

**Department of Examinations – Sri Lanka**  
**G.C.E. (A/L) Examination – 2024**

**02 - Chemistry**  
**Marking Scheme**

This has been prepared for the use of marking examiners. Some changes would be made according to the views presented at the Chief Examiners' meeting.

**Amendments to be included**

**G.C.E. (A/L) Examination - 2024****02 - Chemistry****Distribution of Marks**

**Paper I : 1 X 50 = 50**

**Paper II :**

**Part A : 100 X 4 = 400**

**Part B : 150 X 2 = 300**

**Part C : 150 X 2 = 300**

**Total = 1000**

**Paper II - Final Marks = 100**

## Common Techniques of Marking Answer Scripts.

It is compulsory to adhere to the following standard method in marking answer scripts and entering marks into the mark sheets.

1. Use a red color ball point pen for marking. (Only Chief/Additional Chief Examiner may use a mauve color pen.)
2. Note down Examiner's Code Number and initials on the front page of each answer script.
3. Write off any numerals written wrong with a clear single line and authenticate the alterations with Examiner's initials.
4. Write down marks of each subsection in a  $\triangle$  and write the final marks of each question as a rational number in a  $\square$  with the question number. Use the column assigned for Examiners to write down marks.

Example:

Question No. 03

(i)

.....  
.....  
.....

✓

$\triangle$   
 $\frac{4}{5}$

(ii)

.....  
.....  
.....

✓

$\triangle$   
 $\frac{3}{5}$

(iii)

.....  
.....  
.....

✓

$\triangle$   
 $\frac{3}{5}$

$$\textcircled{03} \quad (i) \quad \frac{4}{5} \quad + \quad (ii) \quad \frac{3}{5} \quad + \quad (iii) \quad \frac{3}{5} \quad = \quad \square \begin{array}{c} 10 \\ 15 \end{array}$$

### MCQ answer scripts: (Template)

1. Marking templates for G.C.E.(A/L) and GIT examination will be provided by the Department of Examinations itself. Marking examiners bear the responsibility of using correctly prepared and certified templates.
2. Then, check the answer scripts carefully. If there are more than one or no answers Marked to a certain question write off the options with a line. Sometimes candidates may have erased an option marked previously and selected another option. In such occasions, if the erasure is not clear write off those options too.
3. Place the template on the answer script correctly. Mark the right answers with a 'v' and the wrong answers with a '0' against the options column. Write down the number of correct answers inside the cage given under each column. Then, add those numbers and write the number of correct answers in the relevant cage.

**structured essay type and assay type answer scripts:**

1. Cross off any pages left blank by candidates. Underline wrong or unsuitable answers. Show areas where marks can be offered with check marks.
2. Use the right margin of the overland paper to write down the marks.
3. Write down the marks given for each question against the question number in the relevant cage on the front page in two digits. Selection of questions should be in accordance with the instructions given in the question paper. Mark all answers and transfer the marks to the front page, and write off answers with lower marks if extra questions have been answered against instructions.
4. Add the total carefully and write in the relevant cage on the front page. Turn pages of answer script and add all the marks given for all answers again. Check whether that total tallies with the total marks written on the front page.

**Preparation of Mark Sheets.**

Except for the subjects with a single question paper, final marks of two papers will not be calculated within the evaluation board this time. Therefore, add separate mark sheets for each of the question paper. Write paper 01 marks in the paper 01 column of the mark sheet and write them in words too. Write paper II Marks in the paper II Column and write the relevant details.

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## ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව

Department of Examinations – Sri Lanka  
අ.පො.ස.(උ.පෙළ)විභාගය/G.C.E. (A/L) - 2024

විෂය අංකය  
Subject No

02

විෂය  
Subject

Chemistry

ලකුණු දීමේ පටිපාටිය/Marking Scheme  
I පත්‍රය/Paper I

ප්‍රශ්න අංකය Question No.	පිළිතුරු අංකය Answer No.	ප්‍රශ්න අංකය Question No.	පිළිතුරු අංකය Answer No.	ප්‍රශ්න අංකය Question No.	පිළිතුරු අංකය Answer No.	ප්‍රශ්න අංකය Question No.	පිළිතුරු අංකය Answer No.	ප්‍රශ්න අංකය Question No.	පිළිතුරු අංකය Answer No.
01.	5	11.	3	21.	4	31.	4/5	41.	1
02.	2	12.	2	22.	3	32.	5	42.	1
03.	4	13.	3	23.	4	33.	3	43.	1
04.	4	14.	1	24.	1	34.	3	44.	1
05.	2	15.	3	25.	1	35.	3	45.	2
06.	4	16.	2	26.	4	36.	4	46.	3
07.	5	17.	4	27.	2	37.	5	47.	4
08.	3	18.	5	28.	5	38.	1	48.	3
09.	3	19.	5	29.	(all)	39.	2	49.	1
10.	5	20.	2	30.	5	40.	2	50.	1

## විශේෂ උපදෙස්/Special Instructions:

එක් පිළිතුරකට ලකුණු 01 බැගින්/ 01 Mark for each question

මුළු ලකුණු/Total Marks 01 × 50 = 50

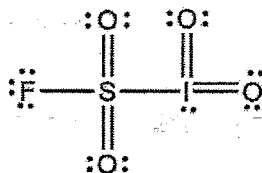
**PART A — STRUCTURED ESSAY***Answer all four questions on this paper itself. (Each question carries 100 marks.)*

1. (a) State whether the following statements are **true** or **false** on the dotted lines. Reasons **not** required.

- |   |                |
|---|----------------|
| (i) Particles in both cathode rays and $\beta$ rays have the same charge to mass ratio (e/m).   | .....<br>true  |
| (ii) In a copper (Cu) atom there are 6 electrons having magnetic quantum number, $m_l = -1$ .   | .....<br>true  |
| (iii) The $\text{F}_2\text{ClO}^+$ ion has a trigonal planar shape.   | .....<br>false |
| (iv) Sulphur (S) has the <b>lowest</b> first ionization energy among the elements F, S and Cl.  | .....<br>true  |
| (v) Rules related to polarizing power of cations and polarizability of anions, predict that the melting point of LiCl is <b>higher</b> than that of KF. | .....<br>false |
| (vi) In nitrous acid ( $\text{HNO}_2$ ) the two N—O bonds are equal in length.  | .....<br>false |
| (vii) The number of Lewis dot-dash structures (resonance structures) that can be drawn for the ion $\text{CN}_2^{2-}$ is 3.                             | .....<br>true  |
| (viii) The boiling point of hexane is <b>higher</b> than that of 2,2-dimethylbutane.  | .....<br>true  |

**(04 marks X 8 = 32 marks)****1(a): 32 marks**

(b) (i) Draw the **most** acceptable Lewis dot-dash structure for the molecule  $\text{ISO}_4\text{F}$ . Its skeleton is given below.

**(06 marks)**

(ii) Give oxidation numbers of the S and I atoms in the structure drawn in (i) above.

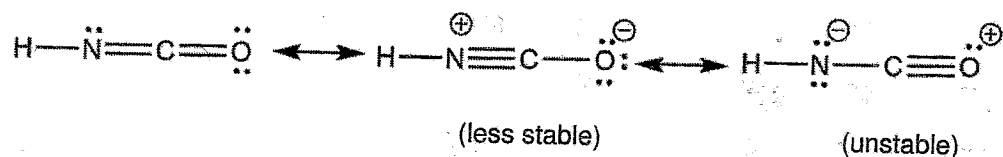
S      +5 or +V      I      +4      or +IV

.....

**(01) + (01)**

**Award marks for (ii) only if the Lewis structure in (i) is correct.**

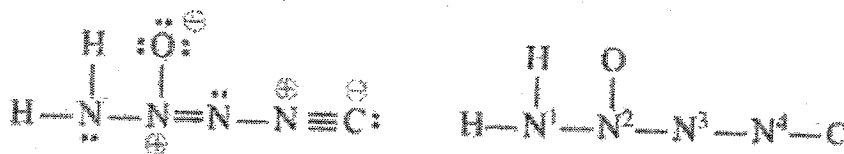
- (iii) An acceptable (stable) Lewis dot-dash structure for the HNCO molecule is given below. Draw **two** more Lewis dot-dash structures (resonance structures) for this molecule and indicate their stabilities relative to the structure given by writing **stable** or **less stable** or **unstable** under these structures.



**(02 marks structure) + (01 mark stability)**

**(06 marks)**

- (iv) Complete the table based on the Lewis dot-dash structure and its labelled skeleton given below.



		N <sup>1</sup>	N <sup>2</sup>	N <sup>3</sup>	N <sup>4</sup>
I	The number of VSEPR pairs around the atom	4	3	3	2
II	electron pair geometry around the atom	tetrahedral	trigonal planar	trigonal planar	linear
III	Shape around the atom	pyramidal / trigonal pyramidal	trigonal planar	angular / V / bent	linear
IV	Hybridization of the atom	sp <sup>3</sup>	sp <sup>2</sup>	sp <sup>2</sup>	sp

**(01 mark X 16 = 16 marks)**

- Parts (v) to (viii) are based on the Lewis dot-dash structure given in part (iv) above. Labelling of atoms is as in part (iv).

(v) Identify atomic/hybrid orbitals involved in the formation of  $\sigma$  bonds between the two atoms given below.

I.	H	1s	N <sup>1</sup>	sp <sup>3</sup>
II.	N <sup>1</sup>	sp <sup>3</sup>	N <sup>2</sup>	sp <sup>2</sup>
III.	N <sup>2</sup>	sp <sup>2</sup>	O	2p / sp <sup>3</sup>
IV.	N <sup>2</sup>	sp <sup>2</sup>	N <sup>3</sup>	sp <sup>2</sup>
V.	N <sup>3</sup>	sp <sup>2</sup>	N <sup>4</sup>	sp
VI.	N <sup>4</sup>	sp	C	2p / sp

(01 mark X 12 = 12 marks)

(vi) Identify the atomic orbitals involved in the formation of  $\pi$  bonds between the two atoms given below.

I.	N <sup>2</sup>	2p	N <sup>3</sup>	2p
II.	N <sup>4</sup>	2p	C	2p
	N <sup>4</sup>	2p	C	2p

(01 mark X 6 = 06 marks)

(vii) State approximate bond angles around the N<sup>1</sup>, N<sup>2</sup>, N<sup>3</sup> and N<sup>4</sup> atoms.

N <sup>1</sup> (107° ± 1)	N <sup>2</sup> (120° ± 1)
N <sup>3</sup> (117° ± 2)	N <sup>4</sup> (180° ± 1)

(01 mark X 4 = 04 marks)

(viii) Arrange the atoms N<sup>1</sup>, N<sup>2</sup>, N<sup>3</sup> and N<sup>4</sup> in increasing order of their electronegativities.

N<sup>1</sup> < N<sup>3</sup> < N<sup>2</sup> < N<sup>4</sup>

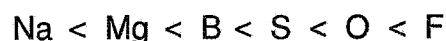
(04 marks)

1(b): 56 marks



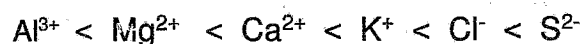
(c) Arrange the following species in the **increasing** order of the property indicated in parenthesis.  
(Reasons are **not** required)

(i) B, O, F, S, Na, Mg (electronegativity)



(06 marks)

(ii)  $\text{K}^+$ ,  $\text{Mg}^{2+}$ ,  $\text{Ca}^{2+}$ ,  $\text{Al}^{3+}$ ,  $\text{Cl}^-$ ,  $\text{S}^{2-}$  (ionic radius)



(06 marks)

**1(c): 12 marks**

2. (a) (i) I. X is an orange coloured ionic compound. It is composed of three elements in the ratio 7:2:2 (not in the order of writing the chemical formula). Of these, two are metals that belong to the same row of the Periodic Table. One of these two metals belongs to the *s*-block and the other to the *d*-block. The *d*-block metal is widely used for electroplating.



II. Y is a mineral acid. It is composed of three elements in the ratio 1:2:4 (not in the order of writing the chemical formula). One of the elements in Y is also found in X. Y is used in the manufacture of phosphate fertilizer.



III. Z is a tri-atomic gas with a pungent smell. It has a V-shape. It is used in the manufacture of Y.



(06 marks x 3 = 18 marks)

(ii) Write the oxidation numbers and the electronic configurations of the two metals in X.

metal K    oxidation number +I    electronic configuration  $1s^2 2s^2 2p^6 3s^2 3p^6$   
or  $1s^2 2s^2 2p^6 3s^2 3p^4 s^1$

metal Cr    oxidation number +VI    electronic configuration  $1s^2 2s^2 2p^6 3s^2 3p^6$   
or  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$

(02 marks x 6 = 12 marks)

- (iii) I. Name the process by which Y is manufactured using Z.  
Contact Process

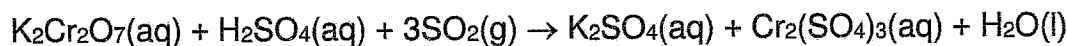
(02 marks)

- II. When the gas formed on reaction of Z with  $O_2(g)$  is dissolved in a concentrated solution of Y, the compound P is formed. When compound P reacts with water, Y is obtained again. Write the name and the chemical formula of compound P.

name Oleum / pyrosulfuric acid / chemical formula (P)  $H_2S_2O_7$   
fuming sulfuric acid / disulfuric acid

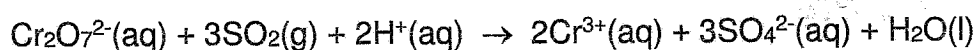
(04 marks x 2 = 08 marks)

- (iv) Write the balanced chemical equation for the reaction taking place when X, Y and Z are reacted together.



(10 marks)

or



(06 marks)

Physical states are not required.

2(a): 50 marks

- (b) A student is provided with eight bottles labelled A, B, C, D, E, F, G and H with aqueous solutions of  $\text{BaCl}_2$ ,  $\text{NaI}$ ,  $\text{Pb}(\text{NO}_3)_2$ , dil.  $\text{HCl}$ ,  $\text{Al}_2(\text{SO}_4)_3$ ,  $\text{AgNO}_3$ , conc.  $\text{NH}_4\text{OH}$  and dil.  $\text{NH}_4\text{OH}$  (not in order). Some useful observations for their identification on mixing two solutions at a time are given below.

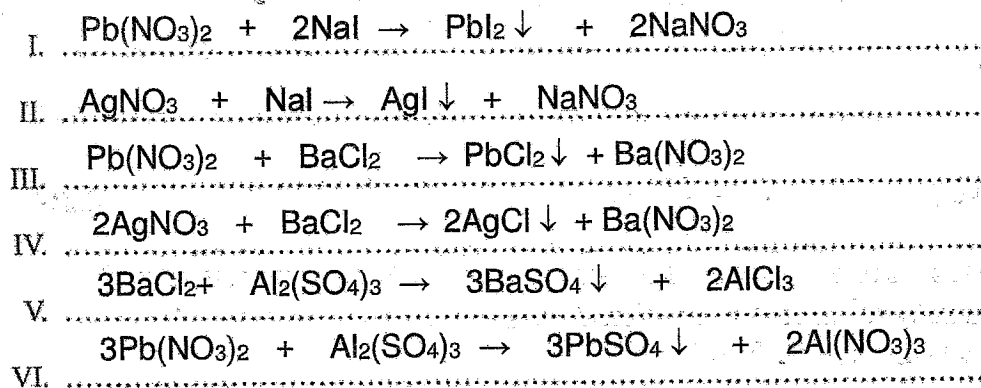
	Solutions Mixed	Observation
I.	A + C	a yellow precipitate soluble in hot water
II.	B + C	a yellow precipitate insoluble in H
III.	A + E	a white precipitate soluble in hot water
IV.	B + E	a white precipitate soluble in D
V.	E + F	a white precipitate insoluble in G
VI.	A + F	a white precipitate insoluble in G
VII.	D + G	a colourless solution
VIII.	H + G	a colourless solution

- (i) Identify A to H.

A	$\text{Pb}(\text{NO}_3)_2$	E	$\text{BaCl}_2$
B	$\text{AgNO}_3$	F	$\text{Al}_2(\text{SO}_4)_3$
C	$\text{NaI}$	G	dil $\text{HCl}$
D	dil $\text{NH}_4\text{OH}$	H	conc $\text{NH}_4\text{OH}$

(04 marks x 8 = 32 marks)

- (ii) Give balanced chemical equations for the formation of precipitates, in each of the reactions I to VI. Use the symbol  $\downarrow$  to indicate precipitates.



(03 marks x 6 = 18 marks)

**Note:** Deduct 01 mark if precipitates are not indicated the using symbol  $\downarrow$

**2(b): 50 marks**

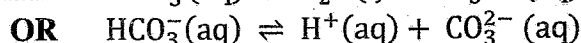
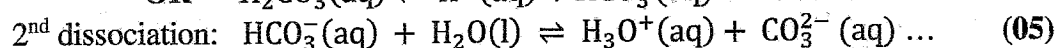
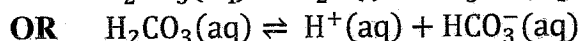
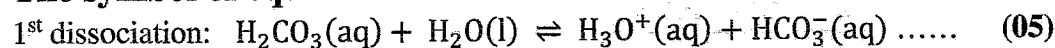
3. (a) At temperature 25 °C, dissociation constants of  $\text{H}_2\text{CO}_3(\text{aq})$  acid are,

$$K_1 = 4.5 \times 10^{-7} \text{ mol dm}^{-3} \text{ and } K_2 = 4.7 \times 10^{-11} \text{ mol dm}^{-3}$$

(i) Write the equilibrium reactions for the first and second dissociations of  $\text{H}_2\text{CO}_3(\text{aq})$ .

i. **NOTE: PHYSICAL STATES ARE NECESSARY**

**The symbol of equilibrium  $\rightleftharpoons$  also needed for all the reactions**



(ii) Considering the first dissociation, calculate the concentrations of  $\text{H}_3\text{O}^+(\text{aq})$  and  $\text{HCO}_3^-(\text{aq})$  in  $0.05 \text{ mol dm}^{-3}$   $\text{H}_2\text{CO}_3(\text{aq})$  solution at 25 °C.

ii.  $K_1 = \frac{[\text{H}_3\text{O}^+(\text{aq})][\text{HCO}_3^-(\text{aq})]}{[\text{H}_2\text{CO}_3(\text{aq})]}$  (05)



$$K_1 = 4.50 \times 10^{-7} = \frac{x \cdot x}{0.05 - x} \approx \frac{x^2}{0.05}$$
 (05)

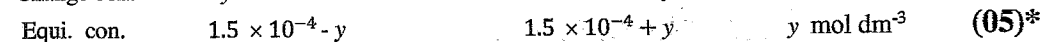
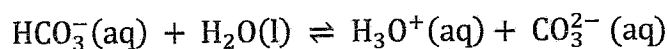
$$x^2 = 225 \times 10^{-10}$$

$$x = 1.5 \times 10^{-4} \text{ mol dm}^{-3}$$
 (04 + 01)

$$[\text{H}_3\text{O}^+(\text{aq})] = [\text{HCO}_3^-(\text{aq})] = 1.5 \times 10^{-4} \text{ mol dm}^{-3}$$
 (04 + 01)

(iii) Considering the second dissociation, show that  $[\text{CO}_3^{2-}(\text{aq})]$  of the solution is approximately equal to  $K_2$ . State any assumption/s made.

iii.  $K_2 = \frac{[\text{H}_3\text{O}^+(\text{aq})][\text{CO}_3^{2-}(\text{aq})]}{[\text{HCO}_3^-(\text{aq})]}$  (05)



$$K_2 = 4.70 \times 10^{-11} = \frac{(1.5 \times 10^{-4} + y) \cdot y}{(1.5 \times 10^{-4} - y)} \approx y$$
 (05)\*

**\*If student writes in words that the amount dissociated from  $\text{HCO}_3^-$  is very small and amount accumulated in  $\text{H}_3\text{O}^+$  is very small, therefore concentration change of the two species are negligible, award these 05 + 05 marks.**

$$[\text{CO}_3^{2-}(\text{aq})] \approx K_2$$
 (05)

Assumption: 2<sup>nd</sup> dissociation is much less compared to the 1<sup>st</sup>. (05)

**3(a): 60 marks**

- (b) You are provided with an aqueous solution containing  $0.01 \text{ mol dm}^{-3} \text{ Al}^{3+}(\text{aq})$  ions and  $0.01 \text{ mol dm}^{-3} \text{ Ag}^{+}(\text{aq})$  ions at temperature  $25^\circ\text{C}$ . To  $1.0 \text{ dm}^3$  of this solution, a concentrated solution of  $\text{PO}_4^{3-}(\text{aq})$  ions was added dropwise with continuous stirring.

At temperature  $25^\circ\text{C}$ ,

$$K_{sp}(\text{AlPO}_4) = 1.3 \times 10^{-20} \text{ mol}^2 \text{ dm}^{-6} \text{ and } K_{sp}(\text{Ag}_3\text{PO}_4) = 8.1 \times 10^{-12} \text{ mol}^4 \text{ dm}^{-12}.$$

- (i) Neglecting any volume change that may occur when the  $\text{PO}_4^{3-}(\text{aq})$  solution is added, state which metal ion ( $\text{Al}^{3+}$  or  $\text{Ag}^{+}$ ) will precipitate first from the mixture. Give reasons for your answer based on a suitable calculation.

i. The precipitates formed are  $\text{AlPO}_4$  and  $\text{Ag}_3\text{PO}_4$

**For  $\text{AlPO}_4$**

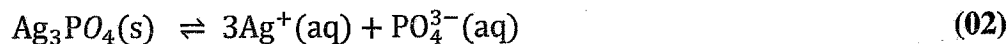


$$K_{sp} = [\text{Al}^{3+}(\text{aq})][\text{PO}_4^{3-}(\text{aq})] \quad (02)$$

$$1.30 \times 10^{-20} = 0.01 \times [\text{PO}_4^{3-}(\text{aq})] \quad (04)$$

$$[\text{PO}_4^{3-}(\text{aq})] = 1.30 \times 10^{-18} \text{ mol dm}^{-3}; \text{ needed to precipitate } \text{AlPO}_4(\text{s}) \quad (03+01)$$

**For  $\text{Ag}_3\text{PO}_4$**



$$K_{sp} = [\text{Ag}^{+}(\text{aq})]^3[\text{PO}_4^{3-}(\text{aq})] \quad (02)$$

$$8.10 \times 10^{-12} = (0.01)^3 \times [\text{PO}_4^{3-}(\text{aq})] \quad (04)$$

$$[\text{PO}_4^{3-}(\text{aq})] = 8.10 \times 10^{-6} \text{ mol dm}^{-3}; \text{ needed to precipitate } \text{Ag}_3\text{PO}_4(\text{s}) \quad (03+01)$$

$$[\text{PO}_4^{3-}(\text{aq})]_{\text{AlPO}_4(\text{s})} < [\text{PO}_4^{3-}(\text{aq})]_{\text{Ag}_3\text{PO}_4(\text{s})} \quad (04)$$

$$\text{AlPO}_4(\text{s}) \text{ precipitates first.} \quad (04)$$

- (ii) Calculate the concentration of the ion which precipitated first when the second ion starts to precipitate.

$$[\text{Al}^{3+}(\text{aq})] \text{ left in the solution after precipitation of } \text{AlPO}_4(\text{s}) = \frac{K_{sp}(\text{AlPO}_4(\text{s}))}{8.10 \times 10^{-6}} \quad (04)$$

$$\begin{aligned} [\text{Al}^{3+}(\text{aq})] \text{ left in the solution} &= \frac{1.30 \times 10^{-20}}{8.10 \times 10^{-6}} \\ &= 1.6 \times 10^{-15} \text{ mol dm}^{-3} \end{aligned} \quad (03+01)$$

**3(b): 40 marks**

4. (a) • The organic compound A having the molecular formula  $C_5H_{10}O_3$  reacts with excess  $PCl_5$  to give compound B, having a relative molecular mass of 155. Compound A liberates  $CO_2$  with aqueous  $Na_2CO_3$ . (C = 12.0, H = 1.0, O = 16.0, Cl = 35.5)

(i) Write the functional groups present in compound A.

OH / hydroxy/ hydroxyl, COOH / carboxylic acid

Note: no marks if 'acid' is not written

(05 marks x 2 = 10 marks)

- Compound A does not exhibit optical isomerism. Compound A reacts with pyridinium chlorochromate to give compound C. Compound C gives a silver mirror with ammoniacal  $AgNO_3$ . Compound B reacts with water to form compound D. Compound D reacts with alcoholic KOH to give the product E which contains a double bond.

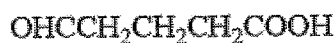
(ii) Draw the structures of A, B, C, D and E in the relevant boxes.



A



B



C



D



OR



E

(07 marks x 5 = 35 marks)

- Compound F is a structural isomer of A. Compound F reacts with excess  $\text{PCl}_5$  to give compound G having a relative molecular mass of 155. Compound F does not liberate  $\text{CO}_2$  with aqueous  $\text{Na}_2\text{CO}_3$ . Compound F exhibits optical isomerism. Compound F does not give a turbidity when treated with conc.  $\text{HCl}$ /anhydrous  $\text{ZnCl}_2$ . Compound F forms a coloured precipitate with 2,4-dinitrophenylhydrazine (2,4-DNP) and gives a silver mirror with ammoniacal  $\text{AgNO}_3$ .

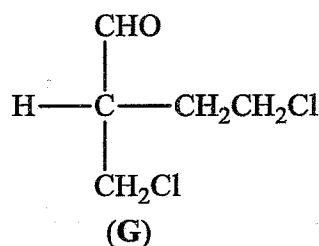
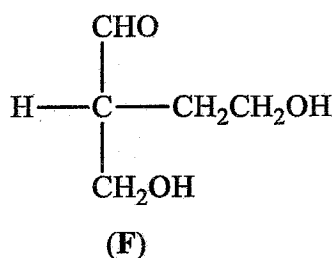
(iii) Write the functional groups present in F.

CHO / aldehyde , OH / hydroxy/ hydroxyl

**Note:** If both are correct, award 09 marks. If only one is correct, award 05 marks only.

**(05 marks + 04 marks = 09 marks)**

(iv) Draw the structures of F and G in the relevant boxes.

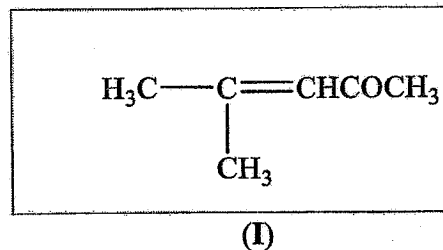
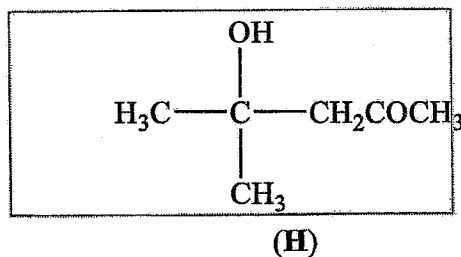


**(07 marks x 2 = 14 marks)**

**4(a): 68 marks**

(b) (i) Draw the structure of the product H formed in the relevant box when acetone is reacted with dilute aqueous  $\text{NaOH}$ .

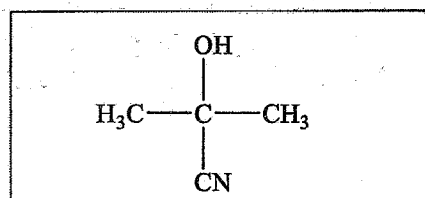
(ii) Draw the structure of the product I formed in the relevant box when H is heated with hydrochloric acid.



**(06 marks x 2 = 12 marks)**

**4(b): 12 marks**

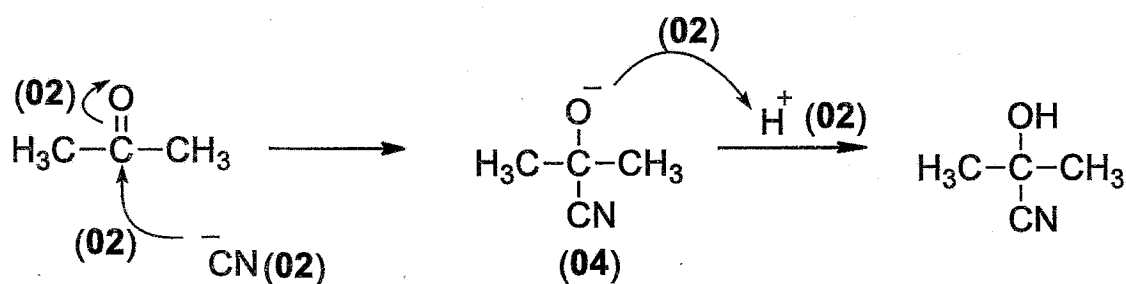
- (c) (i) Draw the structure of the product J formed in the relevant box from the reaction between acetone and HCN.



(J)

(06 marks)

- (ii) Write the mechanism of the above reaction.



**Notes:**

IF HCN is used instead of  $\text{CN}^-$  deduct the 02 marks allocated for  $\text{CN}^-$ .

(14 Marks)

**4(c): 20 marks**



## PART B — ESSAY

Answer two questions only. (Each question carries 150 marks.)

## NOTE: PHYSICAL STATES ARE NECESSARY

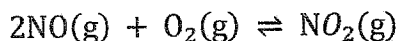
5. (a) A mixture of NO(g) and O<sub>2</sub>(g) in 2:1 molar ratio respectively, was introduced to a rigid closed container of volume 10 dm<sup>3</sup> and allowed to react at temperature *T*. After a certain time, the system reached the equilibrium as given below, at temperature *T*.



At equilibrium, the following observations were noted.

- The pressure of the gaseous mixture was  $32 \times 8.314 \times 10^3$  Pa.
- The total number of moles of the three gases was 0.64.
- The mass of O<sub>2</sub> was 6.4 g.

- (i) Calculate the concentration of each gaseous species in mol dm<sup>-3</sup> at equilibrium. (O = 16)



$$\text{Moles of O}_2(\text{g}) = \frac{6.4 \text{ g}}{32 \text{ g mol}^{-1}} = 0.20 \quad (02)$$

$$\text{Con. of O}_2(\text{g}) = \frac{0.20 \text{ mol}}{10 \text{ dm}^3} = 2.0 \times 10^{-2} \text{ mol dm}^{-3} \quad (02+01)$$

$$\text{Moles of NO}(\text{g}) = 0.40 \text{ (2:1 ratio given)} \quad (02)$$

$$\text{Con. of NO}(\text{g}) = \frac{0.40 \text{ mol}}{10 \text{ dm}^3} = 4.0 \times 10^{-2} \text{ mol dm}^{-3} \quad (02+01)$$

$$\text{Moles of NO}_2(\text{g}) = 0.64 - (0.40 + 0.20) = 0.04 \quad (02)$$

$$\text{Con. of NO}_2(\text{g}) = \frac{0.04 \text{ mol}}{10 \text{ dm}^3} = 4.0 \times 10^{-3} \text{ mol dm}^{-3} \quad (02+01)$$

- (ii) Calculate the equilibrium constant, *K<sub>c</sub>* at temperature *T*.

$$K_c = \frac{[\text{NO}_2(\text{g})]^2}{[\text{O}_2(\text{g})][\text{NO}(\text{g})]^2} \quad (05)$$

$$K_c = \frac{[4.0 \times 10^{-3} \text{ mol dm}^{-3}]^2}{[2.0 \times 10^{-2} \text{ mol dm}^{-3}][4.0 \times 10^{-2} \text{ mol dm}^{-3}]^2} \quad (05)$$

$$K_c = 0.50 \text{ mol}^{-1} \text{ dm}^3 \quad (05)$$

- (iii) Calculate the value of temperature  $T$  (in K) under these conditions. State any assumption/s made.

Assuming ideal gas behavior (03)

$$PV = nRT \quad (02)$$

$$T = \frac{PV}{nR}$$

$$T = \frac{32 \times 8.314 \times 10^3 \text{ Pa} \times 10 \times 10^{-3} \text{ m}^3}{0.64 \text{ mol} \times 8.314 \text{ J K}^{-1} \text{ mol}^{-1}} \quad (05)$$

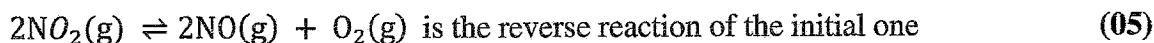
$$T = 500 \text{ K} \quad (04+01)$$

- (iv) Calculate the equilibrium constant  $K_p$  for the reaction,



at the temperature determined in (iii) above.

Reaction of concern is



If the equilibrium constant is  $K'_C$

$$K'_C = \frac{1}{K_C} \quad (05)$$

$$= \frac{1}{0.50} = 2 \text{ mol dm}^{-3} \quad (04+01)$$

$$K_p = K_C (RT)^{\Delta n} \quad \Delta n = 1 \quad (03+02)$$

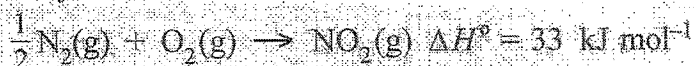
$$K_p = 2 (8.314 \text{ J K}^{-1} \text{ mol}^{-1} \times 500 \text{ K})$$

$$K_p = 8.314 \times 10^3 \text{ Pa} \quad (04+01)$$

5(a): 70 marks

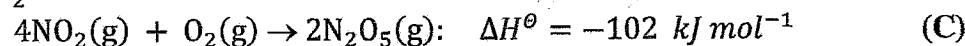
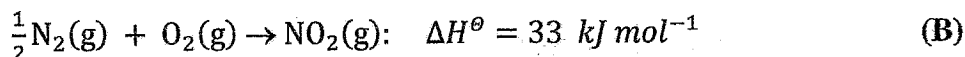
- (b) Consider the information given below at temperature 298 K.

$$\Delta H_f^\circ (\text{NO}(\text{g})) = 90 \text{ kJ mol}^{-1}$$

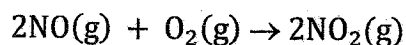


b. Information given:

$$\Delta H_f^\circ (\text{NO}(\text{g})) = 90 \text{ kJ mol}^{-1} \quad (\text{A})$$



i. Reaction needed:



From (A),  $\Delta H_f^\theta(\text{NO}(\text{g}))$ :  $\frac{1}{2}\text{N}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{NO}(\text{g})$ :  $\Delta H^\theta = 90 \text{ kJ mol}^{-1}$ . (D) (05)

(B) - (D) :  $\frac{1}{2}\text{O}_2(\text{g}) + \text{NO}(\text{g}) \rightarrow \text{NO}_2(\text{g}) \dots\dots$  (E) (05)

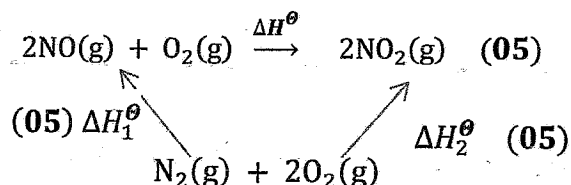
$$\Delta H^\theta = (33 - 90) = -57 \text{ kJ mol}^{-1} \quad (05+05)$$

(E)  $\times 2$  :  $2\text{NO}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}_2(\text{g})$   $\Delta H^\theta = -114 \text{ kJ mol}^{-1}$  (04+01)

**OR:** (B)  $\times 2$  - (D)  $\times 2$  :  $2\text{NO}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}_2(\text{g})$  (05+05)

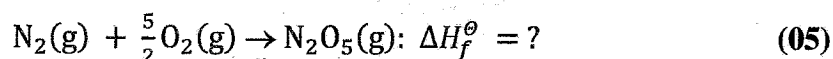
$$\Delta H^\theta = (66 - 180) \text{ kJ mol}^{-1} \quad (05+05)$$

$$\Delta H^\theta = -114 \text{ kJ mol}^{-1} \quad (04+01)$$

**OR**

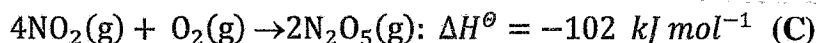
From Hess's law:  $\Delta H^\theta = \Delta H_2^\theta - \Delta H_1^\theta = (2 \times 33 - 2 \times 90) \text{ kJ mol}^{-1}$  (05)

$$= -114 \text{ kJ mol}^{-1} \quad (04 + 01)$$

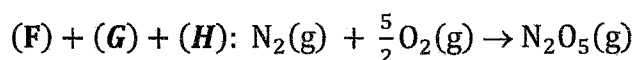
**OR other acceptable method(s)**ii. Formation reaction of  $2\text{N}_2\text{O}_5(\text{g})$ :

Information:  $\frac{1}{2}\text{N}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{NO}(\text{g})$ :  $\Delta H^\theta = 90 \text{ kJ mol}^{-1} \dots\dots$  (D)

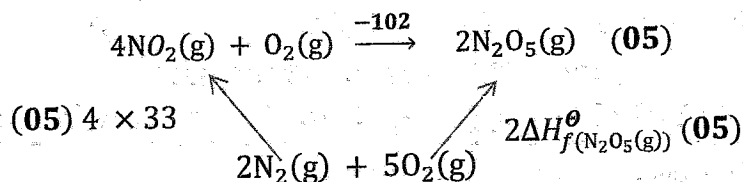
(D)  $\times 2$  :  $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}(\text{g})$ :  $\Delta H^\theta = 180 \text{ kJ mol}^{-1} \dots\dots$  (F) (05+05)



(C)  $\div 2$  :  $2\text{NO}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{N}_2\text{O}_5(\text{g})$ :  $\Delta H^\theta = -51 \text{ kJ mol}^{-1} \dots\dots$  (H) (05)



$$\Delta H_f^\theta(\text{N}_2\text{O}_5(\text{g})) = [180 + (-114) + (-51)] \text{ kJ mol}^{-1} = 15 \text{ kJ mol}^{-1} \quad (05+04+01)$$

**OR**

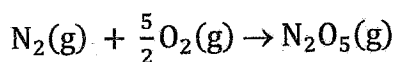
From Hess's law:  $2\Delta H_f^\theta(\text{N}_2\text{O}_5(\text{g})) = (4 \times 33 - 102) \text{ kJ mol}^{-1} \quad (05 + 05)$

$$\Delta H_f^\theta(\text{N}_2\text{O}_5(\text{g})) = 15 \text{ kJ mol}^{-1} \quad (04 + 01)$$

**OR other acceptable method(s)**

(iii) Using the results obtained in (ii) above, predict the following.

I. the sign of  $\Delta S_f^\theta(\text{N}_2\text{O}_5(\text{g}))$



3.5 moles  $\rightarrow$  1 mole : number of moles decreased (05)

$\Delta H_s^\theta(\text{N}_2\text{O}_5(\text{g}))$  is negative ( $< 0$ ) (05)

II. spontaneity of the reaction for the formation of  $\text{N}_2\text{O}_5(\text{g})$  from  $\text{N}_2(\text{g})$  and  $\text{O}_2(\text{g})$

$$\Delta G^\theta = \Delta H^\theta - T\Delta S^\theta \quad (05)$$

$$= +ve - (+ve)(-ve) = +ve \quad (05)$$

The reaction is non-spontaneous at 298 K (05)

**5(b): 80 marks**

**NOTE: PHYSICAL STATES ARE NECESSARY**

6. (a) According to the kinetic molecular theory of gases, for an ideal gas at temperature  $T$ ,  $PV = \frac{1}{3} mN\overline{C^2}$ . Here  $P$  is the pressure of the gas,  $V$  is the volume of the gas,  $m$  is the mass of a gas molecule,  $N$  is the number of molecules of gas and  $\overline{C^2}$  is the mean square speed of the gas.

- (i) Show that  $\overline{C^2} = \frac{3RT}{M}$  for an ideal gas.  $M$  is the molar mass of the gas.

$$PV = \frac{1}{3} mN\overline{C^2} = \frac{1}{3} m(nN_A)\overline{C^2} \quad : n - \text{moles}, N_A - \text{Avogadro no} \quad (04)$$

$$= \frac{1}{3} nM\overline{C^2} \quad : M - \text{molar mass} \quad (04)$$

$$PV = nRT = \frac{1}{3} nM\overline{C^2} \quad (04)$$

$$\overline{C^2} = \frac{3RT}{M} \quad (04)$$

- (ii) A and B are two ideal gases with molar masses  $M_A$  and  $M_B$  respectively. Show that the mean square speed of gas B ( $\overline{C_B^2}$ ) at temperature  $T = 300 \frac{M_B}{M_A}$ , is equal to the mean square speed of gas A ( $\overline{C_A^2}$ ) at  $T = 300$ . (Temperatures are given in kelvin)

$$\text{For gas A: } \overline{C_A^2} = \frac{3RT}{M_A} = \frac{3R \times 300}{M_A} \quad (1)$$

$$\text{For gas B: } \overline{C_B^2} = \frac{3RT}{M_B} = \frac{3R \times 300 \left(\frac{M_B}{M_A}\right)}{M_B} = \frac{3R \times 300}{M_A} \quad (2) \quad (04+04)$$

$$(1) = (2): \quad \overline{C_A^2} = \overline{C_B^2} \quad (04)$$

- (iii) Derive an expression for the ratio between the molar kinetic energies of the two gases A and B at any given temperature  $T$ .

$$\text{For gas A: } (KE)_A = \frac{3RT_A}{2} \quad (04)$$

$$\text{For gas B: } (KE)_B = \frac{3RT_B}{2} \quad (04)$$

$$\text{As } T_A = T_B: (KE)_A = (KE)_B \quad (04)$$

**OR-** Kinetic energy of a gas depends only on the absolute temperature

$$(KE)_A = (KE)_B \quad (12)$$

**6(a): 40 marks**

- (b) (i) Define the term 'an elementary reaction'.

Elementary Reaction: A reaction occurs through a single step (without involving an intermediate).

(05)\*

- (ii) Define the term 'molecularity' of a reaction.

Molecularity: Total number of reacting molecules participating in an elementary reaction or in the rate determining step of a reaction.

(05)

- (iii) For an elementary reaction what is the relationship between 'reaction order' and 'molecularity'?

Elementary reaction : Reaction order = Molecularity

(05)\*

- (iv) The following table gives the variation of the concentration of the reactant in a reaction with time.

Time (minutes)	0	10	20	30	40
Reactant concentration (mol dm <sup>-3</sup> )	1.6	0.8	0.4	0.2	0.1

Reaction order = Molecularity

In 10 minutes time the concentration decreased to half of the initial concentration (05)

This is consistent with all the 10 min time intervals

(05)

I) Reaction is first order

(05)

II) Half-life ( $t_{1/2}$ ) of the reaction is 10 min

(05)

\* Note: If student has attempted Q 6 (b), award marks for parts i and iii

- (v) Consider the information given below for two first order reactions ① and ② at a given temperature.

	Reaction	Reaction rate/ mol dm <sup>-3</sup> s <sup>-1</sup>	Rate constant/s <sup>-1</sup>	Half-life/s
①:	$A \rightarrow P_1$	$r_A$	$k_A$	$(t_{1/2})_A$
②:	$B \rightarrow P_2$	$r_B$	$k_B$	$(t_{1/2})_B$
	(P <sub>1</sub> , P <sub>2</sub> = Products)			

A first order reaction with rate constant,  $k$  has a half-life,  $t_{1/2} = \frac{0.693}{k}$ .

If  $r_B = 3r_A$  when  $[B] = 2[A]$ , show that  $2(t_{1/2})_A = 3(t_{1/2})_B$ .

As the reactions are first order,

$$r_A = k_A[A]: \quad k_A = \frac{r_A}{[A]} \quad (03+02)$$

$$r_B = k_B[B]: \quad k_B = \frac{r_B}{[B]} \quad (03+02)$$

Given that:  $[B] = 2[A]$ ,  $r_B = 3r_A$  and  $t_{1/2} = \frac{0.693}{k}$

We can write;  $k_A = \frac{r_A}{[A]}$  .....(I)

$$k_B = \frac{3r_A}{2[A]} \text{ .....(II)} \quad (05)$$

$$(I) \div (II) \text{ gives } \frac{k_A}{k_B} = \frac{2}{3} \quad (05+05)$$

$$\frac{(t_{1/2})_A}{(t_{1/2})_B} = \frac{0.693/k_A}{0.693/k_B} = \frac{k_B}{k_A} = \frac{3}{2} \quad (05+05)$$

$$2(t_{1/2})_A = 3(t_{1/2})_B \quad (05)$$

**6(b): 75 marks**

(c) At temperature  $25^\circ\text{C}$ ,  $50.0 \text{ cm}^3$  of  $0.30 \text{ g dm}^{-3}$  iodine aqueous solution was shaken well with  $10.0 \text{ cm}^3$  of  $\text{CCl}_4$ . When the system reached equilibrium the concentration of iodine in the water layer was found to be  $0.02 \text{ g dm}^{-3}$ .

(i) Calculate the concentration of iodine in the  $\text{CCl}_4$  layer at equilibrium.

$$\text{Initial } I_2 \text{ mass in water layer} = 0.30 \text{ g dm}^{-3} \times 50 \times 10^{-3} \text{ dm}^3 = 0.015 \text{ g} \quad (03)$$

$$\text{Equilibrium } I_2 \text{ mass in water layer} = 0.02 \text{ g dm}^{-3} \times 50 \times 10^{-3} \text{ dm}^3 = 0.001 \text{ g} \quad (03)$$

$$\text{Equilibrium } [I_2]_{H_2O} = \frac{(0.001 \text{ g})}{50 \times 10^{-3} \text{ dm}^3} = 0.02 \text{ g dm}^{-3}$$

$$\text{Equilibrium } I_2 \text{ mass in } \text{CCl}_4 \text{ layer} = (0.015 - 0.001) \text{ g} = 0.014 \text{ g} \quad (03)$$

$$\text{Equilibrium } [I_2]_{\text{CCl}_4} = \frac{(0.014 \text{ g})}{10 \times 10^{-3} \text{ dm}^3} = 1.4 \text{ g dm}^{-3} \quad (03+03+01)$$

(ii) At temperature  $25^\circ\text{C}$ , calculate the partition co-efficient of  $I_2$  between  $\text{CCl}_4$  and water.

$$K_D = \frac{[I_2]_{\text{CCl}_4}}{[I_2]_{H_2O}} = \frac{1.4 \text{ g dm}^{-3}}{0.02 \text{ g dm}^{-3}} = 70 \quad (03+03)$$

(iii) If the above experiment was done at  $25^\circ\text{C}$  with  $20.0 \text{ cm}^3$  of  $\text{CCl}_4$  instead  $10.0 \text{ cm}^3$ , calculate the concentration of iodine in the water layer at equilibrium.

At this stage take  $I_2$  mass in  $\text{H}_2\text{O}$  layer as  $x$

$$K_D = 70 = \frac{[I_2]_{\text{CCl}_4}}{[I_2]_{H_2O}} = \frac{(0.015-x)/20}{x/50} \quad (05)$$

$$x = 0.0005 \text{ g}$$

$$(04)[I_2]_{H_2O} = \frac{(0.0005 \text{ g})}{50 \times 10^{-3} \text{ dm}^3} = 0.01 \text{ g dm}^{-3} \quad (03+01)$$

**Alternate answer:**At this stage take  $I_2$  mass in  $CCl_4$  layer as  $x$ 

$$K_D = 70 = \frac{[I_2]_{CCl_4}}{[I_2]_{H_2O}} = \frac{x/20}{(0.015-x)/50} \quad (05)$$

$$x = 0.0145 \text{ g} \quad (02)$$

$$I_2 \text{ mass in water layer} = 0.0150 - 0.0145 = 0.0005 \text{ g} \quad (02)$$

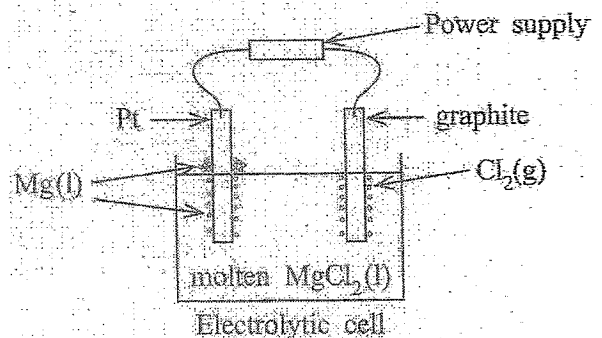
$$[I_2]_{H_2O} = \frac{(0.0005 \text{ g})}{50 \times 10^{-3} \text{ dm}^3} = 0.01 \text{ g dm}^{-3} \quad (03+01)$$

**6(c): 35 marks****NOTE: PHYSICAL STATES ARE NECESSARY**

7.(a) Mg metal can be extracted by the electrolysis of molten  $MgCl_2(l)$  using inert electrodes (examples: Pt, graphite). A simple setup for this is shown in the diagram.

$$E^\circ_{Mg^{2+}(l)/Mg(s)} = -2.37 \text{ V}$$

$$E^\circ_{H_2O(l)/H_2(g)} = -0.63 \text{ V}$$



(i) Identify the anode and the cathode. Write the half reaction taking place at each electrode.

ElectrodeHalf-reaction

Anode : C(graphite, s)| $Cl_2(g)$ | $MgCl_2(l)$   $2Cl^-(l) \rightarrow Cl_2(g) + 2e$  (05+05)

Cathode : Pt(s)|Mg(s)| $MgCl_2(l)$   $Mg^{2+}(l) + 2e \rightarrow Mg(s) \text{ or } Mg(l)$  (05+05)

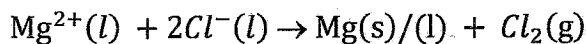
**OR**

$MgCl_2(l) \rightarrow Mg(s)/(l) + Cl_2(g)$  (05)



(ii) Write the overall cell reaction.

Overall cell reaction:



OR



(iii) State the direction of electron flow through the external circuit as the cell operates.

from C(graphite, s)|Cl<sub>2</sub>(g) anode to Pt(s)|Mg(s) cathode (05)

(iv) Explain the following:

I. Molten MgCl<sub>2</sub>(l) is used instead of MgCl<sub>2</sub>(s) in this extraction process.

Solid or crystalline MgCl<sub>2</sub>(s) has no movable ions. Molten state has ionic

Mg<sup>2+</sup>(l) and Cl<sup>-</sup>(l). (05)

II. A solution of MgCl<sub>2</sub>(aq) cannot be used in this extraction process.

Water molecules would reduce to H<sub>2</sub>(g) instead of Mg<sup>2+</sup>(l) (05)

(v) If a 5.37 A current is passed through this cell for one hour and the Cl<sub>2</sub>(g) formed is collected at temperature 300 K and pressure 1 atm (~1.0 × 10<sup>5</sup> Pa), calculate the volume

$$Q = It \quad (05)$$

$$= 5.37 \text{ A} \times (60 \times 60) = 19300 \text{ C} \quad (04+01)$$

$$\text{Moles of electrons} = 19300/96500 = 0.2 \text{ mol} \quad (05)$$

$$2 \text{ mol of electrons} \equiv 1 \text{ mol of Cl}_2(\text{g})$$

$$\text{Moles of Cl}_2(\text{g}) \text{ produced} = 0.10 \text{ mol} \quad (05)$$

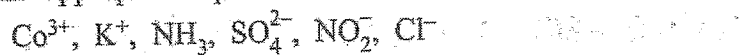
Assuming an ideal gas behavior: PV = nRT (05)

$$V = \frac{nRT}{P} = \frac{0.10 \text{ mol} \times 8.314 \text{ J K}^{-1} \text{ mol}^{-1} \times 300 \text{ K}}{1 \times 10^5 \text{ Pa}} \quad (05)$$

$$= 249.4 \times 10^{-5} \text{ m}^3 \text{ or } 2.49 \text{ dm}^3 \quad (04+01)$$

**7(a): 75 marks**

- (b) (i) P, Q, R, S and T are coordination compounds of Co(III). They have an octahedral geometry. Give the structural formulae or draw the structures of these coordination compounds, selecting the appropriate species from the list given below.



**Note:** In the above coordination compounds  $\text{NO}_2^-$  behaves as a monodentate ligand when attached to the metal ion.

**P** – Only neutral ligands are coordinated to the metal ion. On reaction of an aqueous solution of **P** with dil. HCl, reddish-brown fumes are evolved. **P** gives four ions in aqueous solution.

**Q** – Two types of ligands are coordinated to the metal ion. They are neutral ligands and mono-atomic anionic ligands. A white precipitate insoluble in dilute acid is formed on addition of  $\text{BaCl}_2(\text{aq})$  to an aqueous solution of **Q**. **Q** gives two ions in aqueous solution.

**R** – Two types of ligands are coordinated to the metal ion. They are neutral ligands and multi-atomic anionic ligands. **R** shows geometric isomerism. On reaction of an aqueous solution of **R** with  $\text{AgNO}_3(\text{aq})$ , a white precipitate is formed. This precipitate is soluble in dil.  $\text{NH}_4\text{OH}$ . **R** gives two ions in aqueous solution.

**S** – It is a non-ionic compound. An equal number of neutral ligands and multi-atomic anionic ligands are coordinated to the metal ion.

**T** – Only mono-atomic anionic ligands are coordinated to the metal ion. **T** gives four ions in aqueous solution.

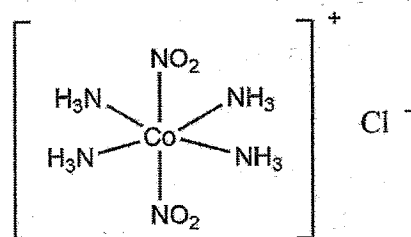
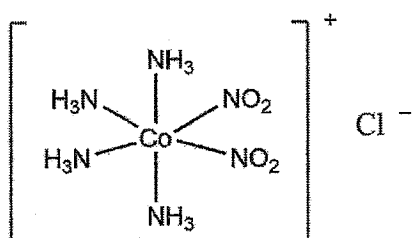


(7 (b) (i) 50 marks)

- (ii) I. Write the IUPAC name of **T**.

potassium hexachloridocobaltate(III) (10)

II. Draw the structures of the geometric isomers of R.



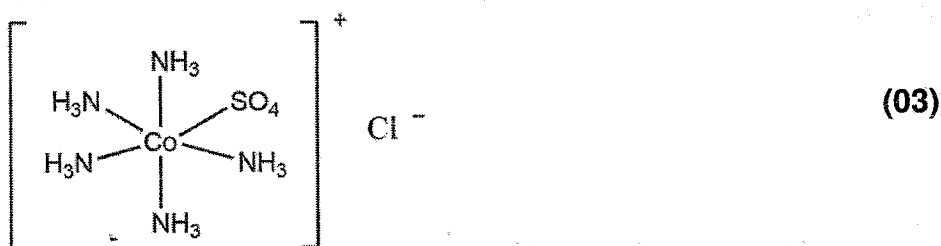
(05 marks)\*

(If both are correct 05 marks. If only one is correct 03 marks)

**\*Note:** Although geometric isomerism is commonly taught in A/Levels, students may not be familiar with them in coordinate complexes. Therefore, as a concession, marks will be awarded in the following manner for 7 b (i) R and (ii) II.

(i) R:  $[\text{Co}(\text{NH}_3)_5(\text{SO}_4)]\text{Cl}$  (06)

(ii) II.



(03)

(iii) X is a coordination compound of  $\text{Co(III)}$  with an octahedral geometry. The ligands  $\text{H}_2\text{O}$  and  $\text{CO}_3^{2-}$  are coordinated to the metal ion. On treatment of an aqueous solution of X with  $\text{AgNO}_3(\text{aq})$  a pale yellow precipitate, soluble in conc.  $\text{NH}_4\text{OH}$  is formed. X gives two ions in aqueous solution. Give the structural formula or draw the structure of X.

Note:  $\text{CO}_3^{2-}$  coordinates to the metal ion through two oxygen atoms.

$[\text{Co}(\text{H}_2\text{O})_4(\text{CO}_3)]\text{Br}$  (10)

7(b): 75 marks

Answer two questions only. (Each question carries 150 marks.)

8. (a)

$\text{CH}_3\text{CH}_2\text{OH} \xrightarrow{\text{Reaction 1}} \text{P} \xrightarrow{\text{Reaction 2}} \text{Q}$

$\downarrow \text{Reaction 3}$

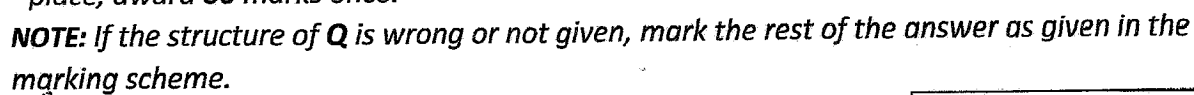
$\text{R}$

$\downarrow \text{Q}$

$\text{S} \xrightarrow{\text{Reaction 4}} \text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_3 \xrightarrow{\text{Reaction 5}} \text{T} \xrightarrow{\text{Q}} \text{U} \xrightarrow{\text{Reaction 6}} \text{CH}_3\text{C}(\text{OH})(\text{CH}_2\text{CH}_3)_2$

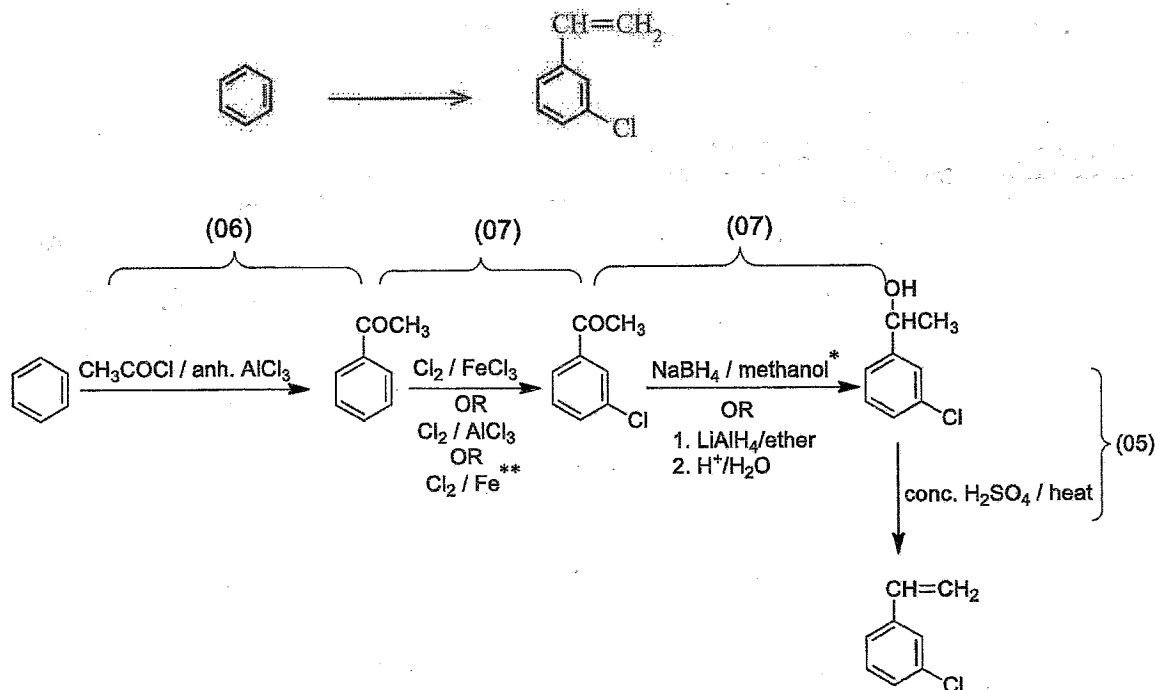
$\text{V}$

Dilute  $\text{H}_2\text{SO}_4$ , Mg/dry ether,  $\text{PBr}_3$ , Pyridinium chlorochromate (PCC)



**8(a): 60 marks**

(b) (i) Show how you would carry out the following conversion in not more than four (04) steps.



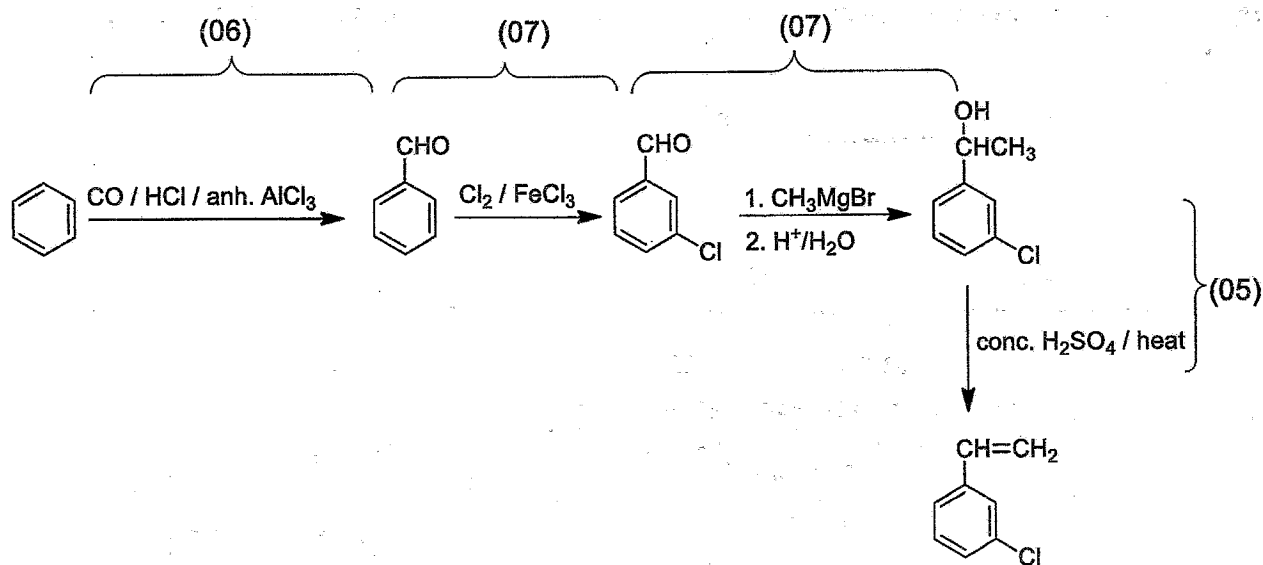
\*Methanol is necessary for the reaction. If methanol is not written deduct 01 mark.

\*\*This is obsolete and not given in the syllabus or in the teacher guide. But it seems that it has been continuously taught in certain schools. Hence in fairness to the students it is included in the marking scheme.

(25 marks)

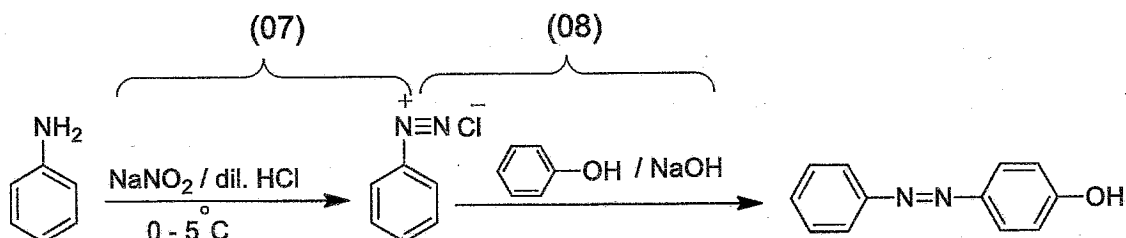
**Alternative answer:**

Although the conversion of benzene to benzaldehyde is not given in the syllabus or in the teacher guide, it seems that it has been continuously taught in certain schools. Hence in fairness to the students the following alternative answer is included in the marking scheme.



(25 marks)

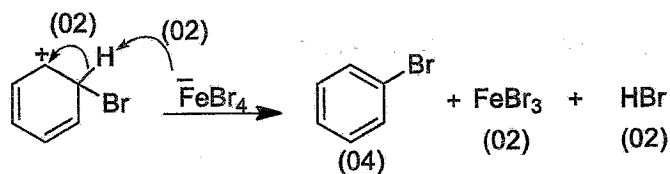
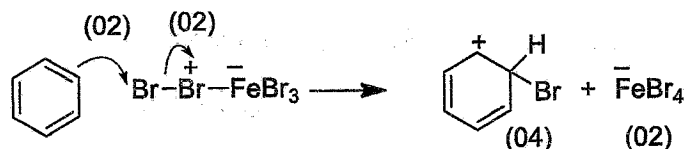
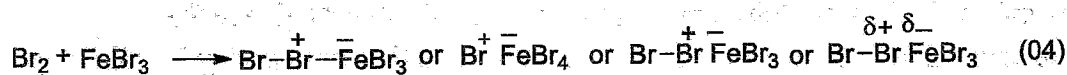
(ii) Propose a method to prepare  $\text{C}_6\text{H}_5\text{N}=\text{NC}_6\text{H}_4\text{OH}$  from aniline in not more than two (02) steps.



(15 marks)

8(b): 40 marks

- (c) (i) Write the product and the mechanism of the reaction that takes place between benzene and bromine in the presence of anhydrous  $\text{FeBr}_3$ .



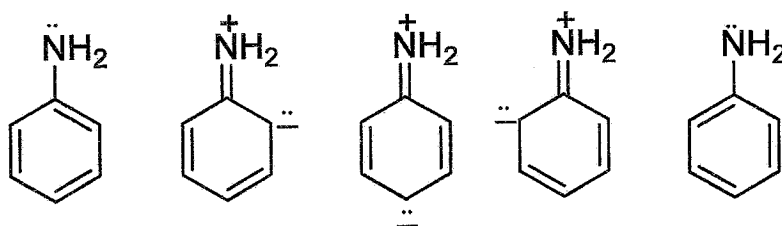
(26 marks)

- (ii) Draw the resonance structures of benzene and aniline.

Resonance structures of benzene



Resonance structures of aniline



Note: IF the lone pair is not written, deduct 02 marks once.

(02 marks x 7 = 14 marks)

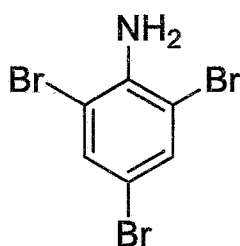
- (iii) Considering the above resonance structures, explain why the benzene nucleus in aniline is more reactive towards electrophilic substitution reactions than benzene itself.

The benzene ring in aniline is electron rich compared to benzene (03 marks) due to the delocalization of the lone pair of electrons on the nitrogen atom, into the benzene ring in aniline (03 marks).

Therefore, benzene ring in aniline is more reactive towards electrophiles, than benzene.

(06 Marks)

- (iv) Draw the structure of the product formed when aniline reacts with bromine.



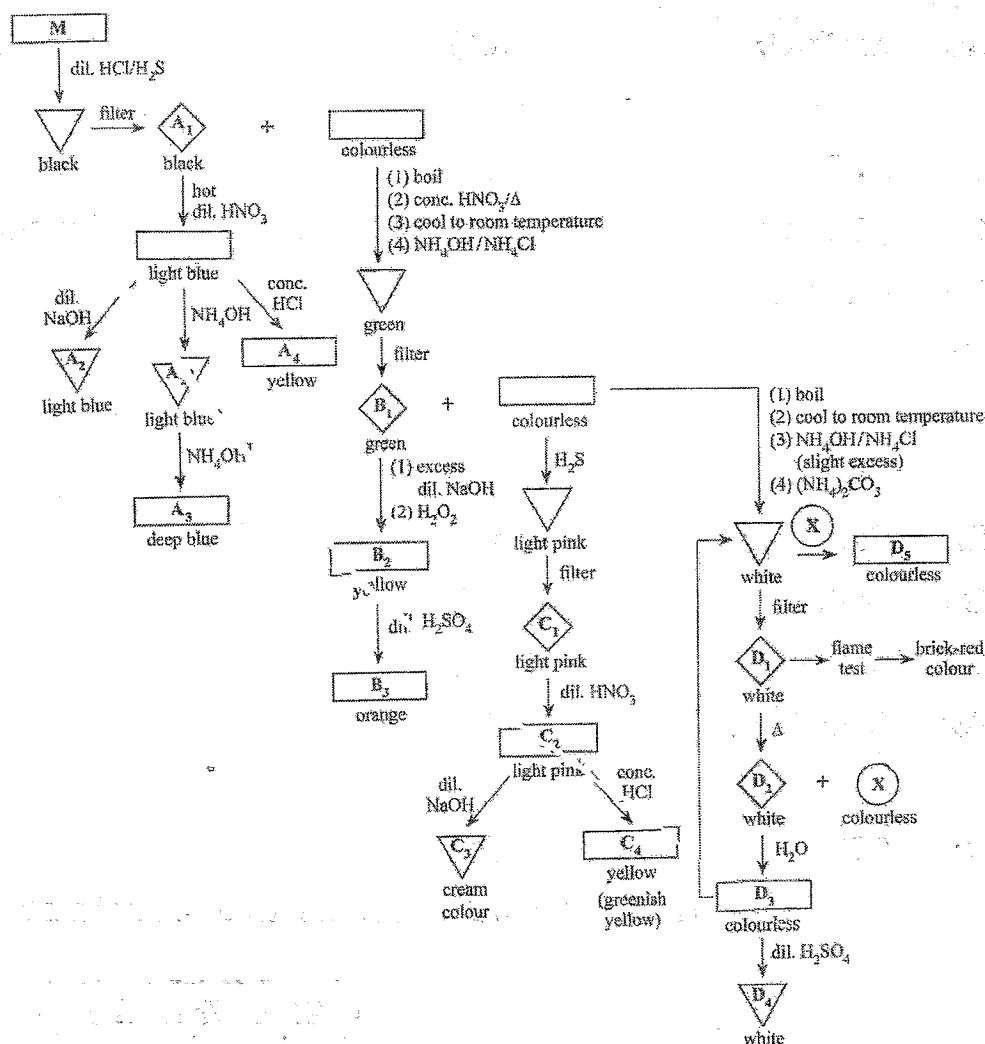
(04 marks)

8(c): 50 marks



**M** is analysed according to the scheme given below.

			
precipitate with solution	solid	solution	gas



(Note : Write **only** chemical formulae. Chemical equations and reasons are **not** required.)

<b>A<sub>1</sub>:</b>	<b>CuS</b>	<b>(06)</b>
<b>A<sub>2</sub>:</b>	<b>Cu(OH)<sub>2</sub></b>	<b>(04)</b>
<b>A<sub>3</sub>:</b>	<b>[Cu(NH<sub>3</sub>)<sub>4</sub>]<sup>2+</sup></b>	<b>(04)</b>
<b>A<sub>4</sub>:</b>	<b>[CuCl<sub>4</sub>]<sup>2-</sup></b>	<b>(04)</b>
<b>B<sub>1</sub>:</b>	<b>Cr(OH)<sub>3</sub></b>	<b>(06)</b>
<b>B<sub>2</sub>:</b>	<b>Na<sub>2</sub>CrO<sub>4</sub></b>	<b>(04)</b>
<b>B<sub>3</sub>:</b>	<b>Na<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub></b>	<b>(04)</b>
<b>C<sub>1</sub>:</b>	<b>MnS</b>	<b>(06)</b>
<b>C<sub>2</sub>:</b>	<b>[Mn(H<sub>2</sub>O)<sub>6</sub>]<sup>2+</sup></b>	<b>(04) Note: If Mn<sup>2+</sup>(aq) only 02 marks</b>
<b>C<sub>3</sub>:</b>	<b>Mn(OH)<sub>2</sub></b>	<b>(04)</b>
<b>C<sub>4</sub>:</b>	<b>[MnCl<sub>4</sub>]<sup>2-</sup></b>	<b>(04)</b>
<b>D<sub>1</sub>:</b>	<b>CaCO<sub>3</sub></b>	<b>(06)</b>
<b>D<sub>2</sub>:</b>	<b>CaO</b>	<b>(04)</b>
<b>D<sub>3</sub>:</b>	<b>Ca(OH)<sub>2</sub></b>	<b>(04)</b>
<b>D<sub>4</sub>:</b>	<b>CaSO<sub>4</sub></b>	<b>(04)</b>
<b>D<sub>5</sub>:</b>	<b>Ca(HCO<sub>3</sub>)<sub>2</sub></b>	<b>(04)</b>
<b>X:</b>	<b>CO<sub>2</sub></b>	<b>(03)</b>

**(06 marks x 4 + 04 marks x 12 + 03 marks x 1)**

**9(a): 75 marks**

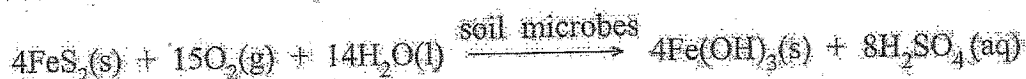
(b) The main compound present in iron pyrite is  $\text{FeS}_2$ . A 1.50 g sample of iron pyrite was oxidized under laboratory conditions and all the sulphur in  $\text{FeS}_2$  was converted to  $\text{SO}_4^{2-}$ . The resultant  $\text{SO}_4^{2-}$  was precipitated as  $\text{BaSO}_4$ . The dry weight of  $\text{BaSO}_4$  obtained was 4.66 g.

(i) Calculate the weight percentage of  $\text{FeS}_2$  present in iron pyrite.

$\text{H}_2\text{SO}_4$  that was produced in this reaction after 120 hours was quantitatively separated and precipitated as  $\text{BaSO}_4$ . The dry weight of  $\text{BaSO}_4$  obtained was 31.13 g.

$\text{FeS}_2$  in 20.0 g of iron pyrite was subjected to oxidation by soil microbes under natural conditions for 120 hours.

This oxidation reaction is represented in the following equation.



$$\text{BaSO}_4 - \text{Molar mass} = 137 + 32 + 64 = 233 \text{ g mol}^{-1} \quad (03)$$

$$\text{FeS}_2 - \text{Molar mass} = 56 + 64 = 120 \text{ g mol}^{-1} \quad (03)$$

$$\text{Moles of BaSO}_4 = \frac{4.66}{233} = 0.02 \text{ mol} \quad (03)$$

$$1 \text{ mole of FeS}_2 \text{ gives 2 moles BaSO}_4 \quad (03)$$

$$\therefore \text{moles of FeS}_2 = \frac{0.02}{2} = 0.01 \text{ mol} \quad (03)$$

$$\therefore \text{weight of FeS}_2 = 0.01 \times 120 = 1.20 \text{ g} \quad (03)$$

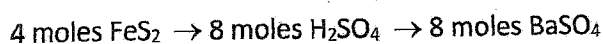
$$\therefore \text{weight percentage of FeS}_2 \text{ in iron pyrite} = \frac{1.20}{1.50} \times 100 \quad (03)$$

$$= 80\% \quad (04)$$

(9b(i): 25 marks)

(ii) Calculate the percentage conversion of  $\text{FeS}_2$  in iron pyrite to  $\text{SO}_4^{2-}$  after 120 hours by soil microbes.

$$\text{Note: Percentage conversion} = \frac{\text{Experimentally obtained mass using soil microbes}}{\text{Theoretical mass}} \times 100$$



$$\text{Amount of FeS}_2 \text{ in 20.0 g of iron pyrite} = 20.0 \times \frac{80}{100} \quad (03)$$

$$= 16.0 \text{ g} \quad (03)$$

Calculation of theoretical mass of  $\text{BaSO}_4$

According to the equation

4 moles  $\text{FeS}_2$  gives 8 moles of  $\text{BaSO}_4$  (03)

$\therefore 4 \times 120 \text{ g FeS}_2$  gives  $8 \times 233 \text{ g of BaSO}_4$  (03)

$\therefore 16 \text{ g FeS}_2$  gives  $\frac{8 \times 233}{4 \times 120} \times 16 \text{ g of BaSO}_4$  (03)

Theoretical mass of  $\text{BaSO}_4 = 62.13 \text{ g}$  (03)

Experimental mass of  $\text{BaSO}_4 = 31.13 \text{ g}$

% conversion  $= \frac{31.13}{62.13} \times 100$  (03)

$= 50.1\%$  (04)

(9b(ii): 25 marks)

### ALTERNATE ANS 1

4 moles  $\text{FeS}_2 \rightarrow 8 \text{ moles H}_2\text{SO}_4 \rightarrow 8 \text{ moles BaSO}_4$

Mass of  $\text{FeS}_2$  in 20.0 g of iron pyrite  $= 20.0 \times \frac{80}{100}$  (03)

$= 16.0 \text{ g}$  (03)

Moles of  $\text{BaSO}_4 = \frac{31.13}{233} \text{ mol}$

Moles of  $\text{H}_2\text{SO}_4 = \frac{31.13}{233} \text{ mol}$  (03)

Moles of  $\text{FeS}_2$  reacted  $= \frac{1}{2} \times \frac{31.13}{233} \text{ mol}$  (03)

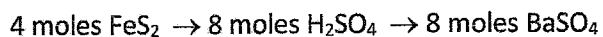
Experimental mass of  $\text{FeS}_2$  reacted  $= \frac{1}{2} \times \frac{31.13}{233} \text{ mol} \times 120 \text{ g mol}^{-1}$  (03)

$= 8.016 \text{ g}$  (03)

% conversion  $= \frac{8.016 \text{ g}}{16 \text{ g}} \times 100\%$  (03)

$= 50.1\%$  (04)

(9b(ii): 25 marks)

**ALTERNATE ANS 2**

$$\text{Mass of FeS}_2 \text{ in } 20.0 \text{ g of iron pyrite} = 20.0 \text{ g} \times \frac{80}{100} \quad (03)$$

$$= 16.0 \text{ g} \quad (03)$$

$$\text{Moles of FeS}_2 = \frac{16.0}{120} \text{ mol} \quad (03)$$

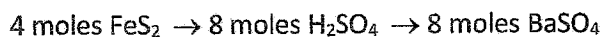
$$\text{Theoretical mass of BaSO}_4 = \frac{16}{120} \times 2 \text{ mol} \times 233 \text{ g mol}^{-1} \quad (03)$$

$$= 62.13 \text{ g} \quad (03)$$

$$\text{Experimental mass of BaSO}_4 \text{ reacted} = 31.13 \text{ g} \quad (03)$$

$$\% \text{ conversion} = \frac{31.13 \text{ g}}{62.13 \text{ g}} \times 100\% \quad (03)$$

$$= 50.1\% \quad (04)$$

**(9b(ii): 25 marks)****ALTERNATE ANS 3**

$$\text{Mass of FeS}_2 \text{ in } 20.0 \text{ g of iron pyrite} = 20.0 \text{ g} \times \frac{80}{100} \quad (03)$$

$$= 16.0 \text{ g} \quad (03)$$

$$\text{Moles of FeS}_2 = \frac{16.0}{120} \text{ mol} \quad (03)$$

$$\text{Theoretical moles of H}_2\text{SO}_4 = \frac{16}{120} \times 2 \text{ mol}$$

$$\begin{aligned} \text{Theoretical mass of H}_2\text{SO}_4 &= \frac{16}{120} \times 2 \text{ mol} \times 98 \text{ g mol}^{-1} \\ &= 26.13 \text{ g} \end{aligned} \quad (03)$$

$$\text{Moles of BaSO}_4 = \frac{31.13}{233} \text{ mol}$$

$$\text{Moles of H}_2\text{SO}_4 = \frac{31.13}{233} \text{ mol}$$

$$\text{Experimental mass of H}_2\text{SO}_4 = \frac{31.13}{233} \text{ mol} \times 98 \text{ g mol}^{-1} \quad (03)$$

$$= 13.09 \text{ g} \quad (03)$$

$$\% \text{ conversion} = \frac{13.09 \text{ g}}{26.13 \text{ g}} \times 100\% \quad (03)$$

$$= 50.1\% \quad (04)$$

(9b(ii): 25 marks)

(iii) Calculate the amount of iron pyrite required to produce 8 kg of  $\text{H}_2\text{SO}_4$  by soil microbes when the conversion percentage of  $\text{FeS}_2$  in iron pyrite to  $\text{SO}_4^{2-}$  is 100%.  
(Relative atomic mass : O = 16, S = 32, Fe = 56, Ba = 137)

$$\text{H}_2\text{SO}_4 = 8 \text{ kg} = 8000 \text{ g} \quad (03)$$

$$\text{Molar mass } \text{H}_2\text{SO}_4 = 98 \quad (03)$$

$$\text{Moles } \text{H}_2\text{SO}_4 = \frac{8000}{98} \quad (03)$$

If the conversion is 100%

$$\therefore \text{ moles of } \text{FeS}_2 \text{ required} = \frac{8000}{98} \times \frac{1}{2} \quad (03)$$

$$= 40.8 \text{ moles} \quad (03)$$

$$= 40.8 \times 120 \text{ g}$$

$$= 4896 \text{ g} \quad (03)$$

$$\therefore \text{ amount of iron pyrite required to produce 8 kg of } \text{H}_2\text{SO}_4 = \frac{4896}{80} \times 100 \text{ g} \quad (03)$$

$$= 6120 \text{ g}$$

$$= 6.12 \text{ kg} \quad (04)$$

9b(iii): 25 marks

9(b): 75 marks

10.(a) The following questions are based on the Solvay process.

(i) What is the main product of the Solvay process?

$\text{Na}_2\text{CO}_3$  / sodium carbonate

(04)

(ii) What is the main by-product of the Solvay process?

$\text{CaCl}_2$  / calcium chloride

(04)

(iii) What are the raw materials (starting materials) used in the Solvay process?

NH<sub>3</sub> gas, (04)

CO<sub>2</sub> gas, (04)

Brine (purified concentrated NaCl solution free from Ca<sup>2+</sup>, Mg<sup>2+</sup> and SO<sub>4</sub><sup>2-</sup> made from sea water (04)

(10a(iii): 12 marks)

(iv) Which one of these raw materials in (iii) above is not consumed in the process but is recycled repeatedly?

NH<sub>3</sub> gas (04)

(v) Identify the first step of the Solvay process in which raw materials are mixed inside a tower which consists of perforated clay trays. Explain why this is carried out at a low temperature.

Ammonification (mixing NH<sub>3</sub> gas and Brine using the counter current principle) (02)

Ammonification is an exothermic process (03)

If the temperature increases, efficiency of dissolving NH<sub>3</sub> gas in Brine decreases and hence low temperature is maintained. (03)

OR

Dissolution of ammonia is exothermic ( $\Delta H < 0$ ) (01)

and the entropy change ( $\Delta S$ ) is negative ( $\Delta S < 0$ ) (01)

According to  $\Delta G = \Delta H - T\Delta S$  (01)

When  $\Delta S$  is negative,  $-T\Delta S$  term is +ve. (01)

When temp increases  $\Delta G$  becomes less negative, (01)

This reduces efficiency of dissolving in water; therefore low Temp more suitable

(03)

(vi) Give three uses of the main product of the Solvay process.

To remove hardness of water

Used in glass industry

Used in paper industry

Used in soap and detergent industry to improve the cleaning action

Used as a powerful cleaning agent (washing soda)

Any three (03 marks x 3 = 09 marks)

(vii) Give three reasons contributing to the economic profitability of the Solvay process.

NaCl and CaCO<sub>3</sub> can be obtained easily with low cost

NH<sub>3</sub> is not used and can be used repeatedly by recycling

Portion of CO<sub>2</sub> can be reused

(03 marks x 03 = 09 marks)

10(a): 50 marks

(b) Briefly explain each of the following statements.

(i) Agriculture contributes to global warming.

Related to agriculture:

- N<sub>2</sub>O (02) and CH<sub>4</sub> (02) contribute to global warming
- Both are greenhouse gases (02)
- Increase in their concentration contributes to global warming. (02)

Formation of N<sub>2</sub>O:

- Action of denitrifying bacteria (02) on
- nitrogen containing fertilizers (02) produce N<sub>2</sub>O

Formation of CH<sub>4</sub>:

- Paddy cultivation in marsh and water logged area (02) favour anaerobic decomposition of organic matter to produce CH<sub>4</sub>. (01)
- Decomposition of organic matter disposed indiscriminately (02) undergo anaerobic decomposition to produce CH<sub>4</sub>. (01)
- Digestion of organic/cellulose matter in guts of ruminant animals (cows, goat, sheep) undergoing bacterial decomposition under anaerobic conditions (02) produce CH<sub>4</sub>

(10b(i): 20 marks)

(ii) Iron extraction contributes to global warming.

Related to iron extraction:

- CO<sub>2</sub> contributes to global warming
- CO<sub>2</sub> is a greenhouse gas and
- increase in concentration contributes to global warming

(02x3)



Formation of CO<sub>2</sub>:

Fossil fuels and coke used in iron extraction are converted to CO<sub>2</sub> during combustion

(04)

(10b(ii): 10 marks)

(iii) Transportation contributes to photochemical smog.

In your answer indicate how the chemical species responsible for the given environmental effect in each of the statements above is/are formed.

Related to transportation:

Species that contribute to photochemical smog

NO and volatile hydrocarbons (CH<sub>3</sub>(CH<sub>2</sub>)<sub>n</sub>CH<sub>3</sub>, n = 1-4)

(02x2)

- NO and volatile hydrocarbons undergo reactions in the presence of sunlight to produce volatile short chain aldehydes and other toxic chemicals (PAN, PBN)
- Aldehydes are further polymerized to produce suspended particles in the atmosphere
- These particles can form large particles by deposition of dust, water vapour, etc
- These large particles can scatter sunlight reducing the visibility/transparency of the atmosphere and appear like a mist in the lower atmosphere

(02 x 8 = 16)

(10b(iii): 20 marks)

**10(b): 50 marks**

(c) (i) The following questions are based on vinegar production.

I. State what is the process used in the production of natural vinegar.  
microbial activity / microbial fermentation

(04)

II. Write the name of the active chemical ingredient present in natural vinegar.  
acetic acid

(04)

III. Name the titrant and the indicator used in the quantitative determination of the active chemical ingredient in natural vinegar.

Titrant – NaOH

(04)

Indicator – Phenolphthalein

(04)

IV. State the difference in composition between natural vinegar and artificial vinegar.

Natural vinegar contains salts, simple sugars, esters and alcohols in minute quantities.

(01x4)

However, synthetic vinegar contains only acetic acid.

(02)

(ii) The following questions are based on the extraction of essential oils from plants.

I. Name three methods that can be used to extract essential oils.

steam distillation

solvent extraction

pressing

(04 marks x 3 = 12 marks)

II. State which of the above methods is based on the application of Daltons Law of partial pressures.

steam distillation

(04 marks)

III. Name the major compound present in each of the essential oils given below.

● Citronella oil

● Cinnamon root oil

● Cinnamon leaf oil

citronella – geraniol

cinnamon root – camphor

cinnamon leaf - eugenol

(04 marks x 3 = 12 marks)

10(c): 50 marks

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