



NEW

Department of Examinations - Sri Lanka
G.C.E. (A/L) Examination - 2020

02 - Chemistry

New Syllabus

Marking Scheme

This document 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

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
 $\frac{3}{5}$

03 (i) $\frac{4}{5}$ + (ii) $\frac{3}{5}$ + (iii) $\frac{3}{5}$ = $\frac{10}{5}$

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 'X' 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. For the subject 51 Art, marks for Papers 01, 02 and 03 should be entered numerically in the mark sheets.

ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව

Department of Examinations – Sri Lanka

අ.පො.ස.(උ.පෙළ)විභාගය/G.C.E. (A/L)- 2020

නව නිර්දේශය/ New Syllabus

විෂය අංකය
Subject No

02

විෂය
Subject

Chemistry

ලකුණු දීමේ පටිපාටිය/Marking Scheme

I පත්‍රය/Paper I

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

විශේෂ උපදෙස්/ Special Instructions:

විෂ් පිළිතුරකට ලකුණු 01 බැගින්/ 01 Mark for each question

මුළු ලකුණු/ Total Marks 01 × 50 = 50

PAPERMASTER.LK

PART A – STRUCTURED ESSAY

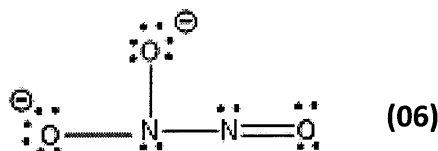
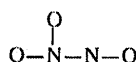
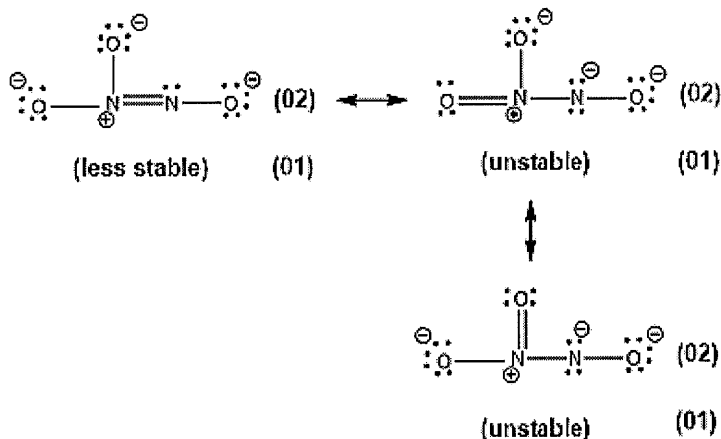
Answer all four questions on this paper itself. (Each question carries 10 marks.)

1. (a) Write the answers to the questions given below on the dotted lines.

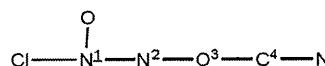
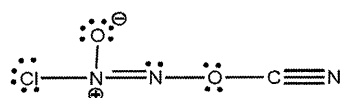
- (i) Of the three ions Na^+ , Mg^{2+} and F^- , which one has the **smallest** ionic radius? Mg^{2+}
- (ii) Of the three elements C, N and O, which one has the **highest** second ionization energy? O
- (iii) Of the three compounds H_2O , HOCl and OF_2 , which one has the **most** electronegative oxygen atom? OF_2
- (iv) Of the three elements Be, C and N, which one will liberate energy when an electron is added to its atom [$\text{Y}(\text{g}) + \text{e} \rightarrow \text{Y}^-(\text{g})$; $\text{Y} = \text{Be}, \text{C}, \text{N}$] in the gaseous state? C
- (v) Of the three ionic compounds NaF , KF and KBr , which one has the **highest** solubility in water? KF or KBr
- (vi) Of the three compounds HCHO , CH_3F and H_2O_2 , which one has the **strongest** intermolecular forces? H_2O_2

(04 marks X 6 = 24)

1(a): 24 marks

(b) (i) Draw the **most** acceptable Lewis structure for the ion, $\text{N}_2\text{O}_3^{2-}$. Its skeleton is given below.(ii) Draw **three** more Lewis structures (resonance structures) for this ion. Indicate the relative stabilities of the structures drawn by you, when compared with the most acceptable structure drawn in (i) above, by writing 'less stable' or 'unstable' under these structures.

(iii) Complete the given table based on the Lewis structure and its labelled skeleton given below.



	N^1	N^2	O^3	C^4
VSEPR pairs around the atom	3	3	4	2
electron pair geometry around the atom	trigonal planar	trigonal planar	tetrahedral	linear
shape around the atom	trigonal planar	angular/ V	angular/ V	linear
hybridization of the atom	sp^2	sp^2	sp^3	sp

(01 X 16 = 16)

- Parts (iv) to (vii) are based on the Lewis structure given in part (iii) above. Labelling of atoms is as in part (iii).

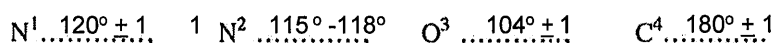
(iv) Identify the atomic/hybrid orbitals involved in the formation of σ bonds between the two atoms given below.

I. Cl—N ¹	Cl	..... 3p OR sp ³	N ¹	..... sp ²	
II. N ¹ —O	N ¹	..... sp ²	O	..... 2p OR sp ³	
III. N ¹ —N ²	N ¹	..... sp ²	N ²	..... sp ²	
IV. N ² —O ³	N ²	..... sp ²	O ³	..... sp ³	
V. O ³ —C ⁴	O ³	..... sp ³	C ⁴	..... sp.....	
VI. C ⁴ —N	C ⁴	..... sp.....	N	..... 2p OR sp.....	(01 X 12 = 12)

(v) Identify the atomic orbitals involved in the formation of π bonds between the two atoms given below.

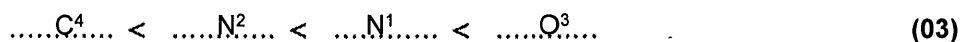
I. N ¹ —N ²	N ¹	..... N ¹ , 2p.....	N ²	..... N ² , 2p.....	
II. C ⁴ —N	C ⁴	..... C ⁴ , 2p.....	N	..... N, 2p.....	
	C ⁴	..... C ⁴ , 2p.....	N	..... N, 2p.....	(01 X 6 = 06)

(vi) State the approximate bond angles around N¹, N², O³ and C⁴ atoms.



(01 X 4 = 04)

(vii) Arrange the atoms N¹, N², O³ and C⁴ in the increasing order of electronegativity.



1(b): 56 marks

(c) Consider the following information.

I. The atoms A and B combine to form a heterodiatomic molecule AB that has a σ bond. This is represented as A—B.

II. The electronegativity of A is less than that of B ($X_A < X_B$).
X = electronegativity of the atom

III. The inter-nuclear distance between A and B atoms (d_{A-B}) of the AB molecule is given by the following equation.

$$d_{A-B} = r_A + r_B - c(X_B - X_A)$$

$$r = \text{atomic radius, } c = 9 \text{ pm}$$

Note: d and r are measured in picometres (pm). (1 pm = 10⁻¹² m)

Based on the above information, answer the following questions.

(i) What is the name used to identify the type of σ bond between A and B?

Polar covalent bond (03)

(ii) Show how fractional charges (δ^+ and δ^-) are located in the molecule AB.

A ^{δ^+} —B ^{δ^-} (03)

(iii) Write the equation to calculate the dipole moment (μ) of molecule AB and show its direction.

$$\mu = d_{AB} \times \delta, \quad \text{OR} \quad \mu = qr, \quad \begin{array}{c} \longrightarrow \\ \text{A} \text{---} \text{B} \end{array} \quad \text{OR} \quad \begin{array}{c} + \longrightarrow \\ \text{A} \text{---} \text{B} \end{array} \quad (01 + 01)$$

- (iv) Calculate the percentage of ionic character of the H-F bond in the HF molecule using the data given below.

$$\text{Inter-nuclear distance of H}_2 (d_{\text{H-H}}) = 74 \text{ pm}$$

$$\text{Electronegativity of F} = 4.0$$

$$\text{Inter-nuclear distance of F}_2 (d_{\text{F-F}}) = 144 \text{ pm}$$

$$\text{Dipole moment of HF} = 6.0 \times 10^{-30} \text{ C m}$$

$$\text{Electronegativity of H} = 2.1$$

$$\text{Charge of an electron} = 1.6 \times 10^{-19} \text{ C}$$

$$\mu = d_{\text{HF}} \times \delta, \quad \text{H}^{\delta+} - \text{F}^{\delta-}$$

$$r_{\text{H}} = \frac{d_{\text{H}_2}}{2} = \frac{74}{2} = 37 \text{ pm} \quad (02)$$

$$r_{\text{F}} = \frac{d_{\text{F}_2}}{2} = \frac{144}{2} = 72 \text{ pm} \quad (02)$$

$$\text{Therefore, } d_{\text{HF}} = 37 + 72 - 9(4.0 - 2.1) \quad (01)$$

$$= 109 - 9 \times 1.9$$

$$= 91.9 \text{ pm} \quad (02)$$

$$\mu = d_{\text{HF}} \times \delta, \quad 6.0 \times 10^{-30} \text{ C m} = \delta \times 91.9 \times 10^{-12} \text{ m} \quad (01)$$

$$\delta = \frac{6.0 \times 10^{-30}}{91.9 \times 10^{-12}} = 0.65 \times 10^{-19} \quad (02)$$

$$\% \text{ Ionic character} = \frac{0.65 \times 10^{-19}}{1.6 \times 10^{-19}} \times 100 \quad (01)$$

$$= 40.6\% \quad (01)$$

OR

$$r_{\text{H}} = \frac{d_{\text{H}_2}}{2} = \frac{74}{2} = 37 \text{ pm} \quad (02)$$

$$r_{\text{F}} = \frac{d_{\text{F}_2}}{2} = \frac{144}{2} = 72 \text{ pm} \quad (02)$$

$$\text{Therefore, } d_{\text{HF}} = 37 + 72 - 9(4.0 - 2.1) \quad (01)$$

$$= 109 - 9 \times 1.9$$

$$= 91.9 \text{ pm} \quad (02)$$

$$\mu_{\text{ionic}} = 1.6 \times 10^{-19} \text{ C} \times 91.9 \times 10^{-12} \text{ m} \quad (03)$$

$$= 147.04 \times 10^{-31} \text{ C m}$$

$$\% \text{ Ionic character} = \frac{6 \times 10^{-30}}{147.04 \times 10^{-31}} \times 100 \quad (01)$$

$$= 40.8\% \quad (01)$$

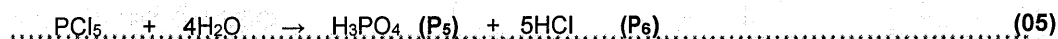
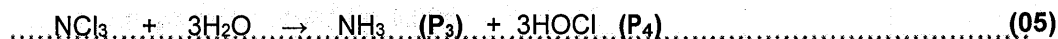
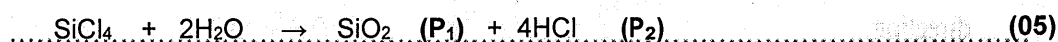
2. (a) A, B, C and D are chlorides of *p*-block elements. These elements have atomic numbers less than 20. A description of the products (P₁-P₉) formed when A is reacted with a limited amount of water and B, C and D are reacted with excess water are given below.

Compound		Description of products
A	P ₁	a compound with a covalent network structure
	P ₂	a strong monobasic acid
B	P ₃	a gas that turns red litmus blue
	P ₄	a compound with bleaching properties
C	P ₅	a tribasic acid
	P ₆	a strong monobasic acid
D	P ₇	a gas that turns acidic KMnO ₄ solution colourless
	P ₈	a colloidal solid
	P ₉	a strong monobasic acid

- (i) Identify A, B, C and D (give the chemical formulae).



- (ii) Give balanced chemical equations for the reactions of A, B, C and D with water to give products P₁ to P₉.



Note: Award marks if correct balanced equations are given.

(iii) Write balanced chemical equations for the following reactions.

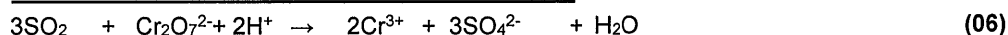
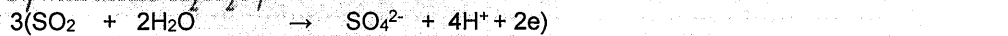
I. P_1 with NaOH(aq)



II. P_3 with Mg



III. P_7 with acidic $\text{K}_2\text{Cr}_2\text{O}_7$



If only half reactions are given – part marks (02 + 02)

2(a): 50 marks

- (b) A student is provided with bottles labelled P, Q, R, S, T and U containing aqueous solutions of $\text{Al}_2(\text{SO}_4)_3$, H_2SO_4 , $\text{Na}_2\text{S}_2\text{O}_3$, BaCl_2 , $\text{Pb}(\text{Ac})_2$ and KOH (not in order). Some useful observations for their identification on mixing two solutions at a time are given below. (Ac - Acetate ion)

	Solutions mixed	Observations
I	T + R	a clear colourless solution
II	P + R	a white precipitate
III	T + S	a gelatinous white precipitate
IV	U + R	a white precipitate
V	P + Q	a white precipitate, turns black on heating
VI	P + U	a white precipitate, dissolves on heating

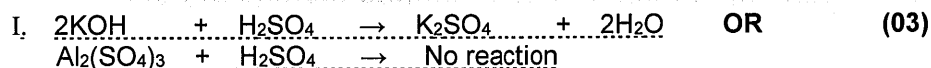
(i) Identify P to U.

P: $\text{Pb}(\text{Ac})_2$ Q: $\text{Na}_2\text{S}_2\text{O}_3$ R: H_2SO_4

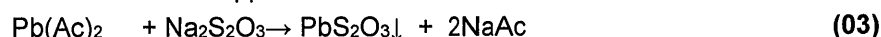
S: $\text{Al}_2(\text{SO}_4)_3$ OR KOH T: KOH OR $\text{Al}_2(\text{SO}_4)_3$ U: BaCl_2

(05 X 6 = 30)

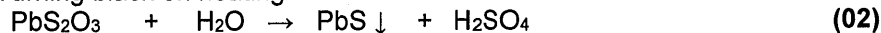
(ii) Give balanced chemical equations for each of the reactions I to VI.



V. Formation of white ppt



Turning black on heating



Note: Precipitates have to be shown by \downarrow or as (s). If not, deduct (01) mark.

2(b): 50 marks

3. (a) A saturated aqueous solution of a sparingly soluble salt $\text{AB}_2(\text{s})$ was prepared by stirring an excess amount of $\text{AB}_2(\text{s})$ in 1.0 dm^3 of distilled water at 25°C . The amount of $\text{A}^{2+}(\text{aq})$ ions present in this saturated aqueous solution was found to be $2.0 \times 10^{-3} \text{ mol}$.

(i) Write the equilibrium related to the dissolution of $\text{AB}_2(\text{s})$ in the above system at 25°C .



(ii) Write the expression for the equilibrium constant for the equilibrium written in (i) above at 25°C .

$$K_{sp} = [\text{A}^{2+}(\text{aq})][\text{B}^{-}(\text{aq})]^2 \quad (05)$$

$$K_c = \frac{[\text{A}^{2+}(\text{aq})][\text{B}^{-}(\text{aq})]^2}{[\text{AB}_2(\text{s})]} \quad \text{Note: If only } K_c \text{ is given award (03 marks)}$$

(iii) Calculate the value of the equilibrium constant stated in (ii) above at 25 °C.

$$[A^{2+}(aq)] = 2.0 \times 10^{-3} \text{ mol dm}^{-3} \quad (04+01)$$

$$[B^{-}(aq)] = 2[A^{2+}(aq)] = 4.0 \times 10^{-3} \text{ mol dm}^{-3} \quad (04+01)$$

$$K_{sp} = 2.0 \times 10^{-3} \text{ mol dm}^{-3} \times (4.0 \times 10^{-3} \text{ mol dm}^{-3})^2 \quad (05)$$

$$K_{sp} = 3.2 \times 10^{-8} \text{ mol}^3 \text{ dm}^{-9} \quad (05)$$

(iv) Another saturated aqueous solution of AB_2 was prepared by stirring an excess amount of $AB_2(s)$ in 2.0 dm^3 of distilled water at 25 °C. Giving reasons, predict the value of the equilibrium constant for this system.

$$K_{sp} = 3.2 \times 10^{-8} \text{ mol}^3 \text{ dm}^{-9} \quad (05)$$

K_{sp} is a constant at constant temperature (05)

and does not depend on the volume (05)

(v) A small amount of the strong electrolyte $NaB(s)$ is added to a saturated aqueous solution of AB_2 at 25 °C. Giving reasons, predict whether the concentration of $A^{2+}(aq)$ is increased or decreased.

Common-ion $B^{-}(aq)$ is added (05)

\therefore More $AB_2(s)$ is formed to keep the K_{sp} constant or reverse reaction takes place (05)

$[A^{2+}(aq)]$, **decreases** (05)

3(a): 60 marks

(b) In an aqueous solution, propanoic acid (C_2H_5COOH) ionizes as given below.



At 25 °C, K_a (propanoic acid) = 1.0×10^{-5}

(i) Write the expression for the equilibrium constant for the above reaction at 25 °C.

$$K_a = \frac{[C_2H_5COO^{-}(aq)][H_3O^{+}(aq)]}{[C_2H_5COOH(aq)]} \quad (05)$$

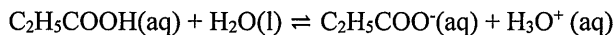
(ii) 100.0 cm^3 of an aqueous solution of $C_2H_5COOH(aq)$ was prepared by dissolving 0.74 cm^3 of C_2H_5COOH in distilled water at 25 °C. Calculate the pH of the solution at 25 °C. ($C = 12$; $O = 16$; $H = 1$; consider the density of C_2H_5COOH as 1.0 g cm^{-3})

$$\text{mass of } C_2H_5COOH(aq) = 0.74 \text{ cm}^3 \times 1.00 \text{ g cm}^{-3} = 0.74 \text{ g}$$

$$\text{moles of } C_2H_5COOH(aq) \text{ in } 100 \text{ cm}^3 = 0.74 \text{ g} / 74 \text{ g mol}^{-1} = 0.01 \text{ mol} \quad (05)$$

$$\therefore [C_2H_5COOH(aq)] = 0.10 \text{ mol dm}^{-3} \quad (05)$$

Consider the equilibrium:



<i>Initial</i>	<i>0.10</i>	<i>0</i>	<i>0</i>	<i>mol dm⁻³</i>	
<i>Change</i>	<i>-x</i>	<i>x</i>	<i>x</i>	<i>mol dm⁻³</i>	
<i>At eqm</i>	<i>0.10-x</i>	<i>x</i>	<i>x</i>	<i>mol dm⁻³</i>	(05)

$$K_a = \frac{[C_2H_5COO^{-}(aq)][H_3O^{+}(aq)]}{[C_2H_5COOH(aq)]} = \frac{x \cdot x}{0.10 - x} = 1.0 \times 10^{-5} \quad (02)$$

$$\frac{x^2}{0.10} = 1.0 \times 10^{-5} \quad (0.10 - x \sim 0.1) \quad (03)$$

$$x^2 = 1.0 \times 10^{-6} \quad (05)$$

$$x = 1.0 \times 10^{-3} \text{ mol dm}^{-3} = [H_3O^{+}(aq)] \quad (05)$$

$$pH = -\log [H_3O^{+}(aq)] = 1.0 \times 10^{-3} \quad (05)$$

$$pH = 3.0 \quad (05)$$

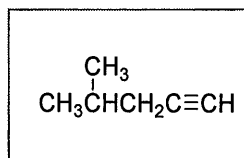
Note : Students may take $-\log$ of both sides of $K_a = \frac{[C_2H_5COO^{-}(aq)][H_3O^{+}(aq)]}{[C_2H_5COOH(aq)]}$ and calculate pH.

Award marks appropriately.

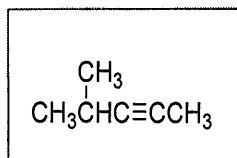
3(b): 40 marks

4. (a) A, B, C and D are structural isomers having the molecular formula C_6H_{10} . None of them show optical isomerism. All four isomers, A, B, C and D when treated with $HgSO_4/dil. H_2SO_4$ give products which react with 2,4-dinitrophenylhydrazine (2,4-DNP) to give coloured precipitates. Only A gives a precipitate with ammonical $AgNO_3$, A has only one position isomer, which is B. B is a chain isomer of C. C reacts with $HgSO_4/dil. H_2SO_4$ to give two products E and F. D reacts with $HgSO_4/dil. H_2SO_4$ to give only one product, which is E.

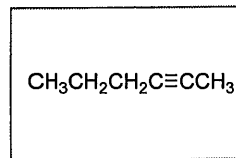
(i) Draw the structures of A, B, C, D, E and F in the boxes given below.



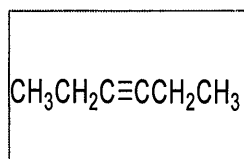
A



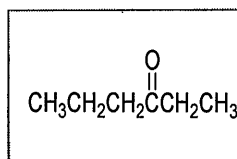
B



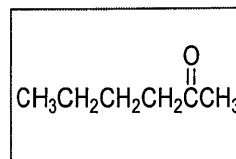
C



D



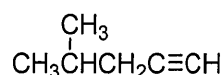
E



F

(06 x 6 = 36)

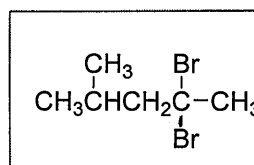
- (ii) Which of the compounds A, B, C and D gives a product that does not show diastereoisomerism when reacted separately with $H_2 / Pd-BaSO_4 /$ quinoline?



(05)

or Appropriate letter (A, B, C or D) identifying the correct structure

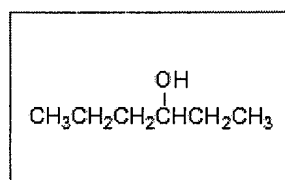
- (iii) Draw, in the box given below, the structure of the product G obtained when A is reacted with excess HBr.



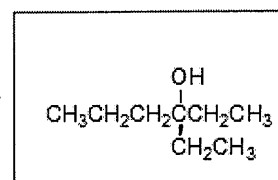
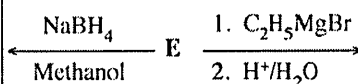
G

(05)

- (iv) Draw the structures of products X and Y obtained in the following reactions of E, in the appropriate boxes.



X



Y

Name a test to distinguish between X and Y.

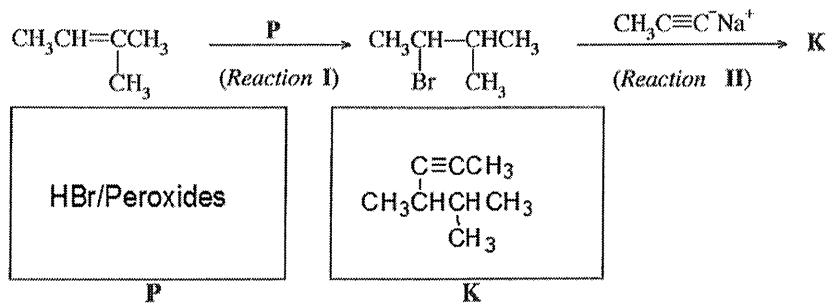
(05 x 2 = 10)

Lucas test or
anh. $ZnCl_2 /$ conc. HCl or
 $H^+ / K_2Cr_2O_7$ or
 $H^+ / KMnO_4$

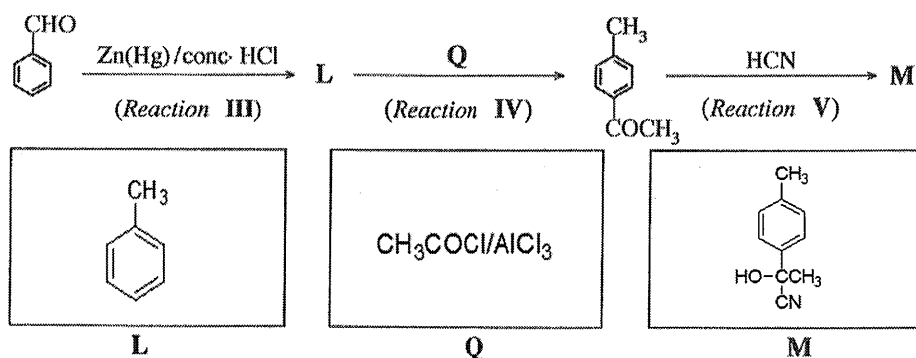
(04)

4(a): 60 marks

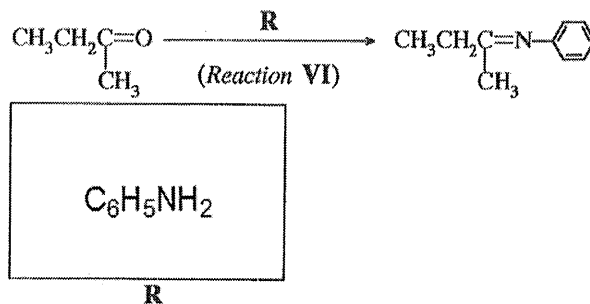
Sequence 1:



Sequence 2:



Sequence 3:



Compounds/reagents (05 x 6 = 30)

(ii) Selecting from the reactions I–VI, give one (01) example for each of the following types of reactions.

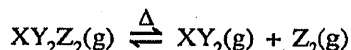
Nucleophilic addition Reaction V

Nucleophilic substitution Reaction II

Reactions (05 x 2 = 10)

PART B – ESSAY

5. (a) A compound $XY_2Z_2(g)$ undergoes dissociation when heated to temperatures above 300 K as given below.



A sample of 7.5 g of $XY_2Z_2(g)$ was placed in an evacuated 1.00 dm³ rigid-closed container and the temperature was raised to 480 K.

Molar mass of $XY_2Z_2(g)$ is 150 g mol⁻¹. Use the approximate value of 4000 J mol⁻¹ for RT at 480 K. Assume ideal gas behaviour for all gases.

- (i) Calculate the number of moles of $XY_2Z_2(g)$ in the container before dissociation.

$$7.5 \text{ g} / 150 \text{ g mol}^{-1} = 5.0 \times 10^{-2} \text{ mol} \quad (05)$$

5(a) (i): 05 marks

- (ii) When the above system reaches equilibrium at 480 K, the total number of moles in the container was found to be 7.5×10^{-2} mol. Calculate the number of moles of $XY_2Z_2(g)$, $XY_2(g)$ and $Z_2(g)$ in the equilibrium mixture at 480 K.

$XY_2Z_2(g)$	\rightleftharpoons	$XY_2(g)$	+	$Z_2(g)$		
<i>Initial</i>		0.05		0	0	<i>mol dm⁻³</i> (05)
<i>Change</i>		-x		x	x	<i>mol dm⁻³</i>
<i>At eqm</i>		0.05-x		x	x	<i>mol dm⁻³</i> (05)

$$\text{Total number of moles} = 0.05 + x = 7.5 \times 10^{-2} \text{ mol} \quad (05)$$

$$x = 2.5 \times 10^{-2} \text{ mol} \quad (05)$$

$$XY_2(g) = Z_2(g) = 2.5 \times 10^{-2} \text{ mol} \quad (05)$$

$$XY_2Z_2(g) = 5.0 \times 10^{-2} \text{ mol} - 2.5 \times 10^{-2} \text{ mol} = 2.5 \times 10^{-2} \text{ mol} \quad (05)$$

5(a) (ii): 30 marks

- (iii) Calculate the equilibrium constant K_c for the above reaction at 480 K.

$$K_c = \frac{[XY_2(g)][Z_2(g)]}{[XY_2Z_2(g)]} \quad (05)$$

$$\text{Concentration} = 2.5 \times 10^{-2} \text{ mol dm}^{-3} \quad (05)$$

$$K_c = \frac{2.5 \times 10^{-2} \text{ mol dm}^{-3} \times 2.5 \times 10^{-2} \text{ mol dm}^{-3}}{2.5 \times 10^{-2} \text{ mol dm}^{-3}} \quad (05)$$

$$K_c = 2.5 \times 10^{-2} \text{ mol dm}^{-3} \quad (05)$$

5(a) (iii): 20 marks

- (iv) Calculate K_p for the equilibrium at 480 K.

$$K_p = K_c (RT)^{\Delta n} \quad (05)$$

$$\Delta n = 1 \quad (05)$$

$$K_p = 2.5 \times 10^{-2} \text{ mol dm}^{-3} \times 4 \times 10^3 \text{ J mol}^{-1} \quad (05)$$

$$K_p = 1.0 \times 10^5 \text{ Pa} \quad (05)$$

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iv. Alternative:Total number of moles at equilibrium = 7.5×10^{-2} mol

$$P_{\text{Total}} = (7.5 \times 10^{-2} \text{ mol} \times 4 \times 10^3 \text{ J mol}^{-1}) / 1.0 \times 10^{-3} \text{ m}^3 = 3.0 \times 10^5 \text{ Pa}$$

Number of moles of $\text{XY}_2\text{Z}_2(\text{g}) = \text{XY}_2(\text{g}) = \text{Z}_2(\text{g}) = 2.5 \times 10^{-2}$ molMole fractions of $\text{XY}_2\text{Z}_2(\text{g}) = \text{XY}_2(\text{g}) = \text{Z}_2(\text{g}) = 1/3$

$$P_i = X_i P_{\text{total}}$$

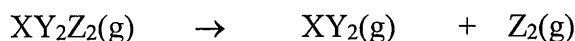
$$P_{\text{XY}_2\text{Z}_2(\text{g})} = P_{\text{XY}_2(\text{g})} = P_{\text{Z}_2(\text{g})} = 1.0 \times 10^5 \text{ Pa}$$

$$K_p = [P_{\text{XY}_2(\text{g})} P_{\text{Z}_2(\text{g})}] / P_{\text{XY}_2\text{Z}_2(\text{g})} = 1.0 \times 10^5 \text{ Pa}$$

5(a): 75 marks

(b) For the reaction $\text{XY}_2\text{Z}_2(\text{g}) \rightarrow \text{XY}_2(\text{g}) + \text{Z}_2(\text{g})$ described in (a), Gibbs free energies (G) at 480 K for $\text{XY}_2\text{Z}_2(\text{g})$, $\text{XY}_2(\text{g})$ and $\text{Z}_2(\text{g})$ are -60 kJ mol^{-1} , -76 kJ mol^{-1} and -30 kJ mol^{-1} , respectively.

(i) Calculate ΔG (in kJ mol^{-1}) for the reaction at 480 K.



$$\Delta G_{\text{rxn}} = G_{\text{products}} - G_{\text{reactants}} \quad (05)$$

$$= (-76 + (-30)) - (-60) = -46 \text{ kJ mol}^{-1} \quad (04+01)$$

Note: No marks if ΔG_{rxn}^0 is written.

5(b) (i): 10 marks

(ii) The magnitude of ΔS of the above reaction is $150 \text{ J K}^{-1} \text{ mol}^{-1}$ at 480 K. Calculate ΔH for the reaction at 480 K by using the appropriate sign ($-$ or $+$) of ΔS .

ΔS must be positive (number of gaseous moles is higher in products) (05)

5(b) (ii): 05 marks

(iii) By using the sign ($-$ or $+$) of ΔH obtained in (ii), explain whether this reaction is exothermic or endothermic.

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

$$-46 \text{ kJ mol}^{-1} = \Delta H - 480 \text{ K} \times 150 \times 10^{-3} \text{ kJ K}^{-1} \text{ mol}^{-1}$$

$$\Delta H = -46 \text{ kJ mol}^{-1} + 72 \text{ kJ mol}^{-1} \quad (04 + 01)$$

$$\Delta H = +26 \text{ kJ mol}^{-1} \quad (04+01)$$

5(b) (iii): 15 marks

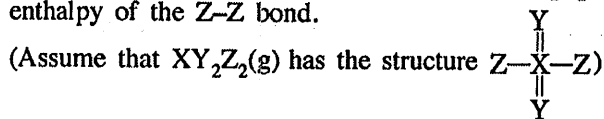
(iv) Deduce the enthalpy difference for the formation of $\text{XY}_2\text{Z}_2(\text{g})$ from $\text{XY}_2(\text{g})$ and $\text{Z}_2(\text{g})$ at 480 K.

The reaction is endothermic (05)

because ΔH is positive (05)

5(b) (iv): 10 marks

- (v) If the bond enthalpy of the X-Z bond in $XY_2Z_2(g)$ is $+250 \text{ kJ mol}^{-1}$, calculate the bond enthalpy of the Z-Z bond.



$$\Delta H = -26 \text{ kJ mol}^{-1} \quad (09 + 01)$$

5(b) (v): 10 marks

- (vi) If liquid XY_2Z_2 is used instead of gaseous XY_2Z_2 , giving reasons, explain whether the value of ΔH obtained for the reaction $XY_2Z_2(l) \rightarrow XY_2(g) + Z_2(g)$ is equal to, or higher or lower than ΔH obtained in (ii).

$$\Delta H_{rxn} = \Delta H_{bonds \text{ formed}} - \Delta H_{bonds \text{ broken}} \quad (05)$$

$$\Delta H_{rxn} = \Delta H_{Z-Z} - 2 \Delta H_{X-Z} \quad (05)$$

$$26 \text{ kJ mol}^{-1} = \Delta H_{Z-Z} - 2 \times 250 \text{ kJ mol}^{-1}$$

$$\Delta H_{Z-Z} = 526 \text{ kJ mol}^{-1} \quad (04+01)$$

(OR students may solve through an appropriate thermo cycle)

Higher (05)

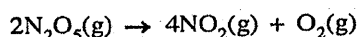
It is necessary to supply energy to convert liquid to gas first (05)

(or $XY_2Z_2(l) \rightarrow XY_2Z_2(g)$ needs an extra energy)

5(b) (vi): 25 marks

5(b): 75 marks

6. (a) Consider the reaction given below occurring in a closed container at a given temperature T .



- (i) Write three expressions for the rate of reaction relevant to each of the compounds appearing in the reaction.

$$\text{Rate} = -\frac{\Delta[N_2O_5(g)]}{2 \Delta t} = \frac{\Delta[NO_2(g)]}{4 \Delta t} = \frac{\Delta[O_2(g)]}{\Delta t} \quad (05)$$

6(a) (i): 05 marks

- (ii) This reaction was carried out at temperature T with an initial concentration of 0.10 mol dm^{-3} of $N_2O_5(g)$. It was found that 40% of the initial amount was decomposed after a period of 400 s.

1. Calculate the average rate of decomposition of $N_2O_5(g)$ in this time interval.

$$\text{Decomposed amount} = 0.10 \text{ mol dm}^{-3} \times 40/100 = 4.0 \times 10^{-2} \text{ mol dm}^{-3} \quad (05)$$

$$\text{Remaining concentration after 400 s} = 6.0 \times 10^{-2} \text{ mol dm}^{-3} \quad (05)$$

$$\text{Average Rate} = \frac{-(0.06 - 0.10) \text{ mol dm}^{-3}}{(400-0) \text{ s}} = 1.0 \times 10^{-4} \text{ mol dm}^{-3} \text{ s}^{-1} \quad (05)$$

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II. Calculate average rates of formation of $\text{NO}_2(\text{g})$ and $\text{O}_2(\text{g})$.

$$\frac{\Delta[\text{N}_2\text{O}_5(\text{g})]}{2 \Delta t} = \frac{\Delta[\text{NO}_2(\text{g})]}{4 \Delta t}$$

$$\frac{\Delta[\text{NO}_2(\text{g})]}{4 \Delta t} = 2.0 \times 10^{-4} \text{ mol dm}^{-3} \text{ s}^{-1} \quad (02)$$

$$\frac{\Delta[\text{O}_2(\text{g})]}{\Delta t} = \frac{\Delta[\text{N}_2\text{O}_5(\text{g})]}{2 \Delta t} = 5.0 \times 10^{-5} \text{ mol dm}^{-3} \text{ s}^{-1} \quad (03)$$

6(a) (ii): 20 marks

(iii) In another experiment, initial rates were measured for this reaction at 300 K and the results are given below.

$[\text{N}_2\text{O}_5(\text{g})] / \text{mol dm}^{-3}$	0.01	0.02	0.03
Initial rate / $\text{mol dm}^{-3} \text{ s}^{-1}$	6.930×10^{-5}	1.386×10^{-4}	2.079×10^{-4}

Derive the rate law for the reaction at 300 K.

When the concentration were increased two and three times, rate increased two and three times, respectively. (05)

\therefore Reaction is first order (05)

\therefore Rate law : Rate = $k [\text{N}_2\text{O}_5(\text{g})]$ (05)

(OR $R_1/R_2 = 1/2 \therefore$ reaction is first order)

6(a) (iii): 15 marks

(iv) Another experiment was carried out at 300 K with an initial concentration of 0.64 mol dm^{-3} of $\text{N}_2\text{O}_5(\text{g})$. It was found that the concentration of $\text{N}_2\text{O}_5(\text{g})$ which remained after a period of 500 s was $2.0 \times 10^{-2} \text{ mol dm}^{-3}$.

I. Calculate the half-life ($t_{1/2}$) of the reaction at 300 K.

$$\text{Order of concentration change} = 0.64/2.0 \times 10^{-2} = 32 = (2)^5 \quad (05)$$

$$\therefore \text{Fraction of initial } \text{N}_2\text{O}_5(\text{g}) = (1/2)^5 \quad (05)$$

That is, 5 half-lives passed to reach this concentration (05)

$$\therefore t_{1/2} = 500 \text{ s} / 5 = 100 \text{ s} \quad (05)$$

II. Calculate the rate constant of the reaction at 300 K.

from iii,

$$\text{Rate} = k [\text{N}_2\text{O}_5(\text{g})] = 6.93 \times 10^{-5} \text{ mol dm}^{-3} \text{ s}^{-1} = k \cdot 0.01 \text{ mol dm}^{-3} \quad (05)$$

$$k = 6.93 \times 10^{-3} \text{ s}^{-1} \quad (04+01)$$

OR

Reaction is first order

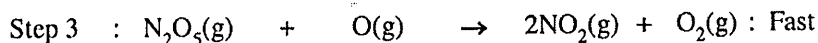
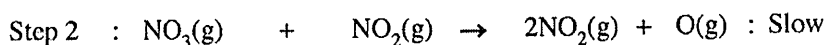
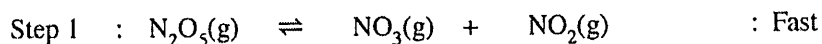
$$\text{For first order reaction: } t_{1/2} = 0.693 / k \quad (05)$$

$$\therefore k = 0.693 / 100 \text{ s} = 6.93 \times 10^{-3} \text{ s}^{-1} \quad (05)$$

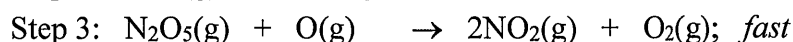
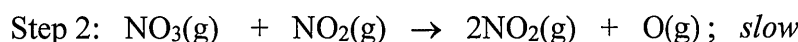
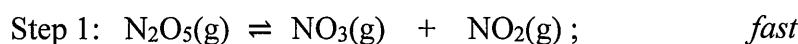
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6(a) (iv): 30 marks

(v) This reaction proceeds through a mechanism involving the following elementary steps.



Show that the above mechanism is consistent with the rate law of the reaction. (8.0 marks)



From step 2 (Slow-step);

$$\text{Rate} = k[\text{NO}_3(\text{g})][\text{NO}_2(\text{g})] \quad (05)$$

For step 1 (equilibrium)

$$K_{eq} = \frac{[\text{NO}_3(\text{g})][\text{NO}_2(\text{g})]}{[\text{N}_2\text{O}_5(\text{g})]} \quad (05)$$

$$\text{We get, } K_{eq}[\text{N}_2\text{O}_5(\text{g})] = \frac{[\text{NO}_3(\text{g})][\text{NO}_2(\text{g})]}{}$$

$$\therefore \text{Rate} = k K_{eq}[\text{N}_2\text{O}_5(\text{g})] = k'[\text{N}_2\text{O}_5(\text{g})] \quad (05)$$

This is a first order reaction which follows the rate law derived (05)

6(a) (v): 20 marks

6(a): 90 marks

(b) An ideal binary-liquid mixture was prepared by mixing two liquids of A and B in a closed evacuated container at temperature T . After establishing the equilibrium at temperature T , partial pressures of A and B in the vapour phase are P_A and P_B , respectively. At temperature T , the saturated vapour pressures of A and B are P_A° and P_B° , respectively. Mole fractions of A and B in solution are X_A and X_B , respectively.

(i) Show that $P_A = P_A^\circ X_A$

(Consider that the rates of vaporization and condensation are equal at equilibrium.)

Consider the above described vapor – liquid equilibrium of an ideal solution with components A and B. As the rate of evaporation equals the rate of condensation, we can write:

$$A_{(l)} \xrightleftharpoons[r_c]{r_v} A_{(g)} \dots \dots \dots (1) \quad (05)$$

r_v and r_c are the rates of vaporization and condensation, respectively of the component A.

Considering (1), we can write;

$$r_v = k[A_{(l)}] = k_1 X_A \quad (05)$$

X_A is the mole fraction of A in solution

Likewise,

$$r'_v = k'[A_{(g)}] = k_2 P_A \quad (05)$$

P_A is the partial pressure of A in vapor phase.

At equilibrium

$$r_v = r'_v$$

$$k_2 P_A = k_1 X_A \quad (05)$$

$$\therefore P_A = \frac{k_1}{k_2} X_A \text{ or } \therefore P_A = k X_A \quad (05)$$

when $X_A = 1$, $P_A = P_A^0$ = saturated vapor pressure of A

$$\therefore k = P_A^0 \quad (05)$$

$$\therefore P_A = P_A^0 X_A \quad (05)$$

6(b) (i): 35 marks

(ii) In the above system at 300 K, the total pressure was 5.0×10^4 Pa. The saturated vapour pressures of pure A and B at 300 K, are 7.0×10^4 Pa and 3.0×10^4 Pa, respectively.

- I. Calculate the mole fraction of A in the liquid phase of the equilibrium mixture.
- II. Calculate the vapour pressure of A in the equilibrium mixture.

$$(I) \quad P_{\text{total}} = P_A + P_B \quad (05)$$

$$= X_A P_A^0 + X_B P_B^0 = X_A P_A^0 + (1 - X_B) P_B^0 \quad (05)$$

$$\therefore X_A = \frac{P_{\text{total}} - P_B^0}{P_A^0 - P_B^0} \quad (05)$$

$$= \frac{5 \times 10^4 - 3 \times 10^4}{7 \times 10^4 - 3 \times 10^4} = \frac{1}{2} \quad (05)$$

$$(II) \quad \therefore P_A = P_A^0 X_A = \frac{1}{2} \times 7 \times 10^4 \text{ Pa} = 3.5 \times 10^4 \text{ Pa} \quad (05)$$

6(b) (ii): 25 marks

6(b): 60 marks

7. (a) (i) To compare the properties of Electrolytic and Galvanic cells, copy and complete the following table using the given terms.

Terms: anode, cathode, positive, negative, spontaneous, non-spontaneous.

		Electrolytic cell	Galvanic cell
A.	Oxidation half reaction takes place at	Anode	Anode
B.	Reduction half reaction takes place at	Cathode	cathode
C.	Sign of E°_{cell}	-ve	+ve
D.	Electron flow	<u>From anode to cathode</u>	<u>From anode to cathode</u>
E.	Spontaneity of reaction	Non-spontaneous	spontaneous

(2 × 10 = 20 marks)

7(a) (i): 20 marks

- (ii) An electrochemical cell was constructed at 300 K by using a Zn(s) anode, an aqueous alkaline electrolyte and a porous Pt cathode which facilitates the collection of oxygen $O_2(g)$ from air as shown below. As the cell operates ZnO(s) is produced.

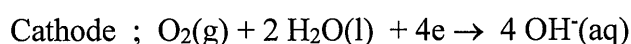
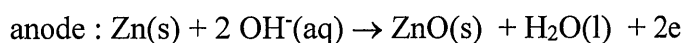
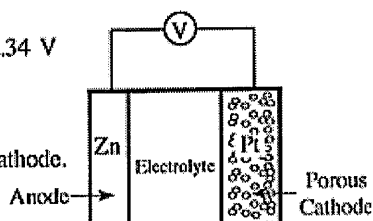
You are given that

$$E^{\circ}_{\text{ZnO(s)}|\text{Zn(s)}|\text{OH}^{\text{(aq)}}} = -1.31 \text{ V} \text{ and } E^{\circ}_{\text{O}_2(\text{g})|\text{OH}^{\text{(aq)}}} = +0.34 \text{ V}$$

$$\text{Zn} = 65 \text{ g mol}^{-1}, \text{ O} = 16 \text{ g mol}^{-1} \text{ and}$$

$$1 F = 96,500 \text{ C}$$

- I. Write the half-reactions occurring at anode and cathode.



- II. Write the overall cell reaction.



- III. Calculate the cell potential E°_{cell} at 300 K.

$$E^{\circ}_{\text{cell}} = E^{\circ}_{\text{R}} - E^{\circ}_{\text{L}} = E^{\circ}_{\text{cathode}} - E^{\circ}_{\text{anode}} \quad (05)$$

$$= 0.34 \text{ V} - (-1.31 \text{ V}) = 1.65 \text{ V} \quad (04+01)$$

- IV. State the direction of migration of $\text{OH}^{\text{(aq)}}$ ions between the electrodes.

From anode to cathode (from Zn electrode to oxygen electrode) (05)

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- V. When the cell operates for a period of 800 s at 300 K, 2 mol of $O_2(g)$ are consumed.
A. Calculate the number of moles of electrons passing through the cell.

$$2 \text{ mol } O_2(g) \times \frac{4 \text{ mol } e^-}{1 \text{ mol } O_2(g)} = 8 \text{ moles of electrons} \quad (05)$$

- B. Calculate the mass of $ZnO(s)$ formed.

$$\text{Mass of } ZnO(s) = \frac{8 \text{ mol } e^- \times 96500 \text{ C}}{1 \text{ mol } e^- \times 800 \text{ s}} \times \frac{1 \text{ mol } e^-}{96500 \text{ C}} \times \frac{2 \text{ mol } ZnO(s)}{4 \text{ mol } e^-} \times \frac{81 \text{ g}}{1 \text{ mol } ZnO} \quad (05)$$

$$= 324 \text{ g} \quad (04+01)$$

OR

$$\text{Mass of } ZnO = 4 \text{ mol} \times 81 \text{ g mol}^{-1} \quad (05)$$

$$= 324 \text{ g} \quad (04+01)$$

- C. Calculate the current passing through the cell.

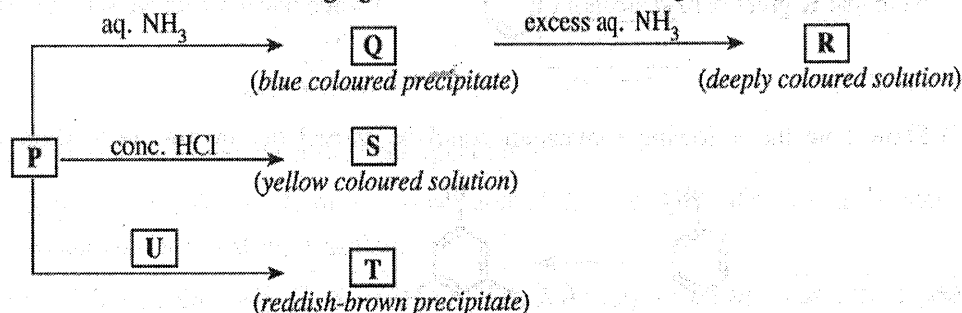
$$I = q/t \quad (05)$$

$$= \frac{8 \text{ mol } e^- \times 96500 \text{ C}}{1 \text{ mol } e^- \times 800 \text{ s}} = 965 \text{ A} \quad (05)$$

7(a) (i): 55 marks

7(a): 75 marks

- (b) A coloured complex ion **P** is formed when the salt $M(NO_3)_n$ is dissolved in distilled water. **M** is a transition element belonging to the 3d block. **P** undergoes the following reactions.



T and **U** are coordination compounds each containing four elements. **P**, **R** and **S** are complex ions.

- (i) Identify the metal **M**. Give the oxidation state of **M** in complex ion **P**.

$$M = Cu \quad (10)$$

$$\text{Oxidation state: } +2 \text{ OR } Cu^{2+} \quad (03)$$

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7(b) (i): 13 marks

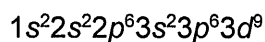
(ii) Give the value of n in $M(NO_3)_n$.

$$n = 2$$

(03)

7(b) (ii): 03 marks

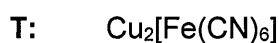
(iii) Write the complete electronic configuration of M in complex ion P .



(03)

7(b) (iii): 03 marks

(iv) Write the chemical formulae of P , Q , R , S , T and U .



7(b) (iv): 16 marks

(v) Give the IUPAC names of P , R , S , T and U .

P : hexaaquacopper(II) ion (03)

R : tetraamminecopper(II) ion (03)

S : tetrachloridocuprate(II) ion (03)

T : copper hexacyanoferrate(II)

U : potassium hexacyanoferrate(II)

7(b) (v): 12 marks

(vi) What is the colour of P ?

pale blue (04)

7(b) (vi): 04 marks

(vii) What would you expect to observe in I and II given below?

I. When H_2S gas is passed into an acidic solution containing P at room temperature

black precipitate (06)

II. When the mixture obtained in I above is heated with dilute HNO_3 after the removal of dissolved H_2S

pale blue solution (04)

solution is turbid/ pale yellow or milky/ white precipitate (02)

or

turbid pale blue solution (06)

7(b) (vii): 12 marks

- (viii) Briefly describe a method with the aid of balanced chemical equations for determining the concentration of M^{n+} present in an aqueous solution, using the following chemicals.
KI, $Na_2S_2O_3$ and starch.

Add excess KI (01)

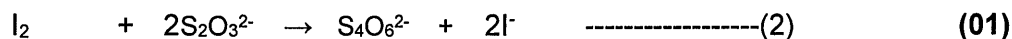
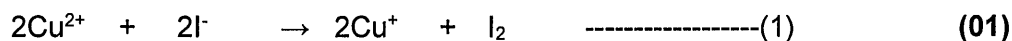
to an aqueous solution of volume V_1 cm³ containing M^{n+} (01)

Here, $M^{n+} = Cu^{2+}$

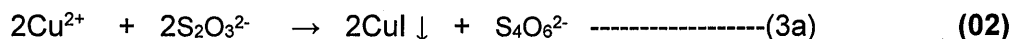
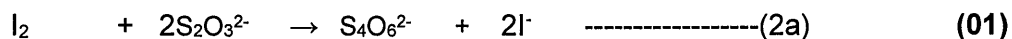
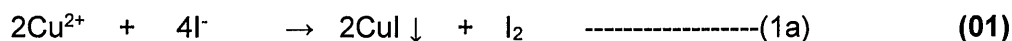
Titrate the liberated I_2 (01)

with $Na_2S_2O_3$ whose concentration is known (M mol dm⁻³) (01)

with starch as the indicator (01)



OR



Note: If correct overall equation is given, award the part marks for half equations as well.

From both (3) or (3a) $Cu^{2+} \equiv S_2O_3^{2-}$ (01)

Let the burette reading of $S_2O_3^{2-}$ be V_2 cm³ (01)

Therefore, moles of $S_2O_3^{2-}$ = $\frac{V_2}{1000} \times M$ (01)

Therefore, moles of Cu^{2+} = $\frac{V_2}{1000} \times M$ (01)

Therefore, $[Cu^{2+}]$ = $\frac{V_2}{1000} \times M \times \frac{1000}{V_1}$ (01)

$$= \frac{MV_2}{V_1} \text{ mol dm}^{-3} \text{ (01)}$$

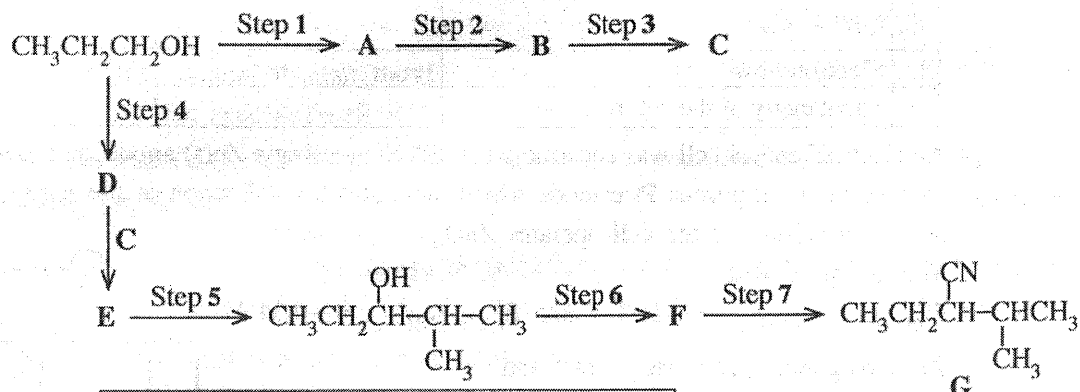
Note: The above explanation could be given in words.

7(b)(viii) : 15 marks

7(b): 75 marks

8. (a) (i) Given below is a reaction scheme for the synthesis of compound G using $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ as the only organic starting compound.

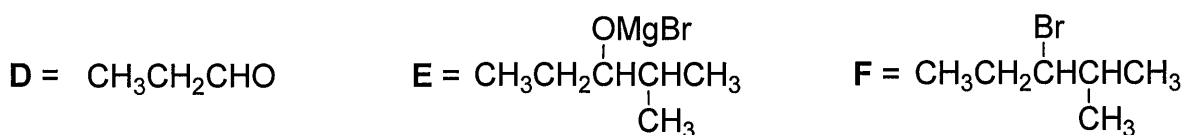
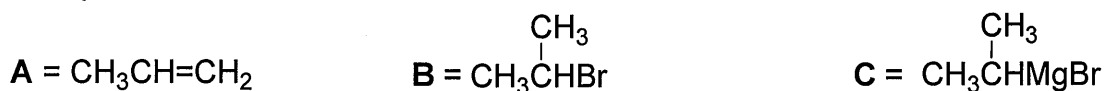
Complete the reaction scheme by drawing the structures of compounds A, B, C, D, E and F and writing the appropriate reagents for steps 1 – 7, selected only from those given in the list.



List of Reagents

HBr, PBr_3 , pyridiniumchlorochromate (PCC),
Mg/dry ether, KCN, conc. H_2SO_4 , dil. H_2SO_4

Compounds, A - F



Reagents:

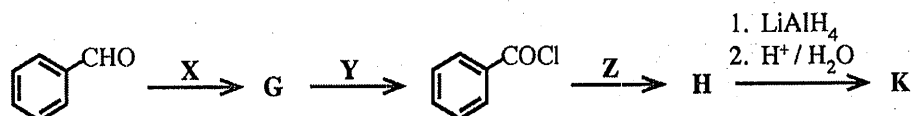
- Step 1 = conc. H_2SO_4 Step 5 = dil. H_2SO_4
Step 2 = HBr Step 6 = PBr_3
Step 3 = Mg / dry ether Step 7 = KCN
Step 4 = PCC

Compounds/Reagents (04 x 13 = 52 marks)

8(a) (i): 52 marks

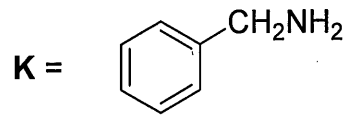
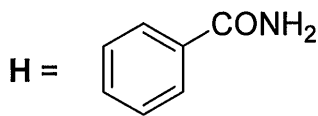
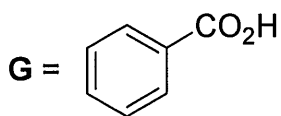
- (ii) Consider the following series of reactions.

Draw the structures of compounds G, H and K. Give the reagents X, Y and Z.

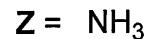
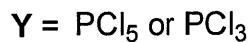
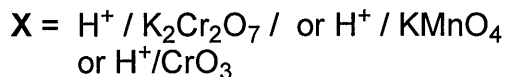


Note that K gives benzyl alcohol ($\text{C}_6\text{H}_5\text{CH}_2\text{OH}$) when reacted with $\text{NaNO}_2/\text{dil. HCl}$.

Compounds G, H and K



Reagents



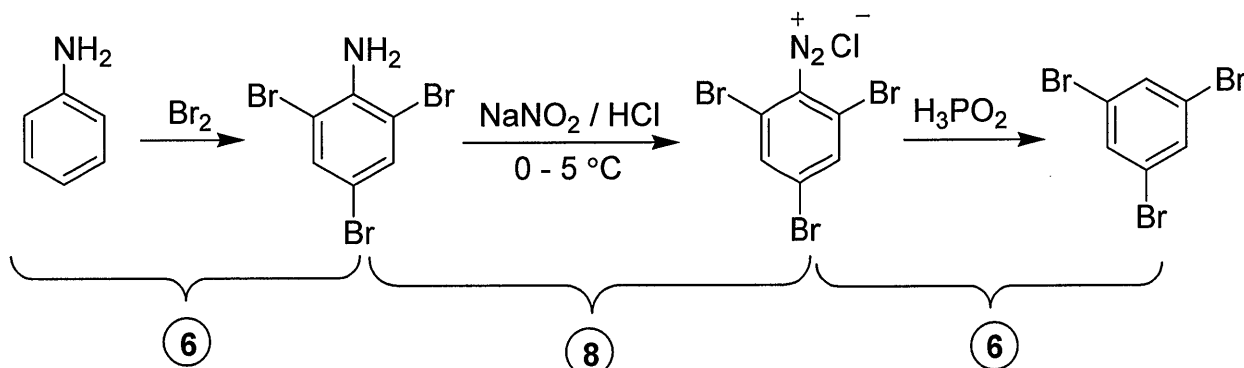
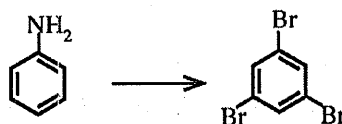
Compounds/Reagents

(04 x 6 = 24 marks)

8(a) (ii): 24 marks

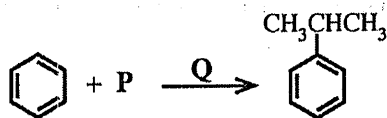
8(a): 76 marks

(b) (i) Show how the following conversion could be carried out in not more than three steps

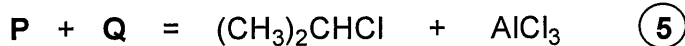


8(b) (i) 20 marks

(ii) Consider the following reaction.

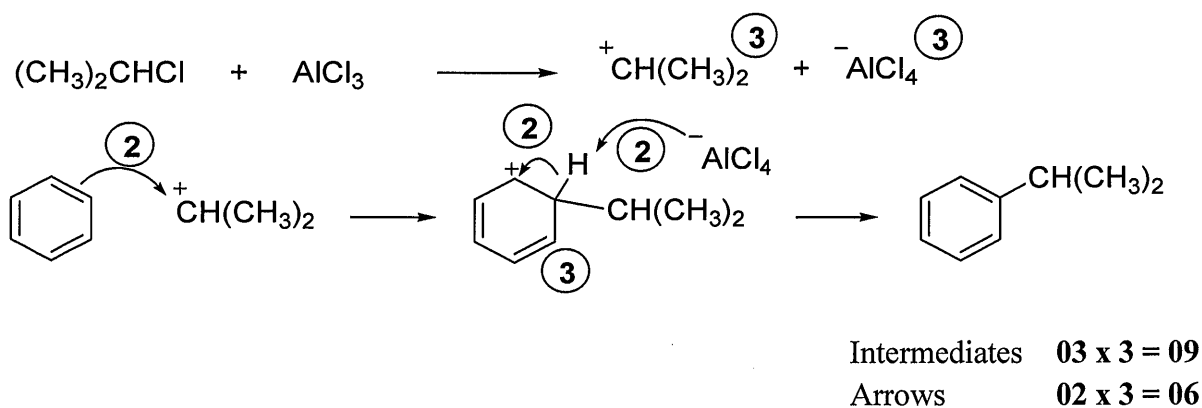


Identify the chemical substances P and Q necessary to carry out this reaction.
Write the mechanism of this reaction.

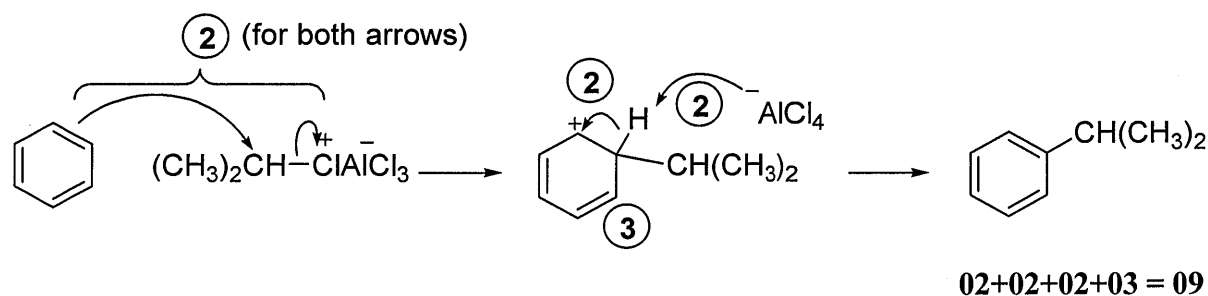


P + Q = (05)

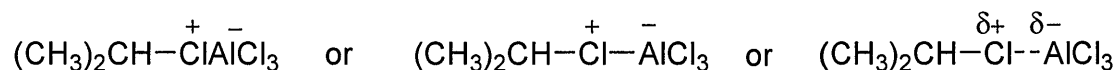
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**Alternative answer:**

IF the student has written the electrophile as R-Cl molecule polarized by coordinating to AlCl_3 , only the marks allocated for the last two steps may be awarded as given below.



The electrophile may be written as:

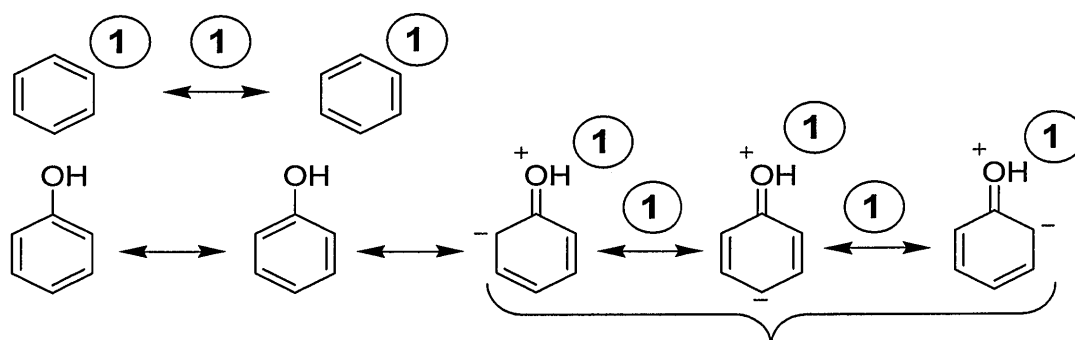


8(b)(ii): 20 marks

8(b): 40 marks

- (c) (i) Explain why phenol is more reactive in electrophilic substitution reactions than benzene, by considering their resonance hybrids.

Structures of benzene and phenol can be illustrated as follows.



Consider these only for marking

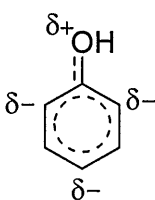
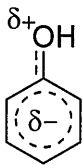
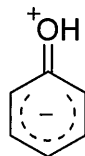
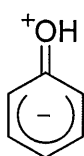
Resonance structures and Double headed arrows **01 x 8 = 08**

OR



Alternative to the resonance hybrid of benzene

3



Any one structure

5

Alternative to the resonance hybrid of phenol

The benzene ring of phenol is more reactive towards electrophiles than benzene itself because:

The benzene ring in phenol is electron rich compared to benzene due to the Delocalization of lone pair of electrons on the oxygen atom

Over the benzene ring of phenol

04 x 3 = 12

8(c)(i): 20 marks

- (ii) Illustrate the difference in reactivity between phenol and benzene as given in (i) above by means of a suitable reaction.

Phenol reacts with bromine at room temperature/ decolorizes bromine / gives a white precipitate with bromine water

Benzene does not react with bromine at room temperature / does not decolorize bromine / does not give a white precipitate with bromine water

OR

Benzene reacts with bromine (only) in the presence of a Lewis catalyst

Reaction of phenol with bromine occurs even in the absence of Lewis catalyst

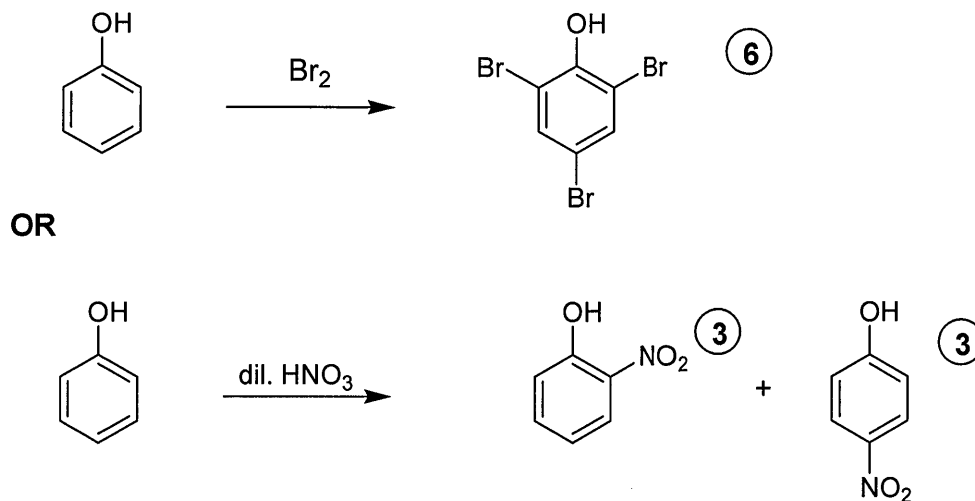
OR

Nitration of phenol takes place at room temperature / at 20 °C / without heating with dilute HNO₃ (20% HNO₃).

Benzene does not react with dilute HNO₃

04 x 2 = 08

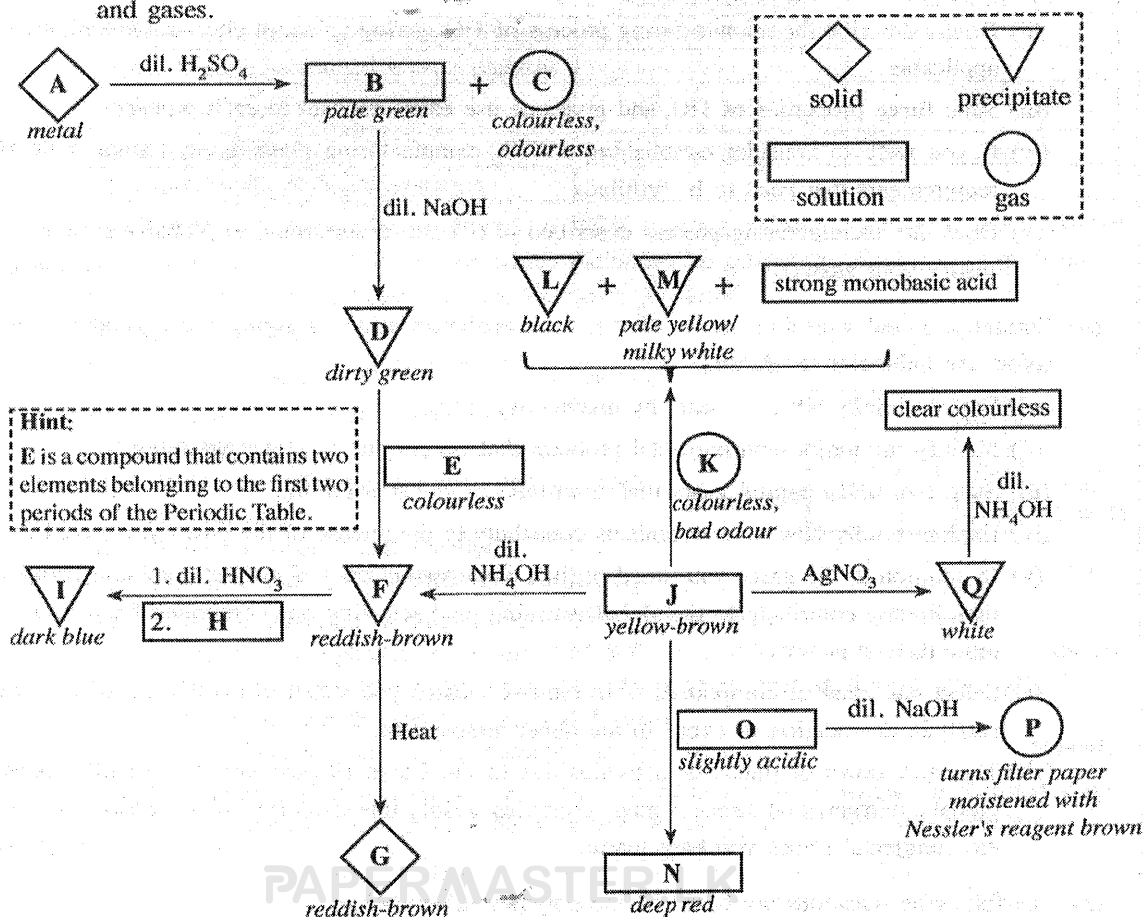
(iii) Draw the structure(s) of product(s) you described in the reaction in (ii) above.



8(c) (iii): 06 marks

8(c): 34 marks

9. (a) (i) Write the chemical formulae of the substances A – Q given in the flow chart below.
 (Note: Chemical equations and reasons are not expected for the identification of substances A – Q.)
 The symbols given in the box (dash lines) are used to represent solids, precipitates, solutions and gases.



A: Fe	B: FeSO ₄ or [Fe(H ₂ O) ₆]SO ₄ or [Fe(H ₂ O) ₆] ²⁺	C: H ₂	D: Fe(OH) ₂
E: H ₂ O ₂	F: Fe(OH) ₃	G: Fe ₂ O ₃	H: K ₄ [Fe(CN) ₆]
I: Fe ₄ [Fe(CN) ₆] ₃ or KFe[Fe(CN) ₆]	J: FeCl ₃	K: H ₂ S	L: FeS
M: S or S ₈	N: Fe(SCN) ₃ or [Fe(SCN)(H ₂ O) ₅] ²⁺ or [Fe(SCN)] ²⁺	O: NH ₄ SCN	P: NH ₃
Q: AgCl			

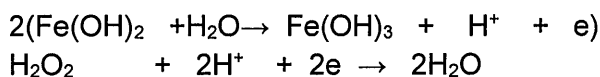
(04 marks x 17 = 68 marks)

9 (a) (i) : 68 marks

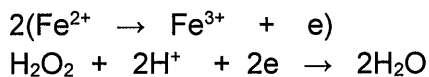
(ii) Write the complete electronic configuration of A.



(iii) State the function of E in the conversion of D to F. Give the relevant balanced chemical equations for the stated function.

E: H₂O₂ function – oxidizing agent (02)

OR



(Half reactions (01) each if written)

9 (a) (ii & iii) marks : 07

- (b) The solid X contains only Cu_2S and CuS . The following procedure was used to determine the percentage of Cu_2S in X.

Procedure

A 1.00 g portion of solid X was treated with 100.00 cm^3 of $0.16 \text{ mol dm}^{-3} \text{ KMnO}_4$ in dilute H_2SO_4 medium. This reaction gave Mn^{2+} , Cu^{2+} and SO_4^{2-} as products. Thereafter, the excess KMnO_4 in this solution was titrated with $0.15 \text{ mol dm}^{-3} \text{ Fe}^{2+}$ solution. The volume required for the titration was 35.00 cm^3 .

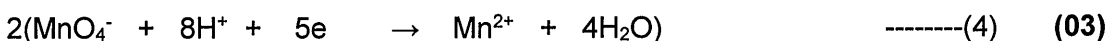
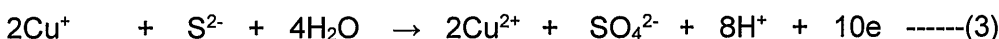
- (i) Write the balanced ionic equations for the reactions taking place in the above procedure.

Reaction of Cu_2S with MnO_4^-

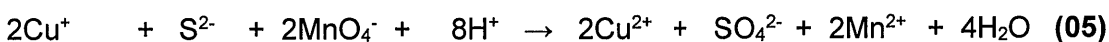


OR

(1) + (2)



(3) + (4)

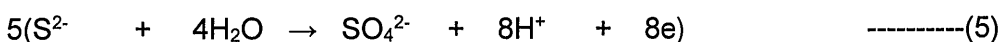


OR

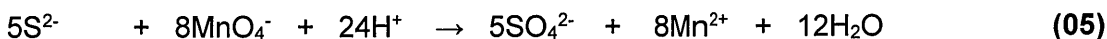


(If only this equation is written award the full 14 marks)

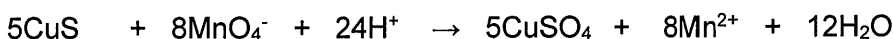
Reaction of CuS with MnO_4^-



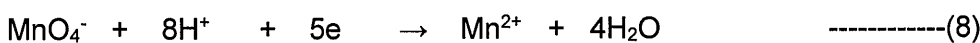
(5) + (6)



OR



Reaction of Fe^{2+} with MnO_4^-



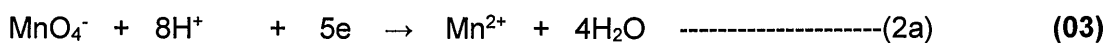
(7) + (8)



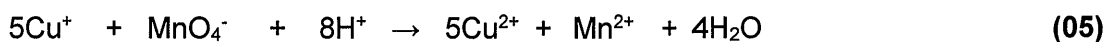
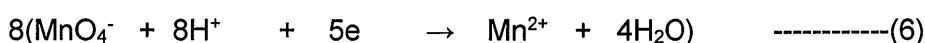
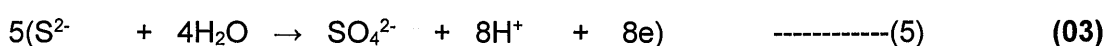
9 (b)(i) : 27 marks

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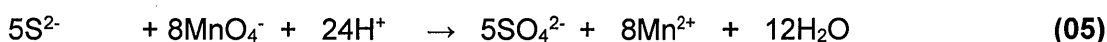
OR

Reaction of Cu⁺ with MnO₄⁻

(1a) + (2a)

**Reaction of S²⁻ with MnO₄⁻**

(5) + (6)

**Reaction of Fe²⁺ with MnO₄⁻**

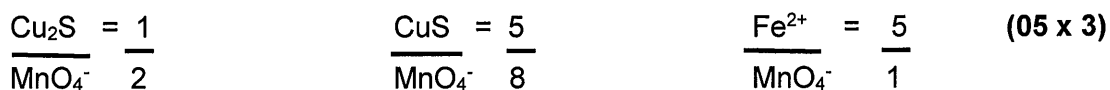
(7) + (8)



Note: If only the overall reaction is written correctly, award the marks due to the half reactions as well.

b (b)(i): 27 marks

(ii) Based on the answers to (i) above, determine the molar ratio between,

I. Cu₂S and KMnO₄II. CuS and KMnO₄III. Fe²⁺ and KMnO₄**Molar ratios**

OR



9 (b)(ii): 15 marks

(iii) Calculate the percentage by weight of Cu_2S in X. (Cu = 63.5, S = 32)

Let the number of moles of Cu_2S and CuS be n_1 and n_2 respectively
in the 1.0 g of sample X

$$\text{Molar mass of } \text{Cu}_2\text{S} = (2 \times 63.5) + 32 = 159 \quad (02)$$

$$\text{Molar mass of } \text{CuS} = 63.5 + 32 = 95.5 \quad (02)$$

$$159n_1 + 95.5n_2 = 1.0 \quad \text{-----}(9) \quad (02)$$

$$\text{Moles of } \text{Fe}^{2+} \text{ reacted} = \frac{0.15}{1000} \times 35.0 \quad (02)$$

$$\text{Moles of } \text{MnO}_4^- = \frac{0.15}{1000} \times 35.0 \times \frac{1}{5} \quad (02)$$

$$\begin{aligned} \text{Moles of } \text{MnO}_4^- \text{ reacted with } \text{Cu}_2\text{S} \text{ and } \text{CuS} \\ &= \frac{0.16}{1000} \times 100.0 - \frac{0.15}{1000} \times 35.0 \times \frac{1}{5} \quad (02) \\ &= 0.016 - 0.001 \quad (02) \\ &= 0.015 \text{ mol} \quad (02) \end{aligned}$$

Based on molar ratios

$$2n_1 + \frac{8}{5}n_2 = 0.015 \quad \text{-----}(10) \quad (02)$$

(9) + (10)

$$2n_1 + \frac{8}{5} \frac{(1-159n_1)}{95.5} = 0.015 \quad (02)$$

$$2 \times 5 \times 95.5 n_1 + 8(1-159n_1) = 0.015 \times 95.5 \times 5 \quad (02)$$

$$955n_1 + 8 - 1272n_1 = 7.1625$$

$$317n_1 = 0.84$$

$$n_1 = 0.0027 \quad (02)$$

$$\text{Weight of } \text{Cu}_2\text{S} = 0.0027 \times 159 \text{ g} \quad (02)$$

$$= 0.43 \text{ g} \quad (02)$$

$$\% \text{ Cu}_2\text{S} = \frac{0.43}{1.0} \times 100 \quad (02)$$

$$= 43\% \quad (03)$$

9 (b)(iii) : 33 marks

OR

$$\text{Moles of } \text{Fe}^{2+} = \frac{0.15}{1000} \times 35.0 \quad (02)$$

$$\text{Moles of } \text{MnO}_4^- \text{ remaining} = \frac{0.15}{1000} \times 35.0 \times \frac{1}{5} \quad (02)$$

$$\text{Moles of } \text{MnO}_4^- \text{ added} = \frac{0.16}{1000} \times 100.0 \quad (02)$$

$$\begin{aligned} \text{Moles of } \text{MnO}_4^- \text{ reacted with } \text{Cu}_2\text{S} \text{ and } \text{CuS} \\ &= \frac{0.16}{1000} \times 100.0 - \frac{0.15}{1000} \times 35.0 \times \frac{1}{5} \quad (02) \\ &= 0.016 - 0.001 \quad (02) \\ &= 0.015 \text{ mol} \quad (02) \end{aligned}$$

Consider the masses of Cu_2S and CuS to be p and q respectively.

$$p + q = 1.0 \text{ g} \quad \text{-----}(9a) \quad (02)$$

$$\text{Molar mass of } \text{Cu}_2\text{S} = (2 \times 63.5) + 32 = 159 \quad (02)$$

$$\text{Molar mass of } \text{CuS} = 63.5 + 32 = 95.5 \quad (02)$$

$$\frac{2p}{159} + \frac{8q}{95.5 \times 5} = 0.015 \quad \text{-----}(10a) \quad (02)$$

From (9a) & (10a)

$$\frac{2p}{159} + \frac{8(1-p)}{95.5 \times 5} = 0.015 \quad (02)$$

$$2p \times 5 \times 95.5 + 8 \times 159(1-p) = 0.015 \times 5 \times 159 \times 95.5 \quad (02)$$

$$955p - 1272p = 1138.84 - 1272 \quad (02)$$

$$317p = 133.16$$

$$p = \frac{133.16}{317} = 0.42 \quad (02)$$

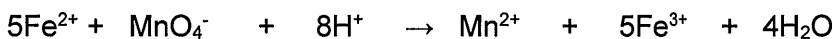
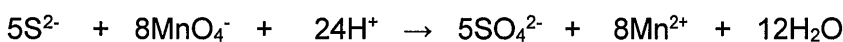
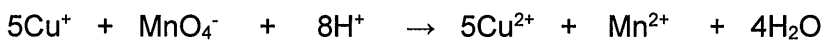
$$\% \text{ Cu}_2\text{S} = \frac{0.42}{1000} \times 100.0 \quad (02)$$

$$= 42\% \quad (03)$$

9 (b)(iii) : 33 marks

OR

Let the number of moles of Cu_2S and CuS be n_1 and n_2 respectively in the 1.0 g of X



$$\text{Moles of } \text{MnO}_4^- \text{ added} = \frac{0.16}{1000} \times 100.0 = 0.016 \quad (02)$$

$$\text{Moles of } \text{Fe}^{2+} \text{ reacted} = \frac{0.15}{1000} \times 35.0 = 0.005 \quad (02)$$

$$\text{Moles of } \text{MnO}_4^- \text{ remaining} = \frac{0.15}{1000} \times 35.0 \times \frac{1}{5} = 0.001 \quad (02)$$

$$\text{Moles of } \text{MnO}_4^- \text{ reacted} = 0.016 - 0.001 = 0.015 \quad (02)$$

$$\text{Molar mass of } \text{Cu}_2\text{S} = (2 \times 63.5) + 32 = 159 \quad (02)$$

$$\text{Molar mass of } \text{CuS} = 63.5 + 32 = 95.5 \quad (02)$$

$$159n_1 + 95.5n_2 = 1 \quad \text{-----}(1) \quad (02)$$

$$\text{Moles of } \text{Cu}^+ = 2n_1$$

$$\text{Therefore, moles of } \text{MnO}_4^- \text{ reacted} = \frac{2n_1}{5}$$

$$\text{Moles of } \text{S}^{2-} = n_1 + n_2 \quad (02)$$

$$\text{Therefore, moles of } \text{MnO}_4^- \text{ reacted with } \text{S}^{2-} = \frac{8(n_1 + n_2)}{5}$$

$$\text{Therefore, total moles of MnO}_4^- \text{ reacted} = \frac{10n_1 + 8n_2}{5} \quad (02)$$

$$\frac{(10n_1 + 8n_2)}{5} \text{ mol} = 0.015 \text{ mol} \quad (02)$$

$$10n_1 + 8n_2 = 0.075 \text{ mol} \quad \text{-----}(2) \quad (02)$$

$$(1) \times 8 - (2) \times 95.5$$

$$1272 n_1 - 955 n_1 = 8 - 7.14 \quad (02)$$

$$317n_1 = 0.86 \quad \text{Therefore, } n_1 = \frac{0.86}{317}$$

$$\text{Therefore, moles of Cu}_2\text{S in 1 g} = \frac{0.86}{317} \quad (02)$$

$$\text{Mass of Cu}_2\text{S} = 0.86 \times 159 \text{ g} \quad (02)$$

$$\% \text{ of Cu}_2\text{S} = \frac{0.86}{317} \times 159 \times 100\% \quad (02)$$

$$= 43\% \quad (03)$$

9 (b)(iii): 33 marks

9(b): 75 marks

10. (a) The following questions are based on the properties of titanium dioxide (TiO₂) and its manufacture carried out by the "Chloride Process".

(i) Name the raw materials used in this process.

Rutile (02)

Coke (02)

Cl₂ (02)

O₂ (02)

10 (a) (i): 08 marks

(ii) Briefly describe the manufacturing process of TiO₂ giving balanced chemical equations where applicable.

Chlorination

Removal of water at 200 °C / 300 °C (02)

Heating of rutile and coke mixture at 900 °C / 950 °C (02)

TiO₂(s) + C(s) → Ti (s) + CO₂ (g) -----(A) (03)

Stream of chlorine is passed over mixture of rutile and coke (02)

Ti(s) + 2Cl₂(g) → TiCl₄(g) -----(B) (03)

OR

Reactions (A) and (B) can be combined.

TiO₂(s) + C(s) + 2Cl₂ → TiCl₄(g) + CO₂(g) (06)

For three descriptions above (02 x 3)

After removal of dust particles, TiCl_4 gaseous mixture is cooled and liquid TiCl_4 is separated. (02)

Oxidation

TiCl_4 is reacted with oxygen and TiO_2 is regenerated.



Cl_2 is re-used in chlorination. (02)

10 (a) (ii): 19 marks

(iii) State **three** properties of TiO_2 and give one use each, relevant to each property.

- White colour – as a pigment in paint, plastic goods and paper, paper
- High refractive index – as a pigment
- Chemically inert – as a pigment in medicine and toothpaste
- Prevents the reach of UV rays to skin – produce substances to prevent sunburn

Any three properties (02 x 3 = 06)

One use for each property (02 x 3 = 06)

10 (a) (iii): 12 marks

(iv) If you were to consider establishing a TiO_2 manufacturing plant in Sri Lanka, state **three** requirements that need to be fulfilled.

- Availability of raw material
- Capital
- Labour force
- Technology
- Storage conditions
- Minimize environmental pollution
- Transport facilities
- Waste product management

Any three (02 x 3 = 06)

10 (a) (iv): 06 marks

(v) Does the manufacturing process described in (ii) above contribute to global warming? Justify your answer.

Yes. (02)

CO_2 is produced and given out to the environment in the oxidation of coke (03)

10 (a) (v): 05 marks

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10(a): 50 marks

(b) Currently, global warming due to change in greenhouse effect is significantly greater than that before the industrial revolution.

(i) Explain briefly what is meant by greenhouse effect.

Heating of earth (01) by infrared absorbing gases (01) in the atmosphere by trapping energy (IR radiation) (02) reradiated from the earth surface (02).

10 (b) (i): 06 marks

(ii) Identify the major environmental problem that occurs due to global warming.

Climate change (03)

10 (b) (ii): 03 marks

(iii) State **two main** natural gases that contribute to global warming.

CO₂, CH₄, and N₂O any two (03 + 03)

10 (b) (iii): 06 marks

(iv) Explain briefly how microorganisms contribute to the release of the gases you stated in (iii).

CO₂- Action of aerobic bacteria on organic substances/ plant materials/ and animal materials

CH₄- Action of anaerobic bacteria on organic substances/ materials

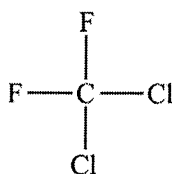
N₂O- Action denitrifying bacteria on ammonia/ nitrogen fertilizers(urea)/ and nitrogen containing substances.

Any two (04 + 04)

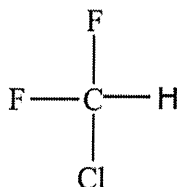
10 (b) (iv): 08 marks

(v) In addition to the gases you stated in (iii), name **two** classes of synthetic volatile compounds that directly contribute to the global warming, and selecting one compound from each class, draw their structures.

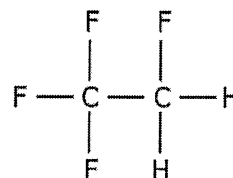
CFC, HFC, HCFC



CFC,



HFC,



HCFC

Any two (03 for class +03 for the structure)

(03 x 4 =12 marks)

No marks for the structure if the class is wrong

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Note In addition to these compounds award marks for the following structures on each class.

CFC - Any saturated organic compound that contain one or two carbon atoms with only Cl and F atom

HCFC - Any saturated organic compound that contain one or two carbon atoms with only one hydrogen atom and others are Cl and F atoms

HFC - Any saturated organic compound that contain one or two carbon atoms with only one hydrogen atom and others are F atoms.

10 (b) (v): 12 marks

(vi) Select **one** class of compounds from the two classes you stated in (v) that contributes to the catalytic degradation of ozone in the upper atmosphere.

CFC or HCFC (must be selected from (v) to get marks)

10 (b) (vi): 03 marks

(vii) The slow down of industrial activities due to the Covid-19 pandemic temporarily eased the global environmental issues in many countries. Justify this statement by using **two** main global environmental issues you have learnt.

Reduction of Global warming (01): Due to the **reduction of emission of CO₂ (01) because of **reduction of fossil fuel burning (02)** due to **limitation of industrial activities (01) and transportation (01)**.**

Reduction of acid rain (01) : Reduction of emission of **SO₂ (01) into the atmosphere due to decrease of **burning of coal and diesel (01+01)** for power generation and **transportation (01+01)** respectively .**

or

Reduction of acid rain (01) Reduction of emission of **NO₂/NO into the atmosphere (01) due to **decrease of fuel burning (01)** in **internal combustion engine (01)** of vehicles caused by limitation of **transportation (02)**.**

Reduction of Photochemical smog (01). Reduction of emission of **NO and volatile hydrocarbons (01+01) into the atmosphere from internal combustion engines/vehicles **(01)** due to limitation of transportation **(02)**.**

Any two (06 x 2 = 12 marks)

10 (b) (vii): 12 marks

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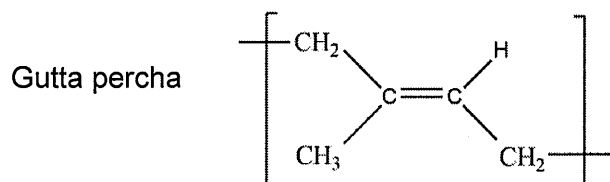
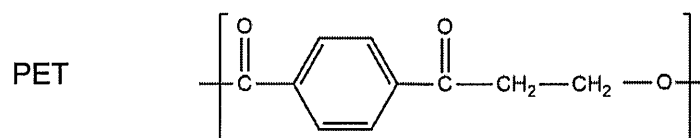
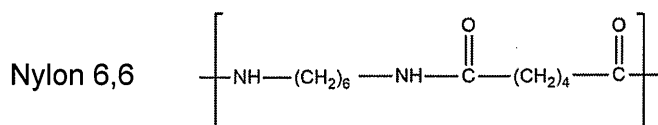
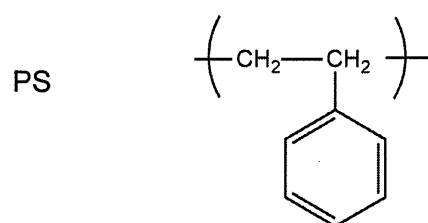
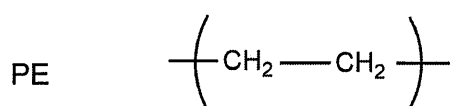
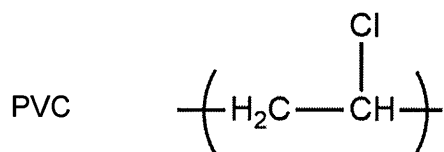
10(b): 50 marks

(c) The following questions are based on the polymers given below.

Polyvinyl chloride (PVC), Polyethylene (PE), Polystyrene (PS), Bakelite,

Nylon 6,6, Polyethylene terephthalate (PET), Gutta percha

(i) Draw the repeating units of the above polymers.



Brackets are not required for award of marks.

Any four

(02 x 4 = 08)

10 (c) (i): 08 marks

(ii) Categorize each of the above seven (7) polymers as either,

- I. natural or synthetic polymers.
- II. addition or condensation polymers.

	I - natural/synthetic	II - addition/condensation
PVC	synthetic	addition
PE	synthetic	addition
PS	synthetic	addition
Bakelite	synthetic	condensation
Nylon 6,6	synthetic	condensation
PET	synthetic	condensation
Gutta percha	natural	addition

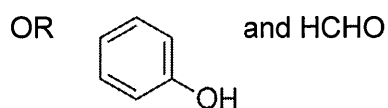
For I – Any 6 (02 x 6 = 12)

For II – Any 6 (02 x 6 = 12)

10 (c) (ii): 24 marks

(iii) Name the two monomers used in the formation of bakelite.

phenol and formaldehyde



(02 x 2 = 04)

10 (c) (iii): 04 marks

(iv) Polymers can be grouped into two categories based on their thermal properties. State these two categories. Write to which of these categories PVC and bakelite belong.

Thermoset polymers (02)

Thermoplastic polymers (02)

Bakelite – thermoset polymer (02)

PVC – thermoplastic polymer (02)

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10 (c) (iv): 08 marks

(v) Give **one** use each for **three** of the polymers given in the above list.

PVC	pipes to supply water, seat cover, electric wire covers
PE	food wrapping, garbage bags
PS	stylofoam cups, rigiform, insulating materials, packing materials
Bakelite	heat resistant parts for electric utensils, insulating materials
Nylon 6,6	clothes, fishing nets & lines, tyre threads
PET	bottles
Gutta percha	insulation, permanent tooth fillings, golf balls

Any three

(02 x 3 = 06)

10(c) (v): 06 marks

10(c): 50 marks