G.C.E. (A/L) Examination - 2019

02 - Chemistry (New Syllabus)

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

ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව
இலங்கைப் பரீட்சைத் திணைக்களம்

අ.පො.ස. (උ.පෙළ) විභාගය/ க.பொ.த. (உயர் தர)ப் பரீட்சை - 2019

නව නිර්දේශය/ புதிய பாடத்திட்டம

විෂයය අංකය பாட இலக்கம்	02	විෂයය பாடம்	**Chemistry**

ලකුණු දීමේ පටිපාටිය/புள்ளி வழங்கும் திட்டம்

I පත්‍රය/பத்திரம் I

ප්‍රශ්න අංකය வினா இல.	පිළිතුරු අංකය விடை இல.	ප්‍රශ්න අංකය வினா இல.	පිළිතුරු අංකය விடை இல.	ප්‍රශ්න අංකය வினா இல.	පිළිතුරු අංකය விடை இல.	ප්‍රශ්න අංකය வினா இல.	පිළිතුරු අංකය விடை இல.	ප්‍රශ්න අංකය வினா இல.	පිළිතුරු අංකය விடை இல.
01.	2 or 4	11.	4	21.	2	31.	1 or 5	41.	1
02.	5	12.	2	22.	2	32.	4	42.	1
03.	3	13.	2	23.	4	33.	2	43.	3
04.	all	14.	2 or 5	24.	3	34.	2	44.	4
05.	5	15.	2	25.	1	35.	2	45.	1
06.	1	16.	5	26.	1	36.	4	46.	4
07.	1	17.	4	27.	5	37.	5	47.	3
08.	2	18.	4	28.	5	38.	3	48.	1
09.	2	19.	3	29.	5	39.	2	49.	1
10.	4	20.	3	30.	3	40.	4	50.	all

✪ **විශේෂ උපදෙස්/ விசேட அறிவுறுத்தல் :**

එක් පිළිතුරකට/ ஒரு சரியான விடைக்கு 01 ලකුණු බැගින්/புள்ளி வீதம்

මුළු ලකුණු/மொத்தப் புள்ளிகள் 1 × 50 = 50

PART A — STRUCTURED ESSAY

*Answer **all four** questions on this paper itself. (Each question carries* **100** *marks.)*

1\. (*a*) The following questions are related to the elements of the second row in the Periodic Table. Write the **symbol** of the element in the space provided in answering parts (i) to (vi).

(i) Identify the element that has the highest electronegativity (disregard the noble gas). ......F......

(ii) Identify the element that has an allotrope which conducts electricity. ......C......

(iii) Identify the element that forms the monoatomic ion largest in size (this should be a stable ion). ......N..........

(iv) Identify the element that has **no** *p* electrons but has a stable *s* configuration. ......Be......

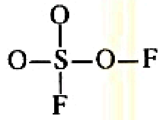
(v) Identify the element that has the highest first ionization energy. ......Ne.........

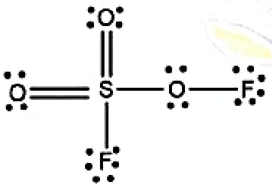
(vi) Identify the element that forms mostly electron deficient trigonal planar covalent compounds. .....B...........

Note: If name is given instead of symbols do not award marks (04 X 6 = 24)

1(a): 24 marks

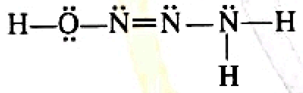
(*b*) (i) Draw the **most** acceptable Lewis dot-dash structure for the molecule SO_3F_2. Its skeleton is given below.

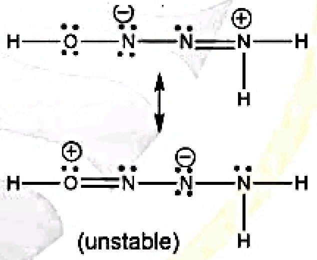




(06)

(ii) The most stable Lewis dot-dash structure for the molecule H_3N_3O is shown below. Draw **two** more Lewis dot-dash structures (resonance structures) for this molecule. Write 'unstable' under the more unstable structure drawn by you.





(04)

(04)

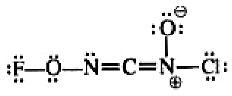
(unstable)

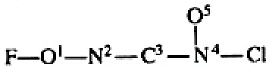
(02)

(iii) Based on the Lewis dot-dash structure given below, state the following regarding the C, N and O atoms given in the table.

I. VSEPR pairs around the atom
II. electron pair geometry around the atom
III. shape around the atom
IV. hybridization of the atom

The atoms numbered as follows.





		O¹	N²	C³	N⁴
I	VSEPR pairs	4	3	2	3
II	electron pair geometry	tetrahedral	trigonal planar	linear	trigonal planar
III	shape	angular / V / bent	angular / V / bent	linear	trigonal planar
IV	hybridization	*sp*³	*sp*²	*sp*	*sp*²

(01 X 16 = 16)

(iv) Identify the atomic/hybrid orbitals involved in the formation of the following σ bonds in the Lewis dot-dash structure given in part (iii) above. (Numbering of atoms is as in part (iii).)

I.	F—O^1	F ....2p OR sp^3....	O^1 ....sp^3....
II.	O^1—N^2	O^1 ....sp^3....	N^2 ....sp^2....
III.	N^2—C^3	N^2 ....sp^2....	C^3 ....sp....
IV.	C^3—N^4	C^3 ....sp....	N^4 ....sp^2....
V.	N^4—O^5	N^4 ....sp^2....	O^5 ....2p OR sp^3....
VI.	N^4—Cl	N^4 ....sp^2....	Cl ....3p OR sp^3....

(01 X 12 = 12)

(v) Identify the atomic orbitals involved in the formation of the following π bonds in the Lewis dot-dash structure given in part (iii) above. (Numbering of atoms is as in part (iii).)

I.	N^2—C^3	N^2 ....2p....	C^3 ....2p....
II.	C^3—N^4	C^3 ....2p....	N^4 ....2p....

(01 X 4 = 04)

(vi) I. How are the two double bonds oriented in the Lewis dot-dash structure given in part (iii)?

Double bonds are perpendicular to each other **(02)**

OR

Sigma bonds linear, π bonds perpendicular **(01 + 01)**

II. Give an example of a molecule/ion that has a similar orientation of double bonds.

....CO_2, NO_2^+, CN_2^{2-}, N_3^-.... **(02)**

Note: Your example should not contain more than 3 atoms.
The elements in your example should be restricted to the first and second periods of the Periodic Table.

1(b): 52 marks

(c) (i) An atomic orbital is described by three quantum numbers n, l and m_l.

Write the appropriate quantum numbers and the name of the atomic orbital in the boxes given below.

	n	l	m_l	atomic orbital
I.	3	1	+1	3p
II.	3	2	−2	3d
III	2	0	0	2s

(01 X 6 = 06)

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

I. LiF, LiI, KF (melting point)

....LiI.... < ....LiF.... < ....KF....

II. NO_2^-, NO_4^{3-}, NF_5 (stability)

....NF_5.... < ....NO_4^{3-}.... < ....NO_2^-....

III. NOCl, $NOCl_3$, NO_2F (N—O bond distance)

..NOCl.. < ....NO_2F < ..$NOCl_3$.

(06 X 3 = 18)

1(c): 24 marks

2.(*a*) **X** is an *s*-block element in the Periodic Table. The first, second and third ionization energies of **X**, in kJ mol^{-1} are 738, 1451 and 7733 respectively. **X** reacts slowly with hot water, liberating H_2(g) and forming its hydroxide. The hydroxide is basic. **X** also liberates H_2(g) on reaction with dilute acids. **X** burns in air with a bright white light. The cation of **X** contributes to hardness of water.

(i) Identify **X**. **X**: Mg **OR** Magnesium **(07)**

(ii) Write the ground state electronic configuration of **X**. $1s^22s^22p^63s^2$ **(04)**

(iii) Write the chemical formulae of the **two** compounds formed when **X** burns in air.

MgO and Mg_3N_2 **(03 + 03)**

Note: If X has been identified correctly marks can be awarded for XO and X_3N_2

(iv) Consider the given compounds of the elements in the group in the Periodic Table to which **X** belongs. In the given boxes, write whether the indicated property **increases** or **decreases** down the group.

I. Solubility of sulphates in water: Decreases **(03)**

II. Solubility of hydroxides in water: Increases **(03)**

III. Thermal stability of metal carbonates: Increases **(03)**

Give reasons for your answer in III.

Cation size increases down the group. Charge same. **(03)**
OR
Charge density decreases down the group. **(03)**
Therefore, polarizing power decreases down the group. **(02)**
Hence, decomposition of the carbonates become difficult on going down the group. **(03)**

(v) Identify the element in the *s*-block of the Periodic Table, which reacts in a similar manner to **X** with H_2(g), O_2(g) and N_2(g), but does **not** belong to the same group as **X**.

Lithium **OR** Li **(04)**

(vi) Identify another **metal ion** that contributes to hardness of water.

Ca^{2+} **(No marks for Ca OR Calcium)** **(04)**

(vii) Identify the compound most commonly used to remove hardness of water.

Na_2CO_3 **OR** Soda Ash **(04)**

(viii) **X** is a component of a well-known reagent used in organic chemistry. Give the **name** of this reagent.

Grignard reagent **(04)**

Note: If X is incorrect, do not award marks for (a)(ii) – (iv).

2(a): 50 marks

(*b*) Test tubes labelled **A** to **E** contain aqueous solutions of $Na_2S_2O_3$, Na_2CO_3, KNO_2, KBr and Na_2S (not in order). The characteristics of the solutions obtained and gases evolved on addition of dil. HCl (warming if required) to each of the test-tubes **A** to **E** are given in the table below.

Test-tube	Appearance of solution	Gas
A	colourless	colourless and odourless
B	colourless	reddish-brown with a pungent odour
C	colourless	colourless with a rotten egg odour
D	turbid	colourless with a pungent odour
E	colourless	not evolved

(i) Identify the solutions in each of the test-tubes **A** to **E**.

A : ...Na_2CO_3.......... **C** : ......Na_2S.......... **E** : ....KBr.......

B : ....KNO_2............ **D** : ......$Na_2S_2O_3$...... **(04 X 5 = 20)**

(ii) Write balanced chemical equations for the reactions that take place in test-tubes **A**, **B**, **C** and **D**.

In A: $Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$

In B: $KNO_2 + HCl \rightarrow KCl + HNO_2$ **OR**

$2KNO_2 + 2HCl \rightarrow 2KCl + NO_2 + NO + H_2O$ **OR**

$3KNO_2 + 3HCl \rightarrow 3KCl + HNO_3 + 2NO + H_2O$ **OR**

$3KNO_2 + 3HCl + O_2 \rightarrow 3KCl + HNO_3 + H_2O + 2NO_2$ **OR**

$4KNO_2 + 4HCl + O_2 \rightarrow 4KCl + 4NO_2 + 2H_2O$

In C: $Na_2S + 2HCl \rightarrow 2NaCl + H_2S$

In D: $Na_2S_2O_3 + 2HCl \rightarrow 2NaCl + SO_2 + S + H_2O$ **(04 X 4 = 16)**

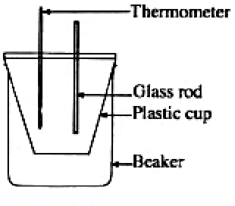
(iii) Write a chemical test to identify each of the gases evolved in **A**, **C** and **D**.
Note: Observations are also required.

In A: **(CO_2)** Pass through a solution of $Ca(OH)_2$. **(02)**
Solution turns milky. On continued passing, milky solution becomes colourless. **(02)**
In C: **(H_2S)** Test with filter paper moistened with lead acetate. **(03)**
Filter paper turns black. **(02)**
OR
Test with filter paper moistened with cadmium acetate. **(03)**
Filter paper turns yellow. **(02)**
OR
Pass through a solution of acidified $KMnO_4$. **(03)**
(Purple) solution becomes colourless, but solution is not clear (cloudy) **(02)**
OR
Pass through a solution of acidified $K_2Cr_2O_7$. **(03)**
(Orange) solution becomes green, but solution is not clear (cloudy) **(02)**
In D: **(SO_2)** Pass through a solution of acidified $KMnO_4$. **(03)**
(Purple) solution becomes colourless. **(02)**
OR
Pass through a solution of acidified $K_2Cr_2O_7$./Test with filter paper moistened with acidified $K_2Cr_2O_7$ **(03)**
(Orange) solution becomes green. / Filter paper turns green. **(02)**
OR
Pass through a solution of $Ca(OH)_2$. **(03)**
Solution turns milky. On continued passing, milky solution becomes colourless. **(02)**
OR
Test with moist coloured flower petals. **(03)**
Petals are decolourized /bleached. **(02)**

Note: Identification in (b)(i) must be correct for award of marks for respective answers in (b)(ii) & (b)(iii).

2(b): 50 marks

3. The set up shown in the figure was used to calculate the heat change associated with the dissolution of MX(s) in water. 100.00 cm^3 of distilled water was added to the cup. The initial temperature of distilled water was measured to be 25.0 °C. Then 0.10 mol of MX(s) was added to the water and stirred continuously. It was observed that the temperature of the solution decreased gradually. The lowest temperature measured was 17.0 °C. The amount of water used was sufficient to completely dissolve MX(s). Density and specific heat capacity of water are 1.00 g cm^{-3} and 4.20 J g^{-1} °C^{-1} respectively. Assume that the density and the specific heat capacity of water are not changed due to the dissolution of MX(s).



(i) Calculate the amount of heat that should be supplied to bring the system (solution) back to 25.0 °C.

......$q = m\,s\,\Delta T$ (OR $q = m\,c\,\Delta T$)........................ **(5)**

...........$= 100.00\ cm^3 \times 1.0\ g\ cm^{-3} \times 4.2\ J\ {}^0C^{-1}\ g^{-1} \times (25.0 - 17.0)\ {}^0C$ **(4+1)+(4+1)+(4+1)+(4+1)**

$= 3360$ J **(4+1)**

(ii) Is the dissolution of MX(s) in water an endothermic or exothermic process? Explain your answer.

Dissolution of MX(s) has absorbed heat (**OR** temperature of water decreased) (2)

Process is endothermic (2)

(iii) Calculate the enthalpy change (in kJ mol^{-1}) associated with reaction

$MX(s) + H_2O(l) \rightarrow M^+(aq) + X^-(aq)$.

$$\Delta H = \frac{3360\ J}{0.10\ mol} \quad (4+1)+(4+1)$$

$= 33.6\ kJ\ mol^{-1}$ (**OR** $33600\ J\ mol^{-1}$) (4+1)

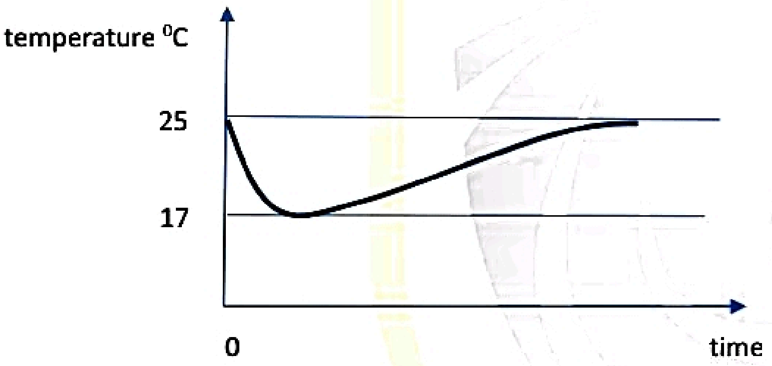
(iv) If this experiment was conducted using 200.00 cm^3 of water, would you expect the temperature change to be larger than the above value? Explain your answer.

No (**OR** the temperature change would be smaller) (2)

Amount of heat (q) is constant, the mass (m) has increased. Therefore, the temperature change (ΔT) would be smaller (**OR** More water is available to release heat) (2)

(v) Show the variation of temperature of the system (solution) by drawing the temperature – time curve.

Note: Eventually the system reaches the room temperature (25.0 °C).



Curve starts from t=0 (or the time of salt addition is marked) (2)
Curve starts from 25 °C (2)
Curve goes down to 17 °C (2)
Curve has the correct shape (4)

(vi) In this experiment, explain why a plastic cup is used instead of a metal cup.

Metals are good thermal conductors. (**OR** when the temperature is decreased, metal provides and conducts heat from surroundings) (2)

Plastics are poor thermal conductors and have low heat capacity (2)

(vii) Gibbs energy change (ΔG) for the dissolution of MX(s) in water at the temperature of 25.0 °C and pressure of 1.0 atm was calculated to be –26.0 kJ mol^{-1}. Calculate the entropy change (ΔS) of dissolution of MX(s) in water at 25.0 °C using the enthalpy change calculated above.

$\Delta G = \Delta H - T\Delta S$ **(No marks for $\Delta G^0 = \Delta H^0 - T\Delta S^0$)** (5)

$$\Delta S = \frac{\Delta H - \Delta G}{T}$$

$$= \frac{33.6\ kJ\ mol^{-1} - (-26.0\ kJ\ mol^{-1})}{298\ K} \quad (4+1)+(4+1)+(4+1)$$

$= 200\ J\ mol^{-1}\ K^{-1}$ (4+1)

(viii) Would you expect the solubility of MX(s) to increase or decrease with increasing temperature? Give reasons for your answer.

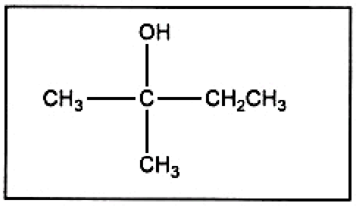
Solubility of MX(s) in water increases with increasing temperature (4)

because ΔG becomes more negative. (4)

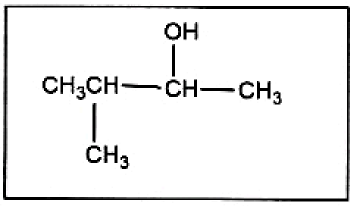
(**OR** because the dissolution of MX(s) is endothermic)

4. (*a*) Compounds **A** and **B** both have the same molecular formula $C_5H_{10}O$. Both **A** and **B** give orange/red precipitates with 2,4-dinitrophenylhydrazine. When **A** and **B** are reacted separately with $NaBH_4$ in methanol, compound **A** gives **C** and compound **B** gives **D**. When **C** is heated with Al_2O_3, two alkenes **E** (C_5H_{10}) and **F** (C_5H_{10}) are formed. When **E** and **F** are reacted separately with conc. H_2SO_4 and the products obtained are hydrolysed, compound **E** gives **G**, while compound **F** gives **H**. **G** gives a turbidity immediately with the Lucas reagent. **H** also gives a turbidity with the Lucas reagent but not immediately.

(i) Draw the structures of **G** and **H**.


$CH_3-\overset{OH}{\underset{CH_3}{C}}-CH_2CH_3$

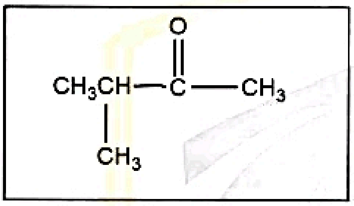
G


$\underset{CH_3}{CH_3CH}-\overset{OH}{CH}-CH_3$

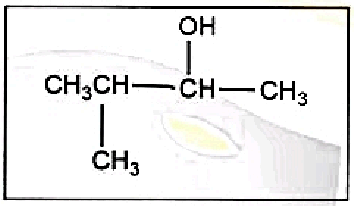
H

(05 x 2 = 10)

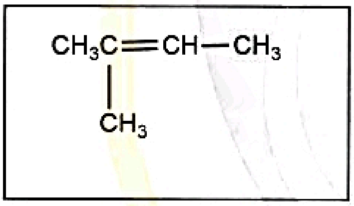
(ii) Draw the structures of **A**, **C**, **E** and **F**.


$\underset{CH_3}{CH_3CH}-\overset{O}{\overset{\|}{C}}-CH_3$

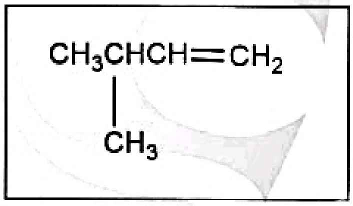
A


$\underset{CH_3}{CH_3CH}-\overset{OH}{CH}-CH_3$

C


$\underset{CH_3}{CH_3C}=CH-CH_3$

E

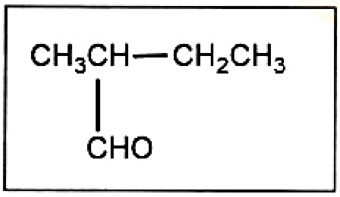

$\underset{CH_3}{CH_3CH}CH=CH_2$

F

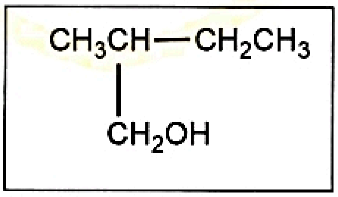
(05 x 4 = 20)

When heated with Al_2O_3, **D** gives alkene **I** (C_5H_{10}). When **I** is reacted with conc. H_2SO_4 and the product obtained hydrolysed, **G** is obtained.

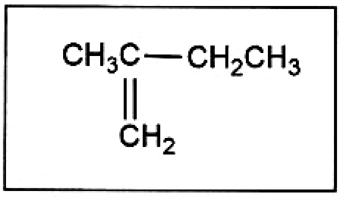
(iii) Draw the structures of **B**, **D** and **I**.


$\underset{CHO}{CH_3CH}-CH_2CH_3$

B


$\underset{CH_2OH}{CH_3CH}-CH_2CH_3$

D


$\underset{CH_2}{\underset{\|}{CH_3C}}-CH_2CH_3$

I

(05 x 3 = 15)

Note : 1. Mark A-I Independently

2. If the correct structure is given for either C or H, award full marks for both C and H (05x2 = 10)

(iv) Describe a test/reaction to distinguish between **A** and **B**.

B gives

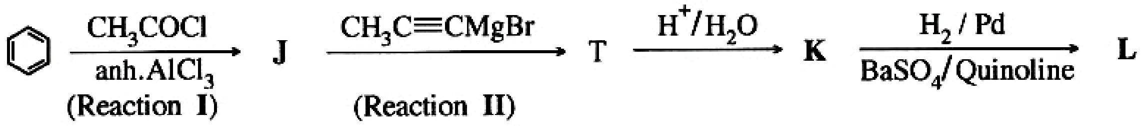
Tollens reagent - Silver mirror
Fehlings solution - Red colouration
Acidic $K_2Cr_2O_7$ - Green colouration
Dilute $KMnO_4$ solution - Decolourization **(05)**

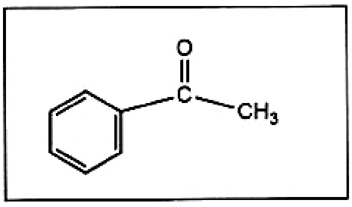
(Any one)

Note: Marks awarded only if A and B are correct.

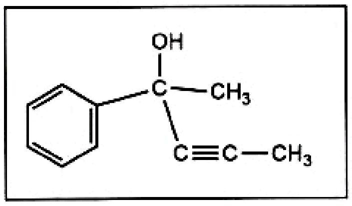
4(a): 50 marks

(*b*) (i) Give the structures of **J**, **K**, **L** and **M** in the following reaction sequences.

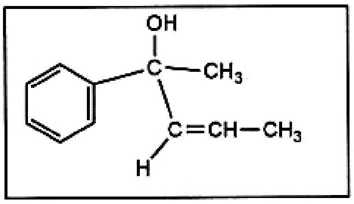




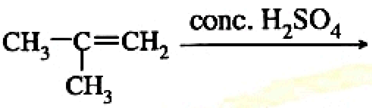
J



K

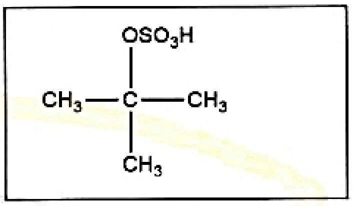


L



$$CH_3-\underset{CH_3}{\underset{|}{C}}=CH_2 \xrightarrow{\text{conc. } H_2SO_4} \mathbf{M}$$

(Reaction **III**)



M

(05 x 4 = 20)

(ii) Selecting from the list given below, write the type of reaction taking place in reactions **I**, **II** and **III**.

Nucleophilic Addition,	Nucleophilic Substitution,	
Electrophilic Addition,	Electrophilic Substitution,	Elimination

Reaction I - Electrophilic substitution

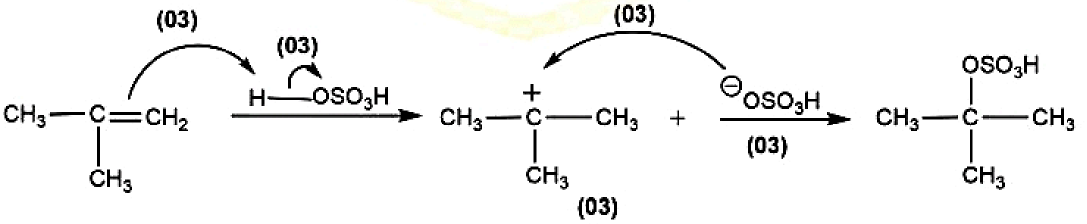
Reaction II - Nucleophilic addition

Reaction III - Electrophilic addition

(05 x 3 = 15)

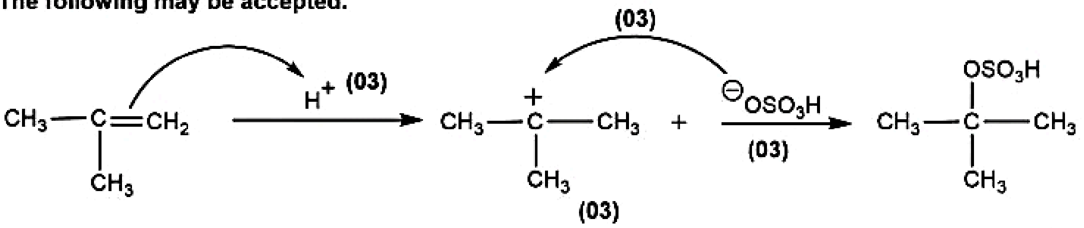
Note : Marks awarded only if each of the reactions I, II and III correct as given in the marking scheme

(iii) Using your knowledge of the mechanism of the reaction between alkenes and HBr, give the mechanism of reaction **III**.



(15 marks)

The following may be accepted.



(12 marks)

4(b): 50 marks

PART B - ESSAY

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

5. (*a*) A titration between the mono acidic weak base **B** (0.15 mol dm^{-3}) and HCl (0.10 mol dm^{-3}) was carried out using a suitable indicator as described below.

The HCl solution (25.00 cm^3) was kept in the titration flask and the weak base **B** was added using a burette. The dissociation constant, K_b of the weak base at 25 °C is 1.00×10^{-5} mol dm^{-3}. All the experiments were conducted at 25 °C.

(i) Calculate the pH of the acid solution in the titration flask, before the addition of the base, **B**.

pH of the HCl solution.

pH = - log[H^+] **(2)**

= - log(0.1)

= 1.0 **(2+1)**

(ii) Calculate the pH of the solution in the titration flask, after the addition of 10.00 cm^3 of the solution of **B**. Can the solution in the titration flask act as a buffer solution? Explain your answer.

pH after addition of 10.00 cm^3 of B solution.

$$[H^+] = \frac{0.1 \text{ mol dm}^{-3} \times 25.00 \text{ cm}^3 - 0.15 \text{ mol dm}^{-3} \times 10.00 \text{ cm}^3}{35.00 \text{ cm}^3}$$ **(4+1)**

= 0.028 mol dm^{-3}

pH = 1.5 (**OR** 1.6) **(4+1)**

No **OR** this solution cannot act as a buffer solution. **(3)**

Only protonated base (conjugate acid) is present (No unreacted or unprotonated base) **(3)**

Note : If correctly explained using the addition of H^+ and OH^-, award full marks

(iii) Calculate the volume of the weak base solution required to reach the equivalence point.

Volume of base required to reach equivalence point.

$$V = \frac{0.1 \text{ mol dm}^{-3} \times 25.00 \text{ cm}^3}{0.15 \text{ mol dm}^{-3}}$$ **(4+1)**

= 16.66 cm^3

(16.67 cm^3 **OR** the answer reported to one decimal place is also accepted) **(4+1)**

(iv) Another 10.00 cm^3 volume of the weak base was added to the titration flask after reaching the equivalence point. Calculate the pH of the solution in the titration flask.

pH after addition of 10.00 cm^3 of base after reaching the equivalence point.

Weak base dissociates according to,

$B(aq) + H_2O(l) \rightleftharpoons BH^+(aq) + OH^-(aq)$ **(2)**

$$K_b = \frac{[BH^+(aq)][OH^-(aq)]}{[B(aq)]}$$ **(4)**

OR

$$pOH = pK_b + log\left(\frac{[BH^+(aq)]}{[B(aq)]}\right)$$

Note : Physical states are required for the award of marks

Assuming that the amount dissociated is negligible, **(2)** Concentration of the weak base [B(aq)] = $\frac{0.15 \text{ mol dm}^{-3} \times 10.00 \text{ cm}^3}{(25.00 \text{ cm}^3 + 16.66 \text{ cm}^3 + 10.00 \text{ cm}^3)}$ **(4+1)**

Concentration of the protonated weak base [$BH^+(aq)$] = $\frac{0.15 \text{ mol dm}^{-3} \times 16.66 \text{ cm}^{-3}}{(25.00 \text{ cm}^3 + 16.66 \text{ cm}^3 + 10.00 \text{ cm}^3)}$ **(4+1)**

$$pOH = -\log(1 \times 10^{-5}) + \log\left(\frac{0.15\ mol\ dm^{-3} \times 16.66\ cm^3}{0.15\ mol\ dm^{-3} \times 10.00\ cm^3}\right)$$ **(4+1)**

pOH = 5.0 + 0.221 = 5.221

pH = 8.78 (or 8.7 or 8.9 or 9) **(4+1)**

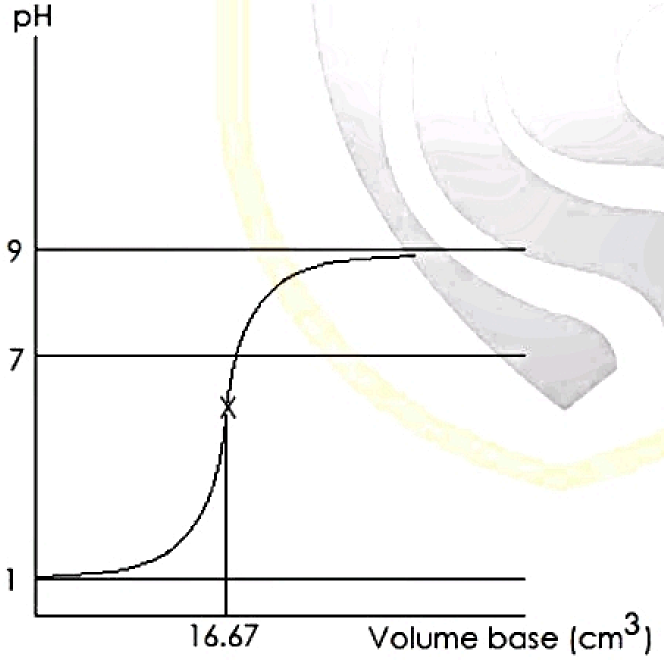
(v) Can the solution obtained in (iv) above act as a buffer solution? Explain your answer.

Yes **OR** it can act as a buffer solution. **(3)**

The solution in the titration flask contains the protonated base (conjugate acid) and unreacted base. **(3)**

Note : If correctly explained using the addition of H^+ and OH^-, award full marks

(vi) Sketch the variation in pH of the mixture in the titration flask with the volume of the weak base solution added (titration curve). Label the axes, indicate pH on the y-axis and the volume of weak base solution added on the x-axis. Mark the equivalence point approximately. [Calculation of pH at equivalence point is not expected.]



Curve starts at pH=1 and reaches pH=9 and has the correct shape **(4)**

Equivalence volume marked **(2)**

Equivalence pH (between pH = 5 and pH=7) marked **(2)**

Axes are labeled (with units where applicable) **(1+1)**

5 (a): 75 marks

(*b*) The following two experiments were carried out at a constant temperature using the volatile liquids **C** and **D** which form an ideal solution.

Experiment I: The liquids **C** and **D** were introduced in to an evacuated rigid container and allowed to reach equilibrium. When the system was at equilibrium, it was observed that the mole fractions of **C** and **D** in the liquid phase (L_I) were 0.3 and 0.7 respectively. Total pressure in the container was 2.70×10^4 Pa.

Experiment II: This experiment was conducted using different amounts of **C** and **D**. When the equilibrium was established, it was observed that the mole fractions of **C** and **D** in the liquid phase (L_{II}) were 0.6 and 0.4 respectively. Total pressure of the container was 2.40×10^4 Pa.

(i) Give the relationship between the partial pressure of **C** in the vapour phase (P_C), its saturated vapour pressure $\left(P_C^\circ\right)$ and its mole fraction in the liquid phase (X_C) in the form of an equation. This equation states a commonly used law in physical chemistry. Write the name of the law.

$P_C = x_C P^0_C$ **(Award marks only for these symbols)** **(5)**

Raoult's law **(4)**

(ii) Calculate the saturated vapour pressures of **C** and **D**.

Experiment I

$2.7 \times 10^4 \text{ Pa} = 0.3 P^0_C + 0.7 P^0_D$ ---(1) **(4+1)**

Experiment II

$2.4 \times 10^4 \text{ Pa} = 0.6 P^0_C + 0.4 P^0_D$ ---(2) **(4+1)**

(1)x2-(2)

$P^0_D = 3.0 \times 10^4 \text{Pa}$ **(4+1)**

$P^0_C = (2.4 \times 10^4 \text{ Pa} - 0.4 \times 3.0 \times 10^4 \text{Pa})/0.6$

$= 2.0 \times 10^4$ Pa **(4+1)**

(iii) Calculate the mole fractions of **C** and **D** in the vapour phase (V_I) of experiment I.

Mole fractions in the gas phase (experiment I, V_I)

$X^g_{C,I} = \dfrac{0.3 \times 2.0 \times 10^4 \text{ Pa}}{2.7 \times 10^4 \text{Pa}}$ **(1+1)**

= 0.2 **(OR** 0.22 **OR** 2/9) **(1+1)**

$X^g_{D,I} = 1 - 0.2$ **(1+1)**

= 0.8 **(OR** 0.78 **OR** 7/9) **(1+1)**

(iv) Calculate the mole fractions of **C** and **D** in the vapour phase (V_{II}) of experiment II.

Mole fractions in the gas phase (experiment II, V_{II})

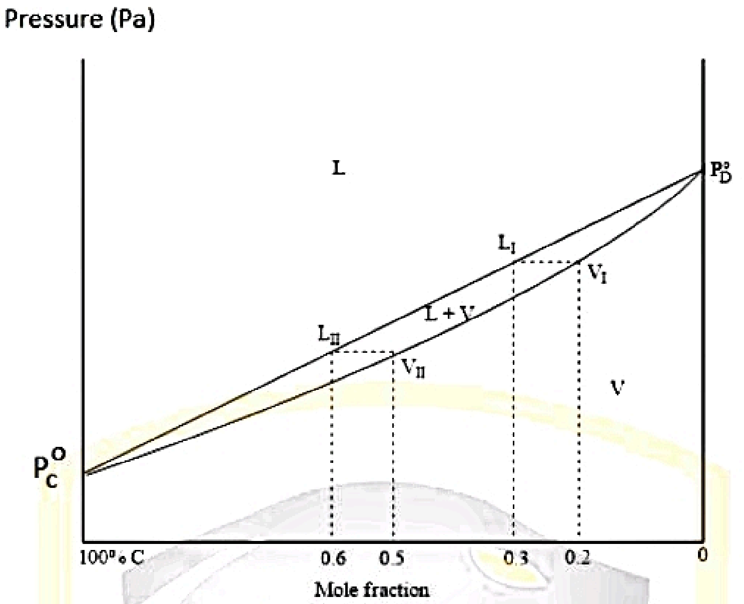
$X^g_{C,II} = \dfrac{0.6 \times 2.0 \times 10^4 \text{ Pa}}{2.4 \times 10^4 \text{Pa}}$ **(1+1)**

= 0.5 **(1+1)**

$X^g_{D,II} = 1 - 0.5$ **(1+1)**

= 0.5 **(1+1)**

(v) Show the compositions of liquid and vapour phases (L_I, L_{II}, V_I and V_{II}) and relevant pressures in the above two experiments on a pressure-composition phase diagram drawn at constant temperature.



L=liquid, V= vapour

Note :Graph could also be drawn by reversing the increasing direction of the mole fraction of C. Mark accordingly

Axes labeled (with appropriate units where applicable)	(2+2)
P^0_C and P^0_D marked	(2+2)
Line & curve (starts and ends at correct pressures)	(2+2)
Phases at equilibrium in each region identified	(2+2+2)
point L_I marked at $X_C = 0.3$	(2)
point L_{II} marked at $X_C = 0.6$	(2)
point V_I marked at $X_C = 0.2$	(2)
point V_{II} marked at $X_C = 0.5$	(2)
points L_I and V_I are at the same level	(2)
points L_{II} and V_{II} are at the same level	(2)

Note : No marks for temperature composition phase diagram

5 (b): 75 marks

6. (*a*) An organic solvent (org-1) and water(aq) are immiscible and form a biphasic system. Partition coefficient for the distribution of **X** between org-1 and water at temperature T is, $K_D = \frac{[\mathbf{X}]_{\text{org-1}}}{[\mathbf{X}]_{\text{aq}}} = 4.0$

An amount of 0.50 mol of **X** was added to a system containing 100.00 cm^3 of org-1 and 100.00 cm^3 of water. The system was allowed to reach equilibrium at temperature T.

(i) Calculate the concentration of **X** in org-1.

Calculation of $[X]_{org\text{-}1}$

$$K_D = \frac{[X]_{org-1}}{[X]_{aq}} = 4.0$$

V= volume, x= amount (mols) in aqueous phase.

$$K_D = \frac{\frac{0.5\,mol - x}{V}}{\frac{x}{V}} = 4.0$$ **(No marks for substitution in mols)** **(4+1)**

x = 0.1 mol **(4+1)**

$$[x]_{org-1} = \frac{0.4\,mol}{100\times10^{-3}\,dm^3} = 4.0\text{ mol dm}^{-3}$$ **(4+1)**

(ii) Calculate the concentration of **X** in water.

$$[x]_{aq} = \frac{0.1\,mol}{100\times10^{-3}\,dm^3} = 1.0\text{ mol dm}^{-3}$$ **(4+1)**

6 (a): 20 marks

(*b*) The compound **Y** is soluble only in the aqueous phase. In the aqueous phase, **X** and **Y** react to form **Z**. The presence of **Y** and **Z** does not affect the distribution of **X** between org-1 and water.

A series of biphasic systems containing org-1 and water were prepared. Then different amounts of **X** were distributed in the biphasic systems and the systems were allowed to reach equilibrium. The initial rate of the reaction between **X** and **Y** in the aqueous phase was measured after adding **Y** into the aqueous phase of these biphasic systems. Results of these experiments conducted at temperature T are given in the table.

Experiment Number	Volume of water (cm^3)	Volume of org-1 (cm^3)	Total amount of X added (mol)	Total amount of Y added (mol)	Initial rate of the reaction (mol dm^{-3} s^{-1})
1	100.00	100.00	0.05	0.02	2.00×10^{-6}
2	100.00	100.00	0.10	0.04	1.60×10^{-5}
3	50.00	50.00	0.25	0.02	4.00×10^{-4}

Orders of the reaction with respect to **X** and **Y** are *m* and *n* respectively. The rate constant of the reaction at temperature T is *k*.

(i) Given that the concentrations of **X** and **Y** in the aqueous phase are $[\mathbf{X}]_{aq}$ and $[\mathbf{Y}]_{aq}$ respectively, write the rate expression for the reaction in terms of $[\mathbf{X}]_{aq}$, $[\mathbf{Y}]_{aq}$, *m*, *n* and *k*.

$$Rate = k\,[X]_{aq}^{m}\,[Y]_{aq}^{n} \quad \textbf{OR} \quad \frac{-\Delta[X]_{aq}}{\Delta t} = k[X]_{aq}^{m}\,[Y]_{aq}^{n} \quad \textbf{OR} \quad \frac{-\Delta[Y]_{aq}}{\Delta t} = k[X]_{aq}^{m}\,[Y]_{aq}^{n}$$ **(10)**

(ii) Calculate the initial concentration of **X** in the aqueous phase in each experiment.

Let x be the amount (moles) of X in the aqueous phase and n_x be the total amount (moles) of X added.
Equal volumes of org-1 and water are used in all the experiments.

$$[X]_{aq} = \frac{n_X}{5 \times V_{aq}}$$

Experiment	$[X]_{aq}$/mol dm^{-3}	
1	0.1	(4)
2	0.2	(4)
3	1.0	(4)

(iii) Calculate the initial concentration of **Y** in the aqueous phase in each experiment.

Let n_Y be the total amount of Y (moles) added.
Y is only soluble in the aqueous phase.

$$[Y]_{aq} = \frac{n_Y}{V_{aq}}$$

Experiment	$[Y]_{aq}$/mol dm^{-3}	
1	0.2	(4)
2	0.4	(4)
3	0.4	(4)

(iv) Calculate the orders *m* and *n* of the reaction with respect to **X** and **Y** respectively.

2.00×10^{-6} mol dm^{-3} s^{-1} = k (0.1 mol dm^{-3})^m (0.2 mol dm^{-3})^n ---(1) (10 +2)
1.60×10^{-5} mol dm^{-3} s^{-1} = k (0.2 mol dm^{-3})^m (0.4 mol dm^{-3})^n ---(2) (10 +2)
4.00×10^{-4} mol dm^{-3} s^{-1} = k (1.0 mol dm^{-3})^m (0.4 mol dm^{-3})^n ---(3) (10 +2)

Finding of the order m

From (2)/(3)

$$\frac{1.60 \times 10^{-5}\ \cancel{\text{mol dm}^{-3}\ \text{s}^{-1}}}{4.00 \times 10^{-4}\ \cancel{\text{mol dm}^{-3}\ \text{s}^{-1}}} = \frac{\cancel{k}\,(0.2\ \cancel{\text{mol dm}^{-3}})^m\ \cancel{(0.4\ \text{mol dm}^{-3})^n}}{\cancel{k}\,(1.0\ \cancel{\text{mol dm}^{-3}})^m\ \cancel{(0.4\ \text{mol dm}^{-3})^n}} \qquad (5)$$

$0.04 = (0.2)^m$
$m = 2$ (4+1)

Finding of the order n

From (3)/(1)

$$\frac{4.00 \times 10^{-4}\ \cancel{\text{mol dm}^{-3}\ \text{s}^{-1}}}{2.00 \times 10^{-6}\ \cancel{\text{mol dm}^{-3}\ \text{s}^{-1}}} = \frac{\cancel{k}\,(1.0\ \cancel{\text{mol dm}^{-3}})^m\ (0.4\ \cancel{\text{mol dm}^{-3}})^n}{\cancel{k}\,(0.1\ \cancel{\text{mol dm}^{-3}})^m\ (0.2\ \cancel{\text{mol dm}^{-3}})^n} \qquad (5)$$

$200 = 10^2\,(2)^n$
$n = 1$ (4+1)

(v) Calculate the rate constant of the reaction.

Rate constant
From (1)

$$k = \frac{2.00 \times 10^{-6}\ \text{mol dm}^{-3}\ \text{s}^{-1}}{(0.1\ \text{mol dm}^{-3})^2\ (0.2\ \text{mol dm}^{-3})^1}$$ **(4+1)**

$= 1.0 \times 10^{-3}\ \text{mol}^{-2}\ \text{dm}^{6}\ \text{s}^{-1}$ **(4+1)**

(vi) An experiment is designed to study the effect of temperature on the reaction rate using the partition coefficient given above.
Is this a suitable experiment to study the effect of temperature on the rate of the reaction? Explain your answer.

Not suitable **(2)**

Partition coefficient depends on temperature. **(3)**

6 (b): 105 marks

(*c*) The organic solvent org-2 and water are also immiscible and form a biphasic system. **X** (0.20 mol) was added to a system containing 100.00 cm^3 of org-2 and 100.00 cm^3 of water and allowed to reach equilibrium at the temperature T. Then **Y** (0.01 mol) was added to the aqueous phase and the initial rate of the reaction was measured. **Y** does not dissolve in org-2. The initial rate of the reaction between **X** and **Y** in the aqueous phase was found to be 6.40×10^{-7} mol dm^{-3} s^{-1}.

Calculate the partition coefficient $\frac{[\mathbf{X}]_{\text{org-2}}}{[\mathbf{X}]_{\text{aq}}}$ for the distribution of **X** between org-2 and water.
$[\mathbf{X}]_{\text{org-2}}$ is the concentration of **X** in the org-2 phase.

Reaction takes place in the aqueous medium. Therefore, the rate constant is the same. **(5)**

$$Rate = k\,[X]_{aq}^2\,[Y]_{aq}$$

$6.40 \times 10^{-7}\ \text{mol dm}^{-3}\ \text{s}^{-1} = 1.00 \times 10^{-3}\ \text{mol}^{-2}\ \text{dm}^{6}\ \text{s}^{-1}\ [X]^2_{aq}\ 0.1\ \text{mol dm}^{-3}$ **(4+1)**

$[X]^2_{aq} = 6.4 \times 10^{-3}\ \text{mol}^2\ \text{dm}^{-6} = 64 \times 10^{-4}\ \text{mol}^2\ \text{dm}^{-6}$

$[X]_{aq} = 8.0 \times 10^{-2}\ \text{mol dm}^{-3}$ **(4+1)**

$$K_D = \frac{[X]_{org-2}}{[X]_{aq}} = \frac{\left(\frac{0.2\ mol}{0.1\ dm^3} - 0.08\ mol\ dm^{-3}\right)}{0.08\ mol\ dm^{-3}}$$ **(4+1)**

$$K_D = 24$$ **(4+1)**

<u>Alternate answer for 6(c)</u>

$$K_D = \frac{\left(\frac{0.2\ mol - x}{0.1\ dm^3}\right)}{\left(\frac{x}{0.1\ dm^3}\right)}$$ **(4+1)**

$$x = \frac{0.2\ mol}{K_D + 1}$$

$$[X]_{aq} = \frac{\frac{0.2\ mol}{(K_D+1)}}{0.1\ dm^3} = \frac{2}{(K_D+1)} mol\ dm^{-3}$$ **(4+1)**

$$Rate\ = k\,[X]_{aq}^{m}\,[Y]_{aq}^{n}$$

$$6.4 \times 10^{-7} mol\ dm^{-3}\ s^{-1} = 1 \times 10^{-3}\ mol\ dm^{-3}\ s^{-1} \left(\frac{2\ mol\ dm^{-3}}{(K_D+1)}\right)^2 (0.1\ mol\ dm^{-3})$$ **(4+1)**

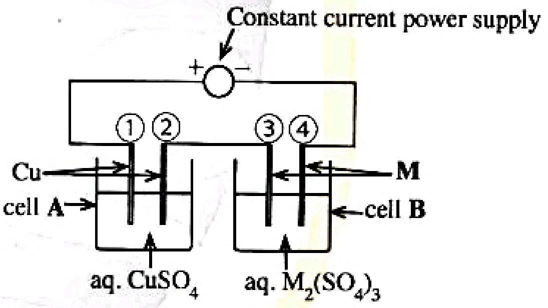
$$64 \times 10^{-4} = \left(\frac{2}{K_D+1}\right)^2$$ **(4+1)**

$$K_D = 24$$ **(4+1)**

6 (c): 25 marks

7. (*a*) The setup shown in the figure was used to find the relative atomic mass of the metal, **M**.

The electrolysis was carried out for 10 minutes using a constant current. The mass of the cathode in cell **A** was increased by 31.75 mg whereas the mass of the cathode in cell **B** increased by 147.60 mg during this time period. (Assume that the electrolysis of water does not take place in cells **A** and **B**.)



(i) Identify the anode and cathode in each of the cells **A** and **B** (in terms of the numbers ①, ②, ③, and ④).

<u>Cell A</u>

Anode = 1 **(5)**

Cathode = 2 **(5)**

<u>Cell B</u>

Anode = 3 **(5)**

Cathode = 4 **(5)**

(ii) Write the half reaction taking place at each electrode in each cell.

Electrode reactions

Cell A electrode 1	$Cu(s) \rightarrow Cu^{2+}(aq) + 2e$	(6)
Cell A electrode 2	$Cu^{2+}(aq) + 2e \rightarrow Cu(s)$	(6)
Cell B electrode 3	$M(s) \rightarrow M^{3+}(aq) + 3e$	(6)
Cell B electrode 4	$M^{3+}(aq) + 3e \rightarrow M(s)$	(6)

Note : physical states must be given

(iii) Calculate the constant current used in electrolysis.

Amount of Cu(s) dissolved = 31.75×10^{-3} g

Charge required for this $= \dfrac{2 \times 96500 \text{ c mol}^{-1} \times 31.75 \times 10^{-3}\text{g}}{63.5 \text{ g mol}^{-1}} = \text{i} \times 10 \times 60 \text{ s}$ **(1+1)+(1+1)+(1+1)+(1+1)**

Correct stoichiometry **(5)**

The current used in the electrolysis = i = 0.16 A **(4+1)**

Alternative Answer for 7(a) (iii)

Amount of Cu deposited $= \dfrac{31.75 \times \overset{(1+1)}{10^{-3}} \, g}{63.5 \, g \, mol^{-1}}$ (1+1)

$= 0.5 \times 10^{-3}$ mol

Amount of charge required $= 0.5 \times 10^{-3} \times 2$ mol For using correct stoichiometry **(5)**

$= 10^{-3}$ mol

$= 10^{-3}$ mol $\times$ 96500 C mol^{-1} **(1+1)**

= 96.5 C

Current $= \dfrac{96.5 \, C}{10 \times 60 \, s}$ **(1+1)**

= 0.16 A **(4+1)**

(iv) Calculate the relative atomic mass of metal, **M.**

Increase in mass of the electrode 4 in cell B is due to deposition of M(s)

Increase in mass = 147.6×10^{-3} g

Amount of M deposited = 147.6×10^{-3} g /W

W=molecular weight of M

Charge needed for this $= \dfrac{3 \times 96500 \text{ c mol}^{-1} \times 147.6 \times 10^{-3} \text{ g}}{\text{W}} = 0.16 \text{ A} \times 600 \text{ s}$ **(1+1)+(1+1)+(1+1)**

Correct stoichiometry **(5)**

W = 445.1 g mol^{-1} **(1+1)**

Alternative Answer (I) for 7(a) (iv)

The amount of charge flown is equal.
M mol x 3 = Cu mol x 2

$$\frac{\overset{(1+1)}{147.6 \times 10^{-3}} \, g \times 3 \, mol}{W} = \frac{\overset{(1+1)}{31.75 \times 10^{-3}} \, g \times 2 \, mol}{63.5 \, g \, mol^{-1}}$$ **For using correct stoichiometry** **(5)**

(1+1)

$$W = \frac{147.6 \times 3 \times 63.5}{31.75 \times 2} \text{ g mol}^{-1}$$

= 442.8 g mol^{-1} **(1+1)**

Alternative Answer (II) for 7(a) (iv)

Amount of M deposited = Amount of charge flown / 3

$= \dfrac{10^{-3}}{3} \overset{(1+1)}{mol}$ **For using correct stoichiometry** **(5)**

Molar mass of M $= \dfrac{147.6 \times \overset{(1+1)}{10^{-3}} \, g}{\frac{10^{-3}}{3} \, mol}$ (1+1)

= 147.6 x 3 g mol^{-1}

= 442.8 g mol^{-1} **(1+1)**

Note : If symbols (or any other values) are used for the atomic mass of Cu and Faraday constant and the answers are provided with those symbols or using those values, award full marks.

7 (a): 75 marks

(*b*) (i) **A**, **B** and **C** are coordination compounds. They have an octahedral geometry. In each compound, **two types** of ligands are coordinated to the metal ion. The molecular formulae of the compounds are (**not** in order): $NiCl_2H_{12}N_4$, $NiI_2H_{16}N_4O_2$ and $NiCl_2H_{15}N_3O_3$.

Given below are the observations when aqueous solutions of the compounds are treated with $Pb(CH_3COO)_2(aq)$.

Compound	**$Pb(CH_3COO)_2(aq)$**
A	A white precipitate that is soluble in hot water
B	No precipitate
C	A yellow precipitate that is soluble in hot water

I. Give the structures of **A**, **B** and **C**.

A: $[Ni(NH_3)_3(H_2O)_3]Cl_2$ **OR** $[Ni(H_2O)_3(NH_3)_3]Cl_2$ **(06)**

B: $[Ni(NH_3)_4Cl_2]$ **OR** $[NiCl_2(NH_3)_4]$ **(06)**

C: $[Ni(NH_3)_4(H_2O)_2]I_2$ **OR** $[Ni(H_2O)_2(NH_3)_4]I_2$ **(06)**

Note: OH_2 may be used instead of H_2O.

II. Write the chemical formulae of the precipitates formed on treatment of the compounds with $Pb(CH_3COO)_2(aq)$.
(**Note**: Indicate compound and reagent)

A with $Pb(CH_3COO)_2$ $PbCl_2\downarrow$ **(03)**

C with $Pb(CH_3COO)_2$ $PbI_2\downarrow$ **(03)**

III. State a chemical test, together with the observation, to identify each of the anion/s if present, that is/are not coordinated to the metal ion in the compounds given above. (**Note**: The tests given by you should not be a test stated here.)

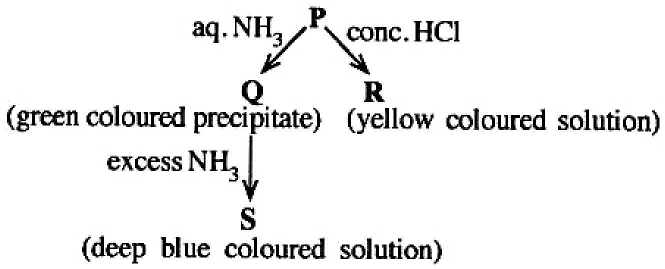
Cl^- Add a solution of $AgNO_3$. **(03)**

A white precipitate is formed. The white precipitate dissolves in dilute NH_4OH. **(03)**

I^- Add a solution of $AgNO_3$. **(03)**

A yellow precipitate is formed. The yellow precipitate does not dissolve in conc. NH_4OH. **(03)**
OR
Add a few drops of $CHCl_3$ and then a little Cl_2 water. **(03)**
Shake the tube.
$CHCl_3$ layer turns violet. **(03)**

(ii) A transition metal **M** forms a coloured complex ion **P** in aqueous medium. It has the general formula $[M(H_2O)_n]^{m+}$. It undergoes the reactions given below.



I. Identify the metal **M**. Give the oxidation state of **M** in complex ion **P**.

Ni, +2 **OR** Ni^{2+} **(06 + 03)**

II. Give the electronic configuration of **M** in the complex ion **P**.

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^8$ **(03)**

III. Give the values of n and m.

n = 6 m = 2 **(03 + 03)**

IV. Give the geometry of **P**.

octahedral **(03)**

V. Give the structures of **Q**, **R** and **S**.

Q:	$Ni(OH)_2$	**(03)**
R:	$[NiCl_4]^{2-}$	**(03)**
S:	$[Ni(NH_3)_6]^{2+}$	**(03)**

VI. Give the IUPAC names of the complex ions, **P**, **R** and **S**.

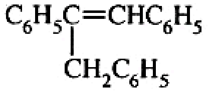
P:	hexaaquanickel(II) ion	**(03)**
R:	tetrachloridonickelate(II) ion	**(03)**
S:	hexaamminenickel(II) ion	**(03)**

7(b): 75 marks

PART C — ESSAY

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

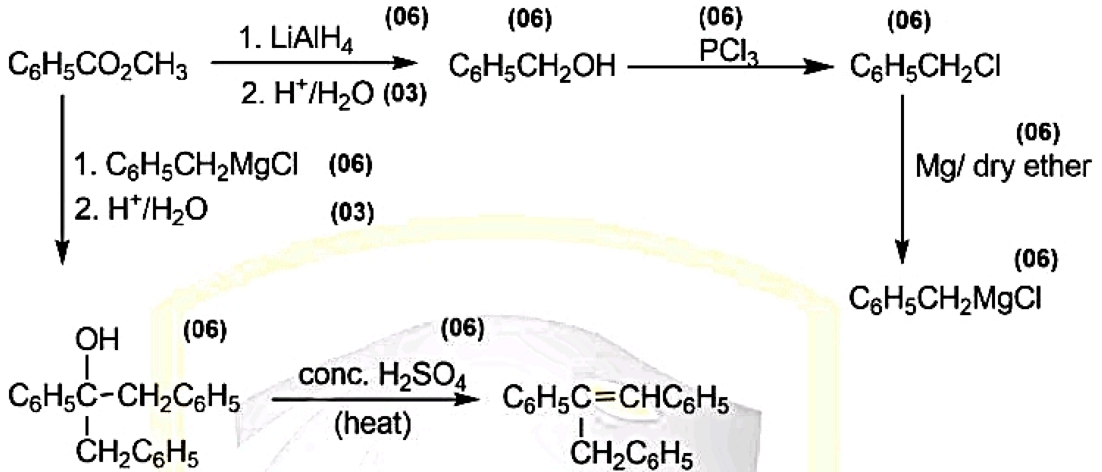
8. (*a*) Using $C_6H_5CO_2CH_3$ as the only organic starting material and as reagents only those given in the list, show how you would synthesize the following compound in **not** more than **seven** (7) steps.



$C_6H_5\underset{\displaystyle CH_2C_6H_5}{\underset{|}{C}}{=}CHC_6H_5$

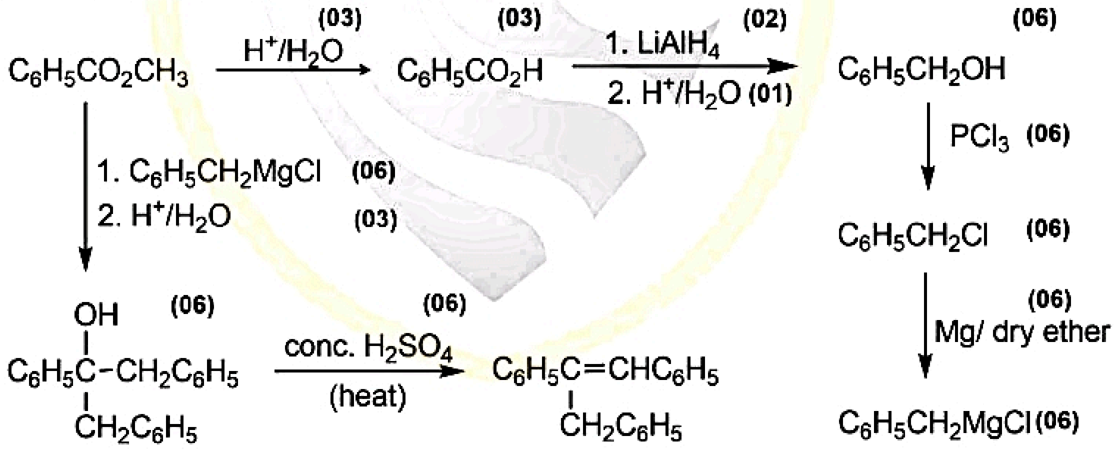
List of reagents

PCl_3, Mg/dry ether, H^+/H_2O, $LiAlH_4$, conc. H_2SO_4



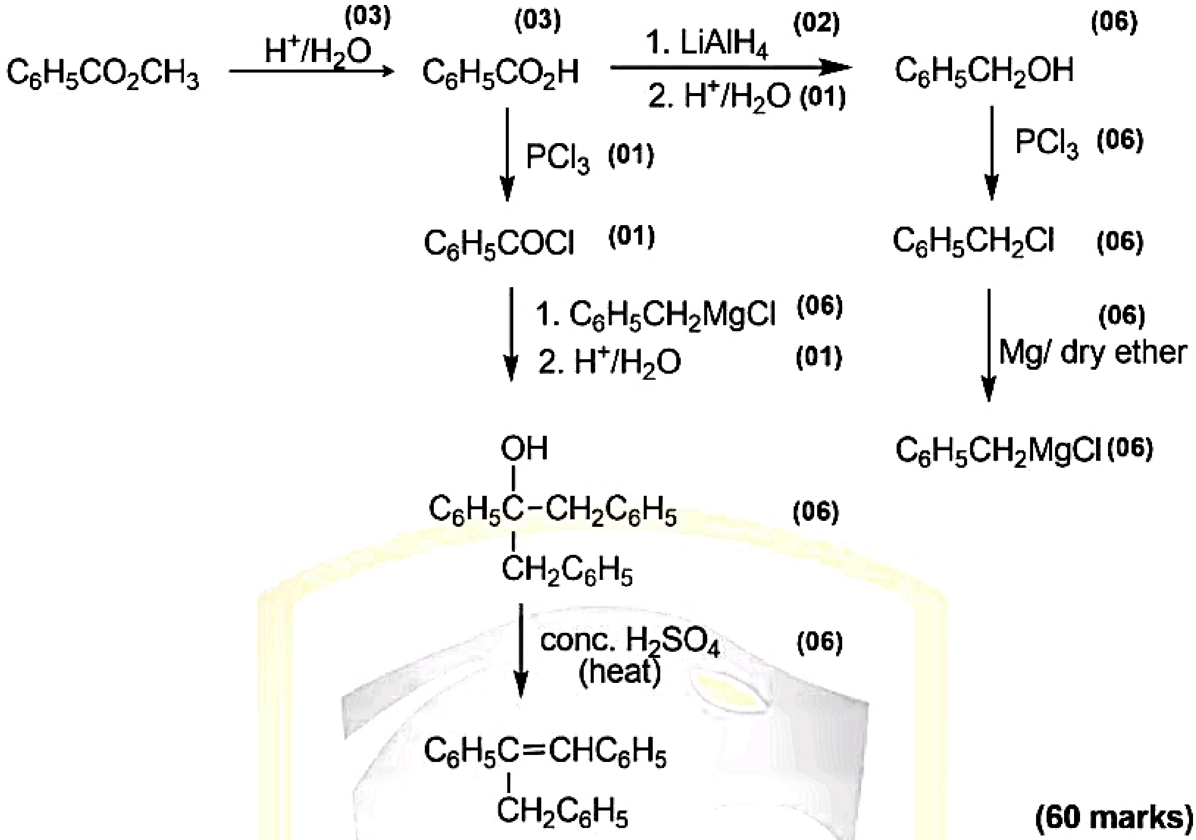
(60 marks)

Alternative Answer (I) for 8(a)



(60 marks)

Alternative Answer (II) for 8(a)



(60 marks)

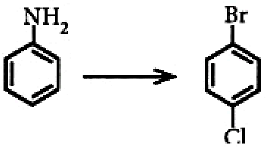
Note : 1. Do not award any marks if there are more than 7 steps.

2. Do not count the hydrolysis steps subsequent to the reaction with Grignard reagent and with $LiAlH_4$ as separate steps.

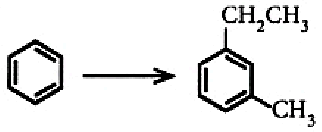
8 (a) : 60 marks

(*b*) Show how you would carry out each of the following conversions in **not** more than **three** (3) steps.

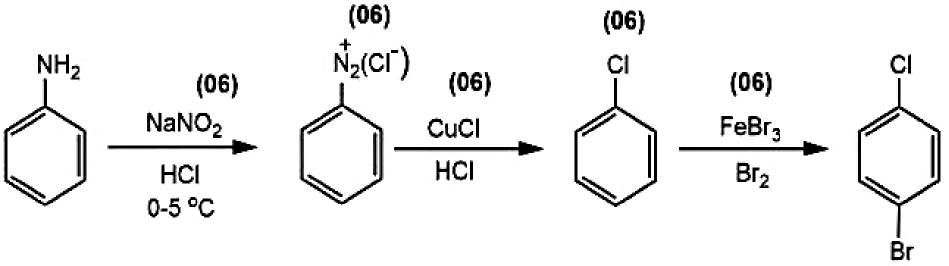
(i)



(ii)

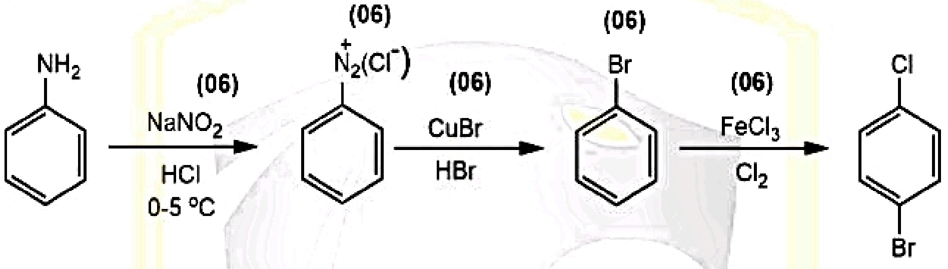


(b) (i)



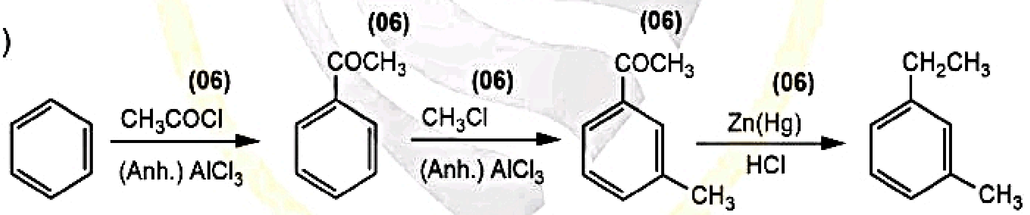
(30 marks)

Alternative Answer for 8(b) (i)



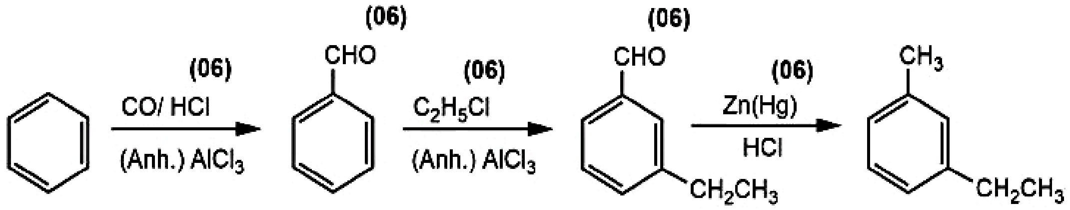
(30 marks)

(ii)



(30 marks)

Alternative Answer for 8(b) (ii)



(30 marks)

8 (b) : 60 marks

(*c*) The following reaction gives two products.

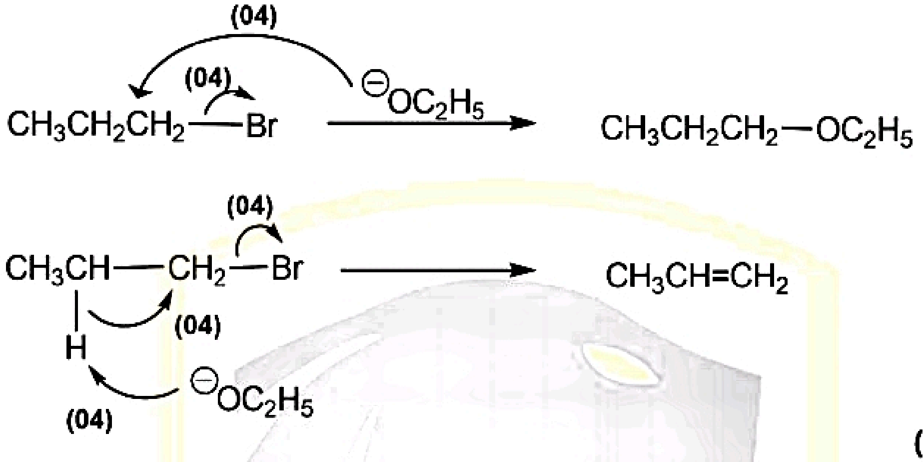
$$CH_3CH_2CH_2Br \xrightarrow{C_2H_5O^-}$$

(i) Write the structures of the two products.

(ii) Write the mechanisms for the formation of these two products.

(i). Products $CH_3CH_2CH_2\text{-}OC_2H_5$ $CH_3CH=CH_2$ **(05 + 05)**

(ii)



(20 marks)

8 (c) :30 marks

9. (*a*) Solution **X** contains **four** metal cations. The following tests were carried out to identify these cations.

	Test	Observation
①	Dilute HCl was added to a small portion of **X**.	No precipitate.
②	H_2S was bubbled through the solution from ① above.	A black precipitate (**P_1**)
③	**P_1** was separated by filtration. The filtrate was boiled to remove the H_2S, cooled, and NH_4Cl/NH_4OH was added.	A green precipitate (**P_2**)
④	**P_2** was separated by filtration and H_2S was bubbled through the filtrate.	A white precipitate (**P_3**)
⑤	**P_3** was separated by filtration. The filtrate was boiled to remove the H_2S, cooled, and $(NH_4)_2CO_3$ was added.	A white precipitate (**P_4**)

The following tests were carried out on precipitates **P_1**, **P_2**, **P_3** and **P_4**.

Precipitate	Test	Observation
P_1	**P_1** was dissolved in hot dil. HNO_3 and conc. NH_4OH was added in excess.	A deep blue coloured solution (**solution 1**)
P_2	* Excess dil. NaOH was added to **P_2** followed by H_2O_2. * Dilute H_2SO_4 was added to **solution 2**.	A yellow coloured solution (**solution 2**) An orange coloured solution (**solution 3**)
P_3	* **P_3** was dissolved in dil. HCl and dil. NaOH was added gradually. * Addition of dil. NaOH was continued.	A white precipitate (**P_5**) **P_5** dissolved to give a colourless solution (**solution 4**)
P_4	**P_4** was dissolved in conc. HCl and subjected to the flame test.	A brick-red flame

(i) Identify the **four** metal cations in solution **X** (**Reasons are not required.**)

Cu^{2+}, Cr^{3+}, Zn^{2+}, Ca^{2+} **(05 marks x 4 = 20)**

(ii) Identify the precipitates P_1, P_2, P_3, P_4 and P_5 and the chemical species responsible for the colours of **solutions** 1, 2, 3 and 4.

(**Note:** Write chemical formulae only.)

P_1: CuS

P_2: $Cr(OH)_3$

P_3: ZnS

P_4: $CaCO_3$

P_5: $Zn(OH)_2$ **(06 marks x 5 = 30)**

solution 1: $[Cu(NH_3)_4]^{2+}$ **(07)**

solution 2: Na_2CrO_4 **OR** CrO_4^{2-} **(06)**

solution 3: $Na_2Cr_2O_7$ **OR** $Cr_2O_7^{2-}$ **(06)**

solution 4: Na_2ZnO_2 **OR** ZnO_2^{2-} **OR** $Na_2Zn(OH)_4$ **OR** $[Zn(OH)_4]^{2-}$ **(06)**

9(a): 75 marks

(*b*) The water sample **Y** contains the anions SO_3^{2-}, SO_4^{2-} and NO_3^-. The following procedures were carried out for the quantitative analysis of the anions present in the water sample.

Procedure 1

To 25.00 cm^3 of sample **Y**, an excess of a dilute solution of $BaCl_2$ was added with stirring. Thereafter, excess dilute HCl was added with stirring to the precipitate formed until there was no further evolution of a gas with pungent odour. The solution was allowed to stand for 10 minutes and filtered. The precipitate was washed with distilled water and dried in an oven at 105 °C until a constant mass was obtained. The mass of the precipitate was 0.174 g. The filtrate obtained was kept for further analysis (**see procedure 3**).

Procedure 2

To 25.00 cm^3 of sample **Y**, an excess of dilute H_2SO_4 and acidified 5% KIO_3 solutions were added. The liberated I_2 was immediately titrated with 0.020 mol dm^{-3} $Na_2S_2O_3$ solution using starch as the indicator. The volume of $Na_2S_2O_3$ used was 20.00 cm^3. (Assume that in this procedure, SO_3^{2-} ions are oxidized to sulphate ions $\left(SO_4^{2-}\right)$ without any loss to the atmosphere.)

Procedure 3

The filtrate from **procedure** 1 was neutralized with dilute NaOH and to it excess Al powder and dilute NaOH were added. The solution was heated and the gas evolved was transferred quantitatively to react with a 20.00 cm^3 volume of 0.11 mol dm^{-3} HCl solution. Completion of the reaction was tested with litmus. The HCl remaining after reacting with the gas evolved was titrated with 0.10 mol dm^{-3} NaOH solution using methyl orange as the indicator. The volume of NaOH required was 10.00 cm^3.

(i) Write balanced ionic/non-ionic equations for the reactions taking place in **procedures 1, 2 and 3.**

Procedure I

$SO_3^{2-} + BaCl_2 \rightarrow BaSO_3\downarrow + 2Cl^-$ **OR** $Ba^{2+} + SO_3^{2-} \rightarrow BaSO_3\downarrow$ **(02)**

$SO_4^{2-} + BaCl_2 \rightarrow BaSO_4\downarrow + 2Cl^-$ **OR** $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4\downarrow$ **(02)**

$BaSO_3\downarrow + 2HCl \rightarrow BaCl_2 + SO_2 + H_2O$ **(03)**

$BaSO_4$ will remain insoluble

Procedure 2

$2IO_3^- + 12H^+ + 10e \rightarrow I_2 + 6H_2O$ **(02)**

$5(SO_3^{2-} + H_2O \rightarrow SO_4^{2-} + 2H^+ + 2e)$ **(02)**

$2IO_3^- + 5SO_3^{2-} + 2H^+ \rightarrow I_2 + 5SO_4^{2-} + H_2O$ **(03)**

OR

$2IO_3^- + 12H^+ + 10e \rightarrow I_2 + 6H_2O$ **(02)**

$5(SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^+ + 2e)$ **(02)**

$2IO_3^- + 5SO_2 + 4H_2O \rightarrow I_2 + 5SO_4^{2-} + 8H^+$ **(03)**

$I_2 + 2e \rightarrow 2I^-$ **(02)**
$2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 2e$ **(02)**
$I_2 + 2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 2I^-$ **(03)**

Therefore, $5SO_3^{2-} \equiv 2S_2O_3^{2-}$ **OR** $5SO_2 \equiv 2S_2O_3^{2-}$ & $SO_2 \equiv SO_3^{2-}$ **(02)**

Procedure 3

$3NO_3^- + 8Al + 5OH^- + 2H_2O \rightarrow 8AlO_2^- + 3NH_3$ **(02)**
$NH_3 + HCl \rightarrow NH_4Cl$ **(02)**
$HCl + NaOH \rightarrow NaCl + H_2O$ **(02)**

(ii) Determine the concentrations (mol dm^{-3}) of SO_3^{2-}, SO_4^{2-} and NO_3^- in water sample **Y**. (Ba = 137; S = 32; O = 16)

Procedure I – Determination of SO_4^{2-}

Molar mass of $BaSO_4$ $= 137 + 32 + 64 = 233$ **(02)**

Mass of $BaSO_4$ precipitate $= 0.174$ g

Therefore, moles of $BaSO_4$ $= \frac{0.174}{233}$ **(02)**

Therefore, moles of SO_4^{2-} $= \frac{0.174}{233} = 7.47 \times 10^{-4}$ **(02)**

Concentration of SO_4^{2-} $= \frac{7.47 \times 10^{-4}}{25} \times 1000$ **(02)**

= 0.029 (0.03) mol dm^{-3} **(03 + 01)**

Procedure 2 – Determination of SO_3^{2-}

Moles of $S_2O_3^{2-}$ $= \frac{0.02}{1000} \times 20$ **(02)**

Therefore, moles of SO_3^{2-} $= \frac{0.02}{1000} \times 20 \times \frac{5}{2}$ **(02)**

Concentration of SO_3^{2-} $= \frac{0.02}{1000} \times 20 \times \frac{5}{2} \times \frac{1000}{25}$ **(02)**

$=$ **0.04 mol dm^{-3}** **(03 + 01)**

Procedure 3 – Determination of NO_3^-

Moles of HCl $= \frac{0.11}{1000} \times 20$ **(02)**

Moles of NaOH $= \frac{0.10}{1000} \times 10$ **(02)**

Since NaOH and HCl react in the ratio of 1:1

Moles of HCl reacted with NH_3 $= \frac{0.11}{1000} \times 20 - \frac{0.10}{1000} \times 10$ **(02)**

$= \frac{1}{1000}(2.2 - 1) = \frac{1.2}{1000}$ **(02)**

Therefore, moles of NH_3 $= \frac{1.2}{1000}$ **(02)**

Therefore, moles of NO_3^- $= \frac{1.2}{1000}$ **(02)**

Concentration of NO_3^- $= \frac{1.2}{1000} \times \frac{1000}{25}$ **(02)**

$=$ **0.048 mol dm^{-3}** **(03 + 01)**

(iii) Give colour changes that would be observed in the titrations in **procedures 2** and **3**.

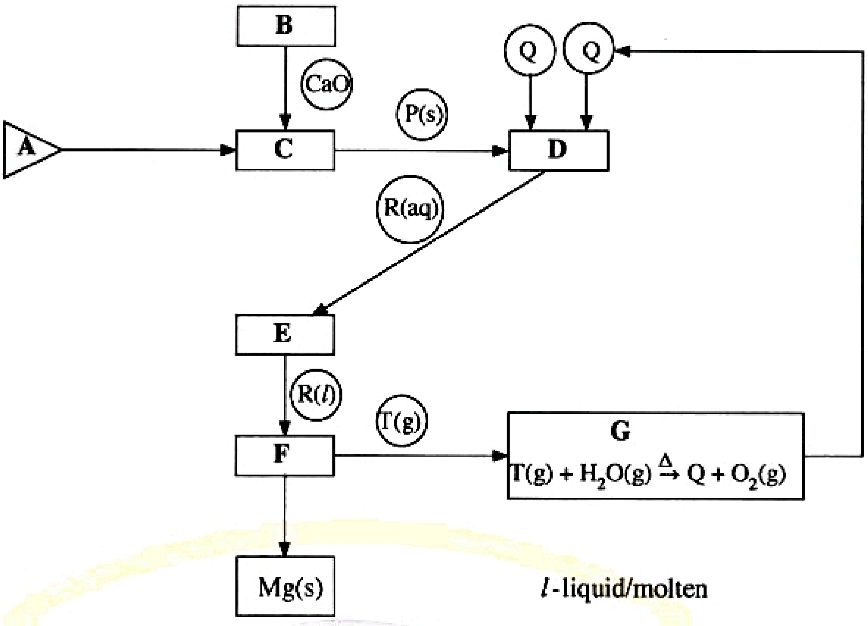
(**Note**: Assume that other ions that may interfere with the analysis are not present in sample **Y**.)

Procedure 2: Blue → Colourless **(03)**

Procedure 3: Red → Yellow **(03)**

9(b): 75 marks

10. (*a*)



The flow chart given above indicates the production of metal magnesium (Mg) using the Dow Process.

Answer the following questions based on the flow chart.

(i) Identify the starting material **A**.

Sea water/ Bittern solution **(03)**

(ii) Identify the processes employed at **B**, **C**, **D**, **E**, **F** and **G** from the list below.

evaporation, dissolution, thermal decomposition, electrolysis, recycling of a reagent, precipitation

B: thermal decomposition

C: precipitation

D: dissolution

E: evaporation

F: electrolysis

G: recycling of a reagent **(02 x 6 = 12 marks)**

(iii) Identify the chemical compound used in **B**.

$CaCO_3$ **OR** lime stone **(03)**

(iv) Identify the chemical species **P**, **Q**, **R** and **T**.

P: $Mg(OH)_2$

Q: HCl

R: $MgCl_2$

T: Cl_2 **(02 x 4 = 8 marks)**

(v) Give balanced chemical equations/half reactions for the processes taking place in **B**, **C**, **D**, and **F**.
(**Note**: When writing half reactions, identify the anode and cathode where applicable.)

B: $CaCO_3 \xrightarrow{\Delta} CaO + CO_2$ **(02)**

Note : Award marks even if heating is not shown.

C: $CaO + H_2O \longrightarrow Ca(OH)_2$ **(02)**

$Ca(OH)_2 \longrightarrow Ca^{2+} + 2OH^-$ **(02)**

$Mg^{2+} + 2OH^- \longrightarrow Mg(OH)_2$ **(02)**

OR

$CaO + H_2O \longrightarrow Ca^{2+} + 2OH^-$ **(04)**

$Mg^{2+} + 2OH^- \longrightarrow Mg(OH)_2$ **02)**

OR

$CaO + H_2O + Mg^{2+} \longrightarrow Mg(OH)_2 + Ca^{2+}$ **(06)**

D: $Mg(OH)_2 + 2HCl \longrightarrow MgCl_2 + 2H_2O$ **(02)**

F: Anode – (C) $2Cl^-(l)/(aq) \rightarrow Cl_2(g) + 2e$ **(02 + 02)**

Cathode – (Fe) $Mg^{2+}(l)/(aq) + 2e \rightarrow Mg(l)$ **(02 + 02)**

Note: Physical states are required for the award of marks for half reactions.

(vi) State the importance of the reaction occurring in **G**.

Here a product is recycled / reproduced. **(03)**

It is very cost effective. **(03)**

10(a): 50 marks

(*b*) (i) Consider the industries given below.

Coal power plants
Refrigeration and air conditioning
Transport
Agriculture
Animal farming

I. All five industries given above contribute to global warming. Identify the gaseous chemical species associated with each of these industries that contribute to global warming.

Coal power plants – CO_2

Refrigeration and air conditioning industry – CFC **OR** HFC **OR** HCFC

Transportation – CO_2

Agriculture – N_2O , CH_4

Animal farming – CH_4

(03 x 5 = 15 marks)

II. State **three** adverse climate changes that could occur due to global warming.

- Rise in sea level
- Frequent strong cyclones and tornadoes
- Severe floods in certain areas
- Reduction in rainfall in certain areas (severe droughts) / Desertification
- Sea water infusion to rivers
- Heavy rainfall in certain areas

(Any three) **(03 x 3 = 9 marks)**

(ii) Identify the main industry/industries given in (i) above that contribute to

I. photochemical smog,

Transportation

II. acid rain,

Coal power plants and transportation

III. eutrophication.

Agriculture and animal farming

(02 x 5 = 10 marks)

(iii) Due to the reduction in rainfall in Sri Lanka, inducing artificial rain has been tested near catchment areas of reservoirs that are used for hydro-power generation. In this process, fine particles of hygroscopic salts (NaCl, $CaCl_2$, NaBr) are sprayed to induce cloud formation by condensation of water vapour.

From the list given below, select the water quality parameters that are directly

I. affected

Conductivity **(02)**

- Concentration of ions increases. Therefore, conductivity increases. **(02)**

II. unaffected

due to salts entering water around catchment areas. Give reasons for your choice briefly.

List of water quality parameters:

pH, conductivity, turbidity, dissolved oxygen

pH, turbidity and dissolved oxygen **(02 + 02 + 02)**

- These salts do not undergo hydrolysis. Therefore, pH is unaffected.
- These salts are very soluble in water. Hence, ions do not contribute to turbidity.
- These salts do not react with O_2.

(02 x 3 = 6 marks)

10(b): 50 marks

(c) The following questions are based on biodiesel production.

(i) State the raw materials used in the manufacture of biodiesel.

Vegetable oil / plant oil (palm oil etc.) and

CH_3OH / methanol / C_2H_5OH / ethanol/ alcohol/ ROH **(05 + 05)**

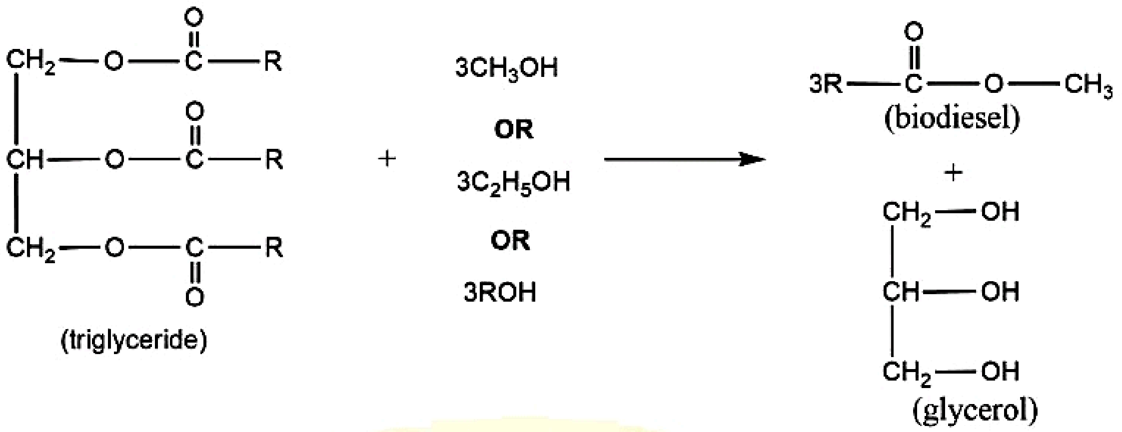
(ii) Name the main chemical compound present in each raw material where applicable.

Vegetable oil – triglycerides **(05)**

(iii) State the name of the chemical compound used as the catalyst in the manufacture of biodiesel in the school laboratory.

Sodium hydroxide (NaOH) / potassium hydroxide (KOH) **(05)**

(iv) Give a balanced chemical equation to show the synthesis of biodiesel using the chemical compounds stated in part (ii) above.



(20)

Note: **1. R could be written as R_1, R_2 and R_3. Equation should be balanced accordingly.**

2. For correct balanced equation (20 marks). If equation is not balanced award (04) for each correct reactant and product.

3. C_2H_5OH and ROH may be accepted for this year ONLY.

(v) Identify a side reaction that would take place, along with its products, if the catalyst is used in excess.

Saponification reaction **OR** its description **(05)**

Product – soap ($R\text{-}COO^-Na^+$) **(05)**

10(c): 50 marks