_4$

This gives the total amount of iron (5)

The difference gives the amount of Fe^{3+} (5)

(Alternative method)

Take a measured volume (5) of solution and add excess KI

Titrate the liberated I_2 with standard thiosulphate solution (5)

This gives the amount of Fe^{3+} (5)

Take another portion and react with H_2O_2 to convert Fe^{2+} to Fe^{3+} (5)

Boil off excess H_2O_2 and add excess of KI

Titrate the liberated I_2 with standard thiosulphate solution.

This gives the total amount of iron (5)

The difference gives the amount of Fe^{3+} (5)

(v) Light green ppt : $Fe(OH)_2$ (5)

yellow - brown ppt : $Fe(OH)_3$ (5)

(vi) Fe as catalyst : Haber process / production of ammonia (5)

(vii) Hematite (Fe_2O_3) (2+3)

Magnetite (Fe_3O_4) (2+3)

Limonite ($2Fe_2O_3.3H_2O$)

Siderite ($FeCO_3$ also acceptable)

9 (b) for 90 marks

10. (a) (i) **(I) Temporary hardness : that which can be removed by boiling** (5)

(II) Bicarbonate of calcium and bicarbonate of magnesium (5+5)

(III) Domestic problems : Difficulty in using soap

Scale formotion in kettles etc.....

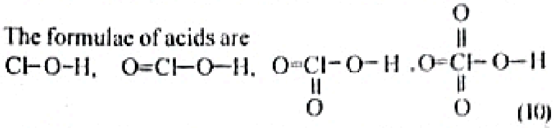
Unpleasant taste in drinking water (any two 5 +5)

(IV) 1. By boiling

$Ca^{2+} + 2HCO_3^- \rightarrow CaCo_3 + CO_2 + H_2O$ (5)

2. Using ion exchange resins/zeolites / clays (5)

(ii) The formulae of acids are



$Cl-O-H,\ O=Cl-O-H,\ O=\underset{\underset{O}{\|}}{Cl}-O-H,\ O=\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{Cl}}-O-H$ (10)

(02 for each correct structure, 10 if all structures correct)

Oxygen is more electronegative than Cl (5)

As more Oxygen atoms get attached to the Cl atom, its positive character increases (5)

This makes the ionization of the H atom as H^+ easier (5)

$\therefore$ The acidity increases in the order

$HClO < HClO_2 < HClO_3 < HClO_4$ (5) OR

Oxidation number of Cl increases from HOCl (+1), $HOCl_2$(+3), $HOCl_3$(+5), $HOCl_4$ (+7) (5)

$\therefore$ The positive character of the H atom as H^+ easier (5)

$\therefore$ The acidity increases in the order

$HClO < HClO_2 < HClO_3 < HClO_4$ (5)

10 (a) for 70 marks

(b) (i) Ammonia (NH_3) and Oxygen (O_2) (4+4)

(ii) NH_3 : by the reaction between H_2(g) and N_2(g) (4)

(Or Haber process)

O_2 : From air (4)

(iii) Step I : Reaction between NH_3(g) and O_2(g) air (2)

$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$ (4)

Catalyst : Pt or Pt/Rh (2)

Temperature : about 850°C (2)

Pressure : near atmospheric pressure (2)

Step II : NO is reacted with O_2 to form NO (2)

$2NO + O_2 \underset{(\rightarrow)}{\rightleftharpoons} 2NO_2$ (4)

Step III : NO_2 gas is dissolved in water in form HNO_3 (2)

$3NO_2 + H_2O \rightarrow 2HNO_3 + NO$ (4)

OR $4NO_2 + O_2 + 2H_2O \rightarrow 4\ HNO_3$

OR $2NO_2 + H_2O \rightarrow HNO_3 + HNO_2$

(iv) For direct oxidation of N_2 to NO,

$2N_2(g) + 2O_2(g) \rightarrow 4NO(g)$ (4)

$\Delta H = 4x\ (+90\ KJ) = +\ 360\ KJ$ (4)

This process (A) is **endothermic** (4)

For reduction of N_2 (g) followed by oxidation.

$2N_2(g) + 6H_2(g) \rightarrow 4NH_3(g)$ (4)

$\Delta H = 4x\ (-46KJ) = -184\ KJ$ (4)

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

$\Delta H = 6x\ (-242\ KJ) + 4x(+90\ KJ) - 4x(-46\ KJ) = -908\ KJ$ (4)

For reduction of N_2(g) to NH_3(g) followed by oxidation.

$\Delta H = -184\ KJ + (-908\ KJ) = -1092\ KJ$ (4)

[For the production of 4 mol of NO (g)]

This process (B) is **exothermic** (4)

Therefore process B is likely to be more feasible compared to process A

10 (b) for 80 marks