



NEW

Department of Examinations - Sri Lanka

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

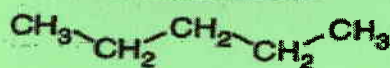
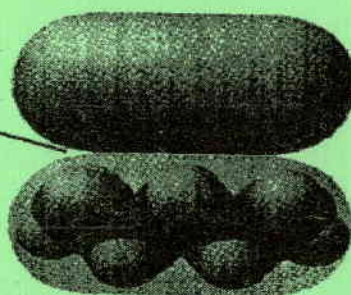
02 - Chemistry

New Syllabus

Marking Scheme

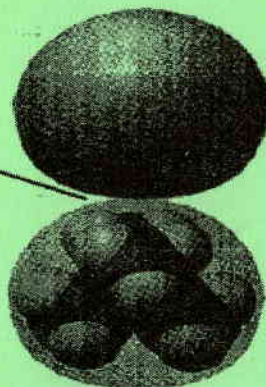
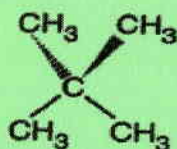
n-Pentane
bp = 36.1°C

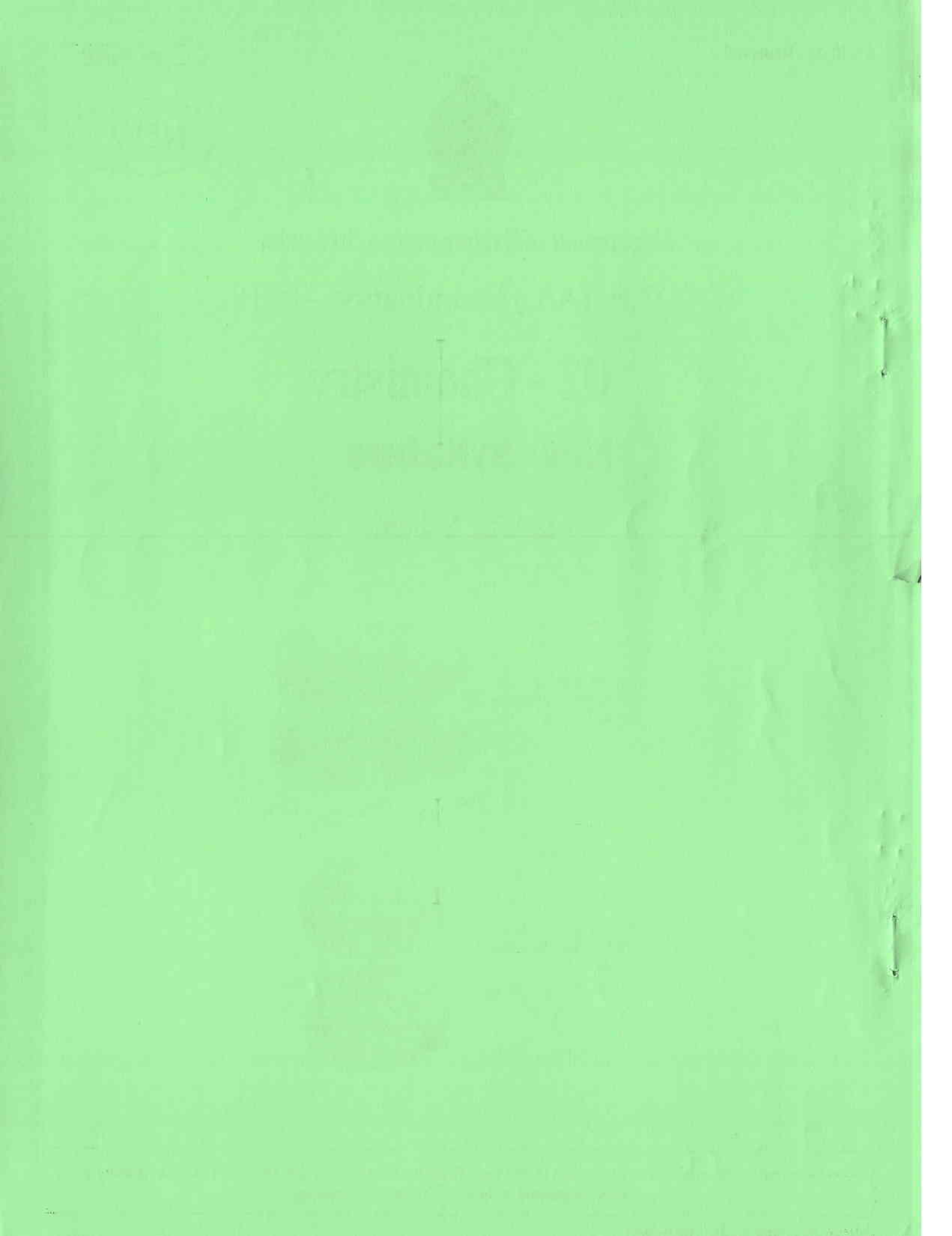
More points for
dispersion forces
to act



Neopentane
bp = 9.5°C

Fewer points for
dispersion forces
to act





AL/2019/02/E-I(NEW)

- 8 -

- In question Nos. 41 to 50, two statements are given in respect of each question. From the Table given below, select the response, out of the responses (1), (2), (3), (4) and (5), that best fits the two statements and mark appropriately on your answer sheet.

Response	First Statement	Second Statement
(1)	True	True, and correctly explains the first statement
(2)	True	True, but does not explain the first statement correctly
(3)	True	False
(4)	False	True
(5)	False	False

	First Statement	Second statement
41.	Among the halogens, I_2 is a solid whereas Br_2 is a liquid.	London forces become stronger with increase in molecular surface area.
42.	At a given pressure, the spontaneity of the reaction between N_2 and H_2 to give NH_3 drops with increasing temperature.	Entropy change of the reaction between N_2 and H_2 to give NH_3 is negative.
43.	Essential oils are generally extracted from plant materials by steam distillation.	Essential oils have a high solubility in water.
44.	A spontaneous reaction always has a negative Gibbs energy change no matter what the conditions are.	Gibbs energy change can be used to predict the direction of a reaction only under constant temperature and constant pressure conditions.
45.	Solubility of 1-butanol in water is less than the solubility of methanol in water.	The solubility of alcohols in water decreases as the size of the non-polar alkyl group increases relative to the polar OH group.
46.	The reaction, $CH_3-CH=CH_2 \xrightarrow{HBr} CH_3-\underset{\substack{ \\ Br}}{CH}-CH_3$ is a nucleophilic addition reaction.	A secondary carbocation is formed as a reaction intermediate in the following reaction. $CH_3-CH=CH_2 \xrightarrow{HBr} CH_3-\underset{\substack{ \\ Br}}{CH}-CH_3$
47.	Coke is used in several industrial processes.	Coke is only used industrially as a fuel.
48.	The carbonyl carbon atom of a ketone and the other atoms bonded to it lie in the same plane.	The carbonyl carbon atom of a ketone is sp^2 hybridized.
49.	Any two ideal gases have the same average kinetic energies at the same temperature.	At a given temperature, the average speed of gas molecules adjust according to their masses.
50.	Although CFC contribute to ozone layer depletion, the contribution from HFC is negligible.	HFC undergoes complete decomposition before reaching the upper atmosphere.

ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව
இலங்கைப் பரீட்சைத் திணைக்களம்

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

නව නිර්දේශය/ புதிய பாடத்திட்டம்

විෂය අංකය
பாட இலக்கம்

02

විෂය
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

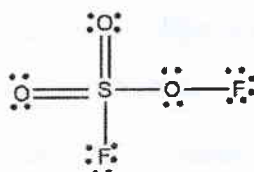
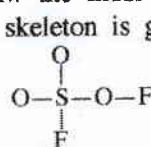
Answer all four questions on this paper itself. (Each question carries 100 marks.)

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)

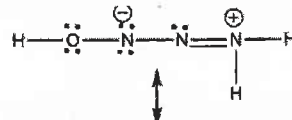
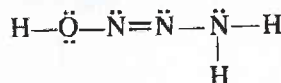
1(a): 24 marks

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

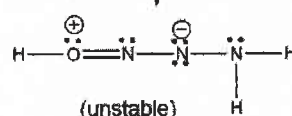


(06)

- (ii) The most stable Lewis dot-dash structure for the molecule $\text{H}_3\text{N}_3\text{O}$ 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)



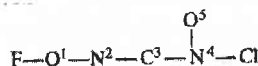
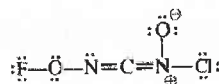
(04)

(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
III. shape around the atom

II. electron pair geometry around the atom
IV. hybridization of the atom
The atoms are numbered as follows.



		O ¹	N ²	C ³	N ⁴
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	<i>sp</i> ³	<i>sp</i> ²	<i>sp</i>	<i>sp</i> 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. | $\text{F}-\text{O}^1$ | $\text{F} \dots 2p \text{ OR } sp^3$ | $\text{O}^1 \dots sp^3$ |
| II. | O^1-N^2 | $\text{O}^1 \dots sp^3$ | $\text{N}^2 \dots sp^2$ |
| III. | N^2-C^3 | $\text{N}^2 \dots sp^2$ | $\text{C}^3 \dots sp$ |
| IV. | C^3-N^4 | $\text{C}^3 \dots sp$ | $\text{N}^4 \dots sp^2$ |
| V. | N^4-O^5 | $\text{N}^4 \dots sp^2$ | $\text{O}^5 \dots 2p \text{ OR } sp^3$ |
| VI. | N^4-Cl | $\text{N}^4 \dots sp^2$ | $\text{Cl} \dots 3p \text{ OR } sp^3 \dots (01 \times 12 = 12)$ |

(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 | $\text{N}^2 \dots 2p$ | $\text{C}^3 \dots 2p$ |
| II. | C^3-N^4 | $\text{C}^3 \dots 2p$ | $\text{N}^4 \dots 2p \dots (01 \times 4 = 04)$ |

(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.

$\text{CO}_2, \text{NO}_2^+, \text{CN}_2^{2-}, \text{N}_3^- \dots (02)$

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)

$\text{LiI} < \text{LiF} < \text{KF}$

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

$\text{NF}_5 < \text{NO}_4^{3-} < \text{NO}_2^-$

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

$\text{NOCl} < \text{NO}_2\text{F} < \text{NOCl}_3$

(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 $\text{H}_2(\text{g})$ and forming its hydroxide. The hydroxide is basic. X also liberates $\text{H}_2(\text{g})$ 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. $1s^2 2s^2 2p^6 3s^2$ (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 $\text{H}_2(\text{g})$, $\text{O}_2(\text{g})$ and $\text{N}_2(\text{g})$, 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.

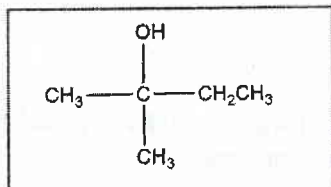
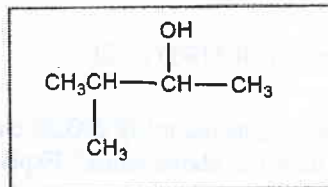
Grignard reagent (04)

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

2(a): 50 marks

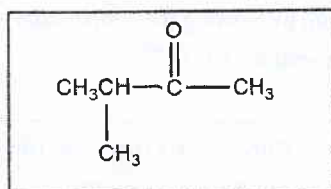
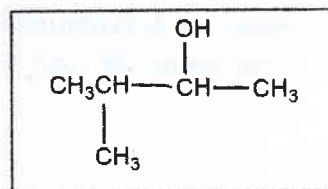
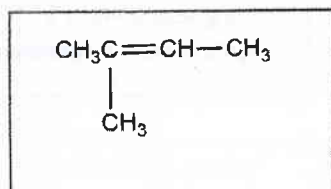
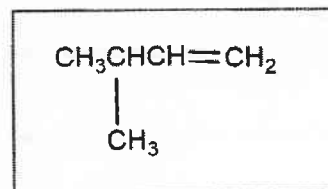
4. (a) Compounds **A** and **B** both have the same molecular formula $C_5H_{10}O$. Both **A** and **B** give orange/red precipitates with 2,4-dinitrophenylhydrazine. When **A** and **B** are reacted separately with $NaBH_4$ in methanol, compound **A** gives **C** and compound **B** gives **D**. When **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**.

**G****H**

(05 x 2 = 10)

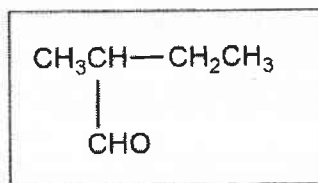
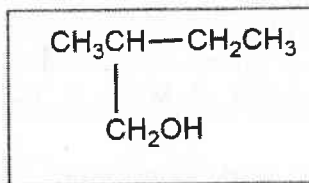
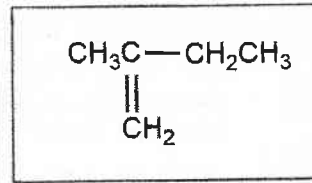
(ii) Draw the structures of **A**, **C**, **E** and **F**.

**A****C****E****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**.

**B****D****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 |

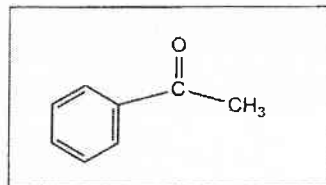
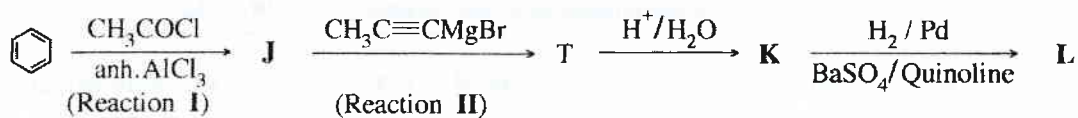
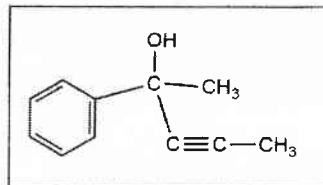
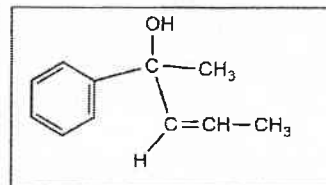
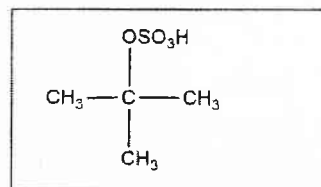
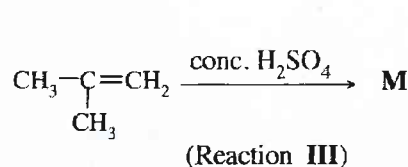
(05)

(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****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

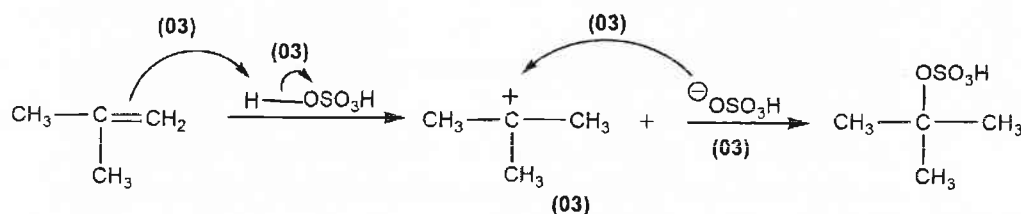
Reaction II - Nucleophilic addition

Reaction III - Electrophilic addition

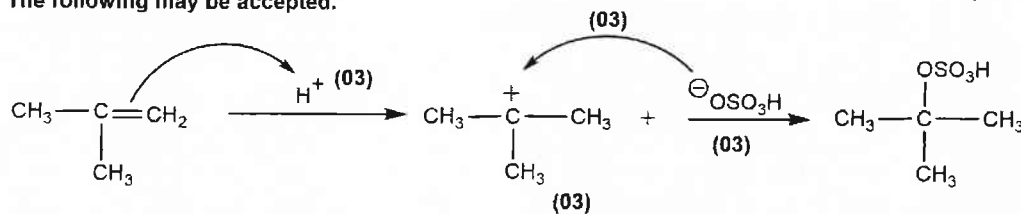
(05 x 3 = 15)

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 $1.00 \times 10^{-5} \text{ mol dm}^{-3}$. 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.

$$\text{pH} = -\log[\text{H}^+] \quad (2)$$

$$= -\log(0.1)$$

$$= 1.0 \quad (2+1)$$

- (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.

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

$$= 0.028 \text{ mol dm}^{-3}$$

$$\text{pH} = 1.5 \text{ (OR } 1.6) \quad (4+1)$$

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.

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

$$= 16.66 \text{ cm}^3$$

$$(16.67 \text{ cm}^3 \text{ OR the answer reported to one decimal place is also accepted}) \quad (4+1)$$

- (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,



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

OR

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

Note : Physical states are required for the award of marks

Assuming that the amount dissociated is negligible, (2)

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

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

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

$$pOH = 5.0 + 0.221 = 5.221$$

$$pH = 8.78 \text{ (or 8.7 or 8.9 or 9)} \quad (4+1)$$

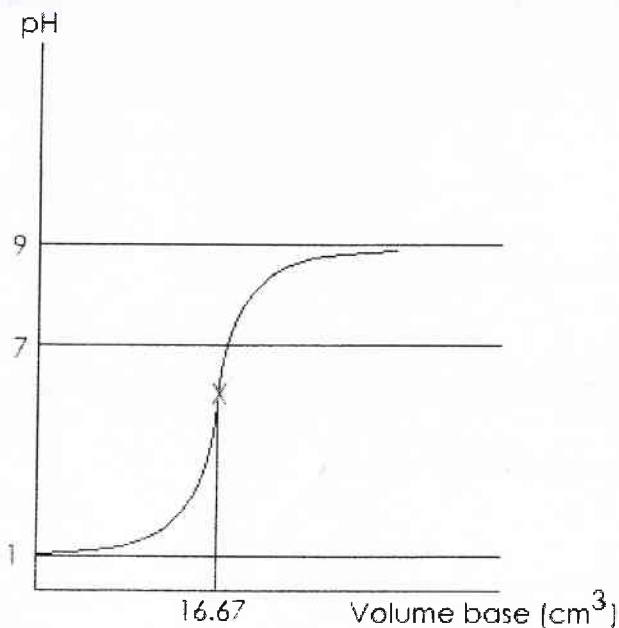
(v) Can the solution obtained in (iv) above act as a buffer solution? Explain your answer.

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 (P_C°) 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.

$$P_C = x_C P_C^\circ \quad (\text{Award marks only for these symbols}) \quad (5)$$

$$\text{Raoult's law} \quad (4)$$

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

Experiment I

$$2.7 \times 10^4 \text{ Pa} = 0.3 P_C^\circ + 0.7 P_D^\circ \quad \text{---(1)} \quad (4+1)$$

Experiment II

$$2.4 \times 10^4 \text{ Pa} = 0.6 P_C^\circ + 0.4 P_D^\circ \quad \text{---(2)} \quad (4+1)$$

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

$$P_D^\circ = 3.0 \times 10^4 \text{ Pa} \quad (4+1)$$

$$\begin{aligned} P_C^\circ &= (2.4 \times 10^4 \text{ Pa} - 0.4 \times 3.0 \times 10^4 \text{ Pa}) / 0.6 \\ &= 2.0 \times 10^4 \text{ Pa} \end{aligned} \quad (4+1)$$

- (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)

$$X_{C,I}^\circ = \frac{0.3 \times 2.0 \times 10^4 \text{ Pa}}{2.7 \times 10^4 \text{ Pa}} \quad (1+1)$$

$$= 0.2 \quad (\text{OR } 0.22 \text{ OR } 2/9) \quad (1+1)$$

$$X_{D,I}^\circ = 1 - 0.2 \quad (1+1)$$

$$= 0.8 \quad (\text{OR } 0.78 \text{ OR } 7/9) \quad (1+1)$$

- (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})

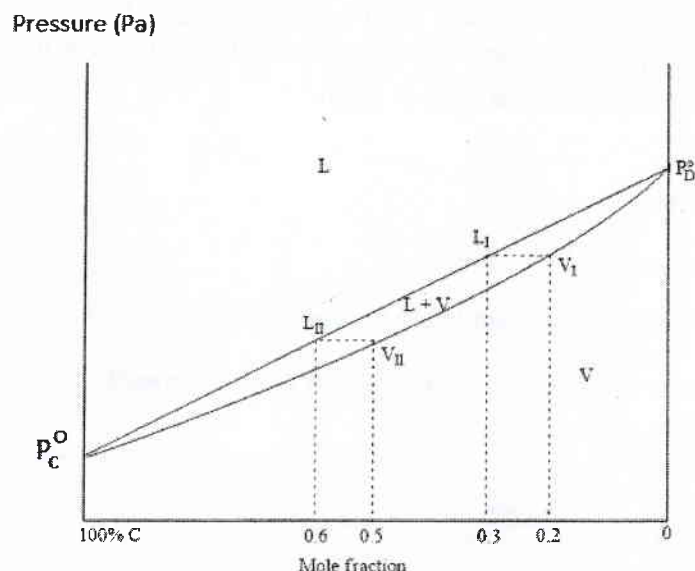
$$X_{C,II}^\circ = \frac{0.6 \times 2.0 \times 10^4 \text{ Pa}}{2.4 \times 10^4 \text{ Pa}} \quad (1+1)$$

$$= 0.5 \quad (1+1)$$

$$X_{D,II}^\circ = 1 - 0.5 \quad (1+1)$$

$$= 0.5 \quad (1+1)$$

- (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_C^0 and P_D^c 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, $K_D = \frac{[X]_{org-1}}{[X]_{aq}} = 4.0$

An amount of 0.50 mol of X was added to a system containing 100.00 cm³ of org-1 and 100.00 cm³ of water. The system was allowed to reach equilibrium at temperature T.

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

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

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

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

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

$$x = 0.1 \text{ mol} \quad (4+1)$$

$$[x]_{org-1} = \frac{0.4 \text{ mol}}{100 \times 10^{-3} \text{ dm}^3} = 4.0 \text{ mol dm}^{-3} \quad (4+1)$$

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

$$[x]_{aq} = \frac{0.1 \text{ mol}}{100 \times 10^{-3} \text{ dm}^3} = 1.0 \text{ mol dm}^{-3} \quad (4+1)$$

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 $[X]_{aq}$ and $[Y]_{aq}$ respectively, write the rate expression for the reaction in terms of $[X]_{aq}$, $[Y]_{aq}$, m, n and k.

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

(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	$[X]_{aq}/\text{mol dm}^{-3}$	
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	$[Y]_{aq}/\text{mol dm}^{-3}$	
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.

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

$$1.60 \times 10^{-5} \text{ mol dm}^{-3} \text{ s}^{-1} = k (0.2 \text{ mol dm}^{-3})^m (0.4 \text{ mol dm}^{-3})^n \quad \text{---(2)} \quad (10+2)$$

$$4.00 \times 10^{-4} \text{ mol dm}^{-3} \text{ s}^{-1} = k (1.0 \text{ mol dm}^{-3})^m (0.4 \text{ mol dm}^{-3})^n \quad \text{---(3)} \quad (10+2)$$

Finding of the order m

From (2)/(1)

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

$$0.04 = (0.2)^m$$

$$m = 2$$

(4+1)

Finding of the order n

From (3)/(1)

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

$$200 = 10^2 (2)^n$$

$$n = 1$$

(4+1)

(v) Calculate the rate constant of the reaction.

Rate constant

From (1)

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

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

(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 cm³ of org-2 and 100.00 cm³ 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 $6.40 \times 10^{-7} \text{ mol dm}^{-3} \text{ s}^{-1}$.

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

$[X]_{\text{org-2}}$ 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)

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

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

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

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

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

$$K_D = 24 \quad (4+1)$$

Alternate answer for 6(c)

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

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

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

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

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

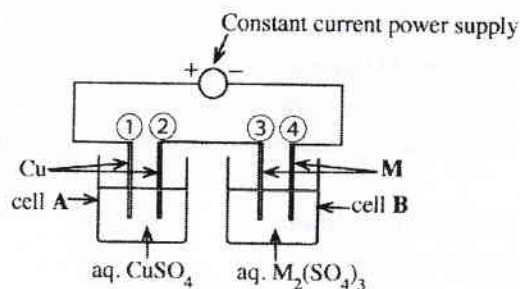
$$64 \times 10^{-4} = \left(\frac{2}{K_D + 1}\right)^2 \quad (4+1)$$

$$K_D = 24 \quad (4+1)$$

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).

Cell A

Anode = 1 (5)

Cathode = 2 (5)

Cell B

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 $\text{Cu(s)} \rightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{e}^-$ (6)

Cell A electrode 2 $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu(s)}$ (6)

Cell B electrode 3 $\text{M(s)} \rightarrow \text{M}^{3+}(\text{aq}) + 3\text{e}^-$ (6)

Cell B electrode 4 $\text{M}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{M(s)}$ (6)

Note : physical states must be given

(iii) Calculate the constant current used in electrolysis.

Amount of Cu(s) dissolved = $31.75 \times 10^{-3} \text{ g}$

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

Correct stoichiometry

(5)

The current used in the electrolysis = $i = 0.16 \text{ A}$

(4+1)

Alternative Answer for 7(a) (iii)

$$\begin{aligned} \text{Amount of Cu deposited} &= \frac{31.75 \times 10^{-3} \text{ g}}{63.5 \text{ g mol}^{-1}} \quad (1+1) \\ &= 0.5 \times 10^{-3} \text{ mol} \\ \text{Amount of charge required} &= 0.5 \times 10^{-3} \times 2 \text{ mol} \quad \text{For using correct stoichiometry} \quad (5) \\ &= 10^{-3} \text{ mol} \\ &= 10^{-3} \text{ mol} \times 96500 \text{ C mol}^{-1} \quad (1+1) \\ &= 96.5 \text{ C} \\ \text{Current} &= \frac{96.5 \text{ C}}{10 \times 60 \text{ s}} \quad (1+1) \\ &= 0.16 \text{ A} \quad (4+1) \end{aligned}$$

(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 = $147.6 \times 10^{-3} \text{ g}$

Amount of M deposited = $147.6 \times 10^{-3} \text{ g} / W$

W = molecular weight of M

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

Correct stoichiometry

(5)

$W = 445.1 \text{ g mol}^{-1}$

(1+1)

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

The amount of charge flown is equal.

$M \text{ mol} \times 3 = \text{Cu mol} \times 2$

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

$$\begin{aligned} W &= \frac{147.6 \times 3 \times 63.5}{31.75 \times 2} \text{ g mol}^{-1} \\ &= 442.8 \text{ g mol}^{-1} \quad (1+1) \end{aligned}$$

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

$$\begin{aligned} \text{Amount of M deposited} &= \text{Amount of charge flown} / 3 \\ &= \frac{10^{-3}}{3} \text{ mol} \quad (1+1) \quad \text{For using correct stoichiometry} \quad (5) \end{aligned}$$

$$\begin{aligned} \text{Molar mass of M} &= \frac{147.6 \times 10^{-3} \text{ g}}{\frac{10^{-3}}{3} \text{ mol}} \quad (1+1) \\ &= 147.6 \times 3 \text{ g mol}^{-1} \\ &= 442.8 \text{ g mol}^{-1} \quad (1+1) \end{aligned}$$

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): $\text{NiCl}_2\text{H}_{12}\text{N}_4$, $\text{NiI}_2\text{H}_{16}\text{N}_4\text{O}_2$ and $\text{NiCl}_2\text{H}_{15}\text{N}_3\text{O}_3$.

Given below are the observations when aqueous solutions of the compounds are treated with $\text{Pb}(\text{CH}_3\text{COO})_2(\text{aq})$.

Compound	$\text{Pb}(\text{CH}_3\text{COO})_2(\text{aq})$
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: $[\text{Ni}(\text{NH}_3)_3(\text{H}_2\text{O})_3]\text{Cl}_2$ OR $[\text{Ni}(\text{H}_2\text{O})_3(\text{NH}_3)_3]\text{Cl}_2$ (06)
- B: $[\text{Ni}(\text{NH}_3)_4\text{Cl}_2]$ OR $[\text{NiCl}_2(\text{NH}_3)_4]$ (06)
- C: $[\text{Ni}(\text{NH}_3)_4(\text{H}_2\text{O})_2]\text{I}_2$ OR $[\text{Ni}(\text{H}_2\text{O})_2(\text{NH}_3)_4]\text{I}_2$ (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 $\text{Pb}(\text{CH}_3\text{COO})_2(\text{aq})$.

(Note: Indicate compound and reagent)

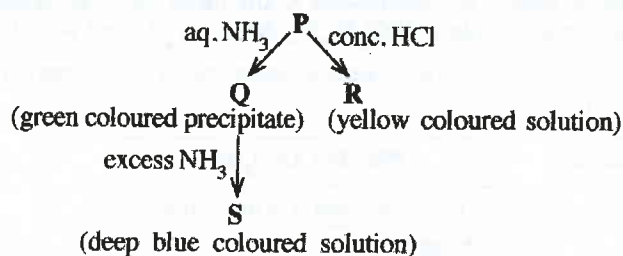
- A with $\text{Pb}(\text{CH}_3\text{COO})_2$ $\text{PbCl}_2 \downarrow$ (03)
- C with $\text{Pb}(\text{CH}_3\text{COO})_2$ $\text{PbI}_2 \downarrow$ (03)

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 $[\text{M}(\text{H}_2\text{O})_n]^{m+}$. 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: $\text{Ni}(\text{OH})_2$ (03)

R: $[\text{NiCl}_4]^{2-}$ (03)

S: $[\text{Ni}(\text{NH}_3)_6]^{2+}$ (03)

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

P: hexaaquanickel(II) ion (03)

R: tetrachloridonickelate(II) ion (03)

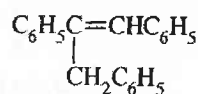
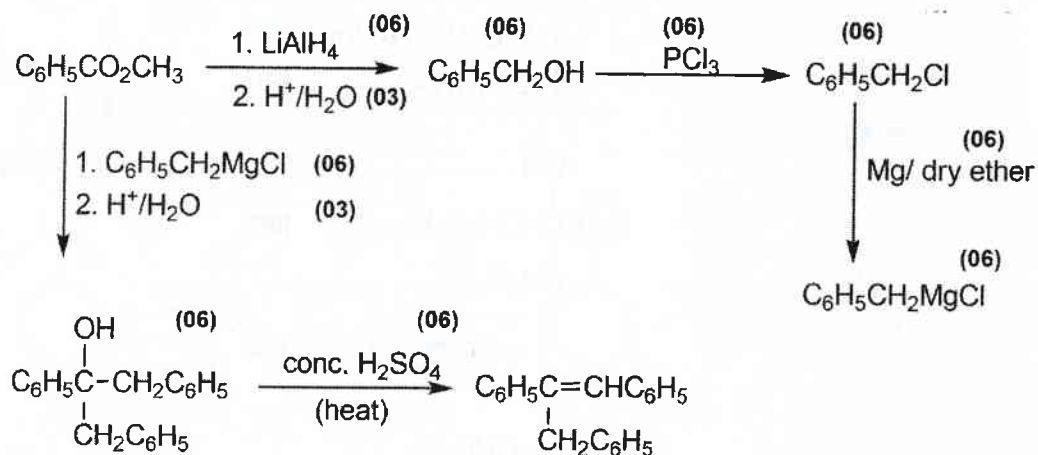
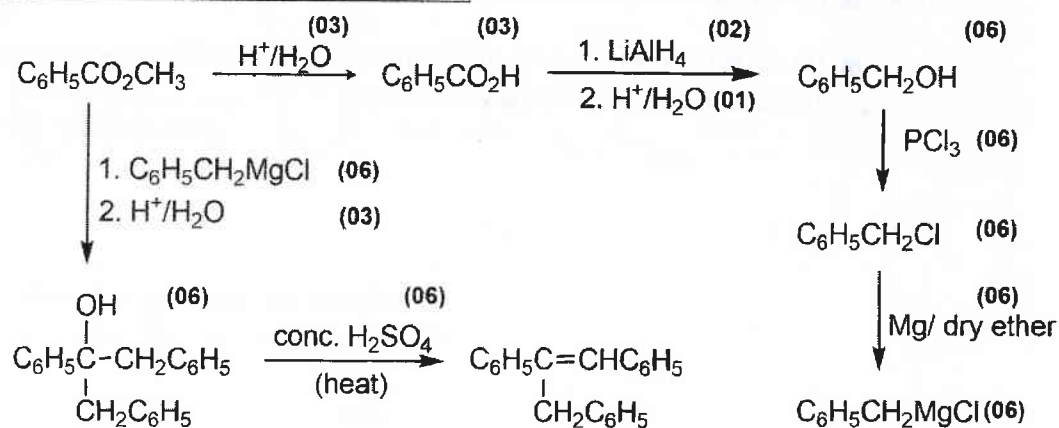
S: hexaamminenickel(II) ion (03)

7(b): 75 marks

PART C – ESSAY

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

8. (a) Using $\text{C}_6\text{H}_5\text{CO}_2\text{CH}_3$ 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.

**List of reagents** PCl_3 , Mg/dry ether , $\text{H}^+/\text{H}_2\text{O}$, LiAlH_4 , $\text{conc. H}_2\text{SO}_4$ **(60 marks)****Alternative Answer (I) for 8(a)****(60 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 / $\text{C}_2\text{H}_5\text{OH}$ / ethanol/ alcohol/ ROH (05 + 05)

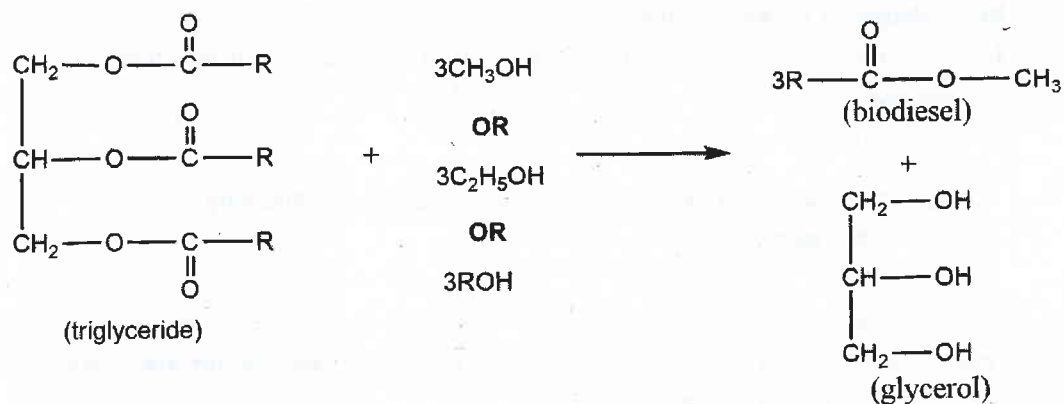
- (ii) Name the main chemical compound present in each raw material where applicable.

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 R₁, R₂ and R₃. 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. C₂H₅OH 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-COO⁻Na⁺) (05)

10(c): 50 marks