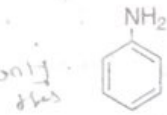
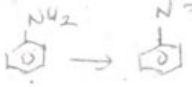
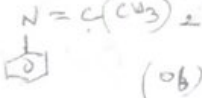
React with aniline (06)

(ii)



~~(06)~~ 04

(02) CH_3, CH_3 >C=O +  →  (06)

Total 10(d)(ii) = 06 marks

Total 10(d) = 30 marks

N.B.

- For the hydrolysis dilute HCl can be used instead of dil. H_2SO_4.
- For the conversions the product(s) should be correct to award the mark allocated to the reagent.

MCQ Answers

1)	4	11)	2	21)	2	31)	1	41)	5
2)	5	12)	1	22)	1	32)	3	42)	2
3)	1	13)	4	23)	4	33)	1	43)	3
4)	1	14)	2	24)	3	34)	4	44)	3
5)	3	15)	2	25)	4	35)	3	45)	2/3
6)	2	16)	3	26)	3	36)	5/3	(46)	2
7)	5	17)	3	27)	5	37)	5 (a,b,d)	47)	4
8)	3	18)	4	28)	2	38)	4	48)	1
9)	3/4	19)	1	29)	5	39)	1/5	49)	5
10)	5	20)	3/5	30)	3	40)	5 (c)	(50)	5

V. Selvanayagam
Royal college
Colombo-7

) You are provided with the following list of compounds.

KIO_3, PCl_5, $CdCl_2$, $Co(NO_3)_2$, $Na_2S_2O_3$

Which one of the above compounds,

(i) is used as a primary standard in volumetric analysis? KIO_3

(ii) gives a pale yellow precipitate when dil. H_2SO_4 is added to its aqueous solution? $Na_2S_2O_3$

(iii) undergoes hydrolysis to give an acid with a tetrahedral structure? PCl_5

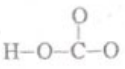
(iv) gives a dark yellow precipitate when dissolved in dil. HCl and H_2S is passed through the solution? $CdCl_2$

(v) gives a blue coloured solution on addition of conc. HCl to its aqueous solution? $Co(NO_3)_2$ (04 × 5)

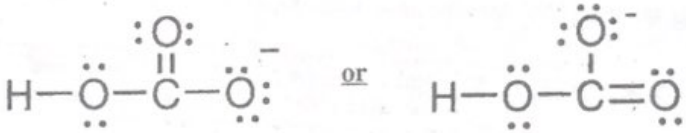
more than one response no marks

20

) The following parts (i) - (vi) are based on the bicarbonate ion, HCO_3^-. The skeleton of HCO_3^- is given below.



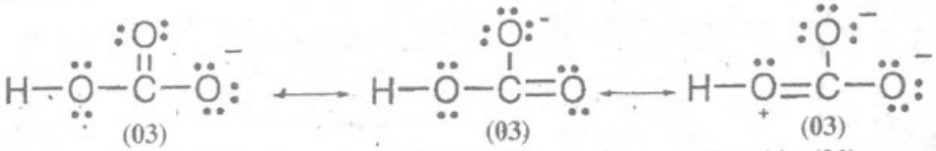
(i) Draw the **most** acceptable Lewis structure for this ion.



or

(07)

(ii) Draw resonance structures for this ion and comment on their relative stabilities.



(03) Stable (01)

(03) Stable (01)

(03) Unstable (01)

Reason -
Oxygen carries a positive charge (03)

Structures that do not indicate lone pairs of electrons are accepted, provided that the correct Lewis structure is given in (b)(i).

(iii) Deduce the shapes around the following atoms using the VSEPR theory.

I. C

Total number of electron pairs around C = 4 (01)
VSEPR pairs **or** sigma electron pairs = 3 (01)
Lone pairs = 0 (01)
Shape = trigonal planar (04)

II. O attached to H

Total number of electron pairs around O = 4 (01)
VSEPR pairs = 4 **or** two sigma electron pairs and two lone pairs of electrons (01)
Lone pairs = 2 (01)
Shape = angular/ V shape (04)

If only shape is given award 04 marks only.

(iv) Indicate the electron pair geometry (arrangement of electron pairs) around the following atoms.

I. C ..... trigonal planar ..... (0

II. O attached to H ..... tetrahedral ..... (0

(v) Indicate the hybridization of the following atoms.

I. C ..... sp^2 ..... (0

II. O attached to H ..... sp^3 ..... (0

(vi) Identify the atomic orbitals / hybrid orbitals involved in the formation of the following σ bonds present in the Lewis structure drawn in (i) above.

I. between C and O attached to H $O - sp^3$ (hybrid orbital) **(03)** + $C - sp^2$ (hybrid orbita

II. between O and H $O - sp^3$ (hybrid orbital) **(03)** + $H - 1s$ (atomic orbital

For H, instead of 1s atomic orbital, s atomic orbital is accepted.

6

(c) The following table gives the approximate values of melting points and electrical conduction (in relative terms excellent, good, poor, very poor or nil) of five substances, Mg, CO_2, SiO_2, NaCl and MgO. Complete the table by writing the formula of the appropriate substance in the column provided under the heading "Substance".

	Substance	Melting point / K	Electrical conduction in the solid state	Electrical conduction in the molten/liquid state
(1)	MgO ?	3200	poor	good
(2)	NaCl ?	1100	poor	good
(3)	Mg ?	920	excellent	excellent
(4)	CO_2 ?	200	very poor / nil	very poor / nil
(5)	SiO_2 ?	1900	very poor / nil	very poor / nil

(04

2

1

2. **M** is a non-transition element. Some chemical properties of this element are given below.

- It burns in air with a bright white flame to give a mixture of two compounds, **A** and **B**.
- It does not react with cold water but reacts slowly with hot water and steam with the evolution of a colourless, flammable gas, **C**.
- It reacts with conc. HNO_3 to form NO_2.

(i) Identify the element **M** and state one **important** use of it.

Mg (magnesium)

Uses

- Manufacture of alloys (light weight) used in aircraft manufacture.
- Fireworks (Mg powder)
- Flashlight powders for photography
- Manufacture of batteries
- To prevent corrosion
- Synthesis of Grignard reagent

(any one use)

(ii) Write the ground state electronic configuration of **M**.

$1s^2 2s^2 2p^6 3s^2$

iii) Write the chemical formulae of **A**, **B** and **C**.

A MgO or Mg_3N_2 (05)

B Mg_3N_2 or MgO (05)

C H_2 (05)

iv) **One** of the compounds **A** or **B**, reacts with water with the evolution of a gas. Identify this gas.

NH_3 **or** Ammonia (05)

v) Give the balanced chemical equation for the reaction between conc. HNO_3 and **M**.

$$Mg + 4HNO_3 \rightarrow Mg(NO_3)_2 + 2NO_2 + 2H_2O$$ (10)

vi) Give the balanced chemical equation for the reaction of **M** with hot water.

$$Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2$$ (10)

vii) Using an acid-base indicator explain how you would demonstrate in the laboratory, the occurence of the reaction of **M** with hot water.

1. Place a strip of Mg in a boiling tube containing hot water (03)
2. Add a few drops of an acid-base indicator e.g. phenolphthalein (03)
3. OH^- / $Mg(OH)_2$ are formed. (03)
4. This will cause the phenolphthalein to turn pink (03)

(if any other indicator is given, the appropriate colour should be stated)

methyl orange not accepted

Although litmus paper is not an acid-base indicator, it can be accepted as an answer.

viii) Giving reasons indicate whether the electron affinity of **M** would be positive or negative.

positive (06)

The added electron occupies a $3p$ sub-shell that is higher in energy. (03)

This is energetically unfavourable. (03)

Hence, electron affinity is positive

or

Magnesium has s^2 configuration for the valency shell which is stable (02)

Addition of an electron disturbs the stability. (02)

Hence, difficult to add. Therefore, electron affinity is positive (02)

ix) State whether the solubilities of oxides and hydroxides of the elements in the group of the Periodic Table to which **M** belongs decrease or increase down the group. (Reasoning not required.)

Oxides – increases (05)

Hydroxides – increases (05)

x) **P** and **Q** are respectively the two elements found immediately before and after **M** in the Periodic Table. Indicate in the table given below with a 'tick' (✓) in the appropriate cage, the nature of the oxides of **P**, **M** and **Q**.

element	strongly acidic	weakly acidic	amphoteric	weakly basic	strongly basic
P					✓
M				✓	
Q			✓		

(02 × 3)

100

3. (*a*) Consider the chemical reaction,

$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$,

and the thermochemical data given below (at 25 °C).

Chemical species	$N_2(g)$	$H_2(g)$	$NH_3(g)$
Standard enthalpy of formation / kJ mol^{-1}	0.00	0.00	−46.1
Standard entropy / J K^{-1} mol^{-1}	191.5	130.7	192.3

(i) Calculate ΔH^0 for the above reaction at 25 °C.

$\Delta H^\circ_{rxn} = \sum \Delta H^\circ_{f(products)} - \sum \Delta H^\circ_{f(reactants)}$ (02)

$= 2 \times (-46.1 \text{ kJ mol}^{-1}) - \{1 \times 0.00 \text{ kJ mol}^{-1} + 3 \times 0.00 \text{ kJ mol}^{-1}\}$ (02)

$\Delta H^\circ_{rxn} = -92.2 \text{ kJ mol}^{-1}$ 0.22 should be one last mark.

OR kJ

(ii) Calculate ΔS^0 for the above reaction at 25 °C.

$\Delta S^\circ_{rxn} = \sum S^\circ_{(products)} - \sum S^\circ_{(reactants)}$ (0

$= 2 \times (192.3 \text{ J K}^{-1} \text{ mol}^{-1}) - \{1 \times 191.5 \text{ J K}^{-1} \text{ mol}^{-1} + 3 \times 130.7 \text{ J K}^{-1} \text{ mol}^{-1}\}$ (0

$= -199 \text{ J K}^{-1} \text{ mol}^{-1}$

OR J K^{-1}

(iii) I. Write an expression to relate ΔG of a chemical reaction to its ΔH and ΔS.

$\Delta G = \Delta H - T\Delta S$ not $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$

II. Calculate ΔG^0 for the above reaction at 25 °C.

$\Delta G^0 = -92.2 \text{ kJ mol}^{-1} - 298 \text{ K } (-0.199 \text{ kJ mol}^{-1} \text{ K}^{-1})$ (0

$= -32.9 \text{ kJ mol}^{-1}$ (0

OR kJ

(*b*) (i) Non-volatile solute **A** dissolves in solvent **B** forming the ideal solution **C**. At a given temperature, the vapour pressure of the pure solvent and that of solution **C** are p° and p, respectively. The mole fraction of the solvent in solution **C** is x_B.

I. Write the Raoult's law in the form of an equation for solution **C**, in terms of the symbols given above.

$p = x_B p^\circ$ **OR** $\frac{p^\circ - p}{p^\circ} = 1 - x_B$

II. The mole fraction of the solute in solution **C** is x_A. Write an equation for the Raoult's law in terms of p, p° and x_A. Hence, derive a mathematical expression for x_A.

$p = (1 - x_A)p^\circ$ **OR** $1 - x_B = x_A$

$p = p^\circ - x_A p^\circ$

$x_A = \frac{p^\circ - p}{p^\circ}$ $\frac{p^\circ - p}{p^\circ} = x_A$

(ii) Calculate the mole fraction of the solute in each of the following solutions **P**, **Q** and **R**.

P: 2.0 mol dm^{-3} aqueous solution of glucose which has a density of 1.26 g cm^{-3}

Q: Solution containing 180 g of glucose in 162 g of water

R: Solution containing 171 g of sucrose in 171 cm^3 of water

Consider that the density of water is 1.0 g cm^{-3}

Relative molar masses of water, glucose and sucrose are 18, 180 and 342 respectively.

Consider 1000 cm^3 of solution

Total mass = 1000 cm^3 × 1.26 g cm^{-3} = 1260 g **(02)**

Mass of glucose = 2 mol × 180 g mol^{-1} = 360 g **(02)**

Mass of water = 1260 g − 360 g = 900 g **(02)**

$$\text{Amount of water} = \frac{900\ \text{g}}{18\ \text{g mol}^{-1}} = 50\ \text{mol} \quad \textbf{(02)}$$

$$\text{Moles fraction of glucose} = \frac{2\ \text{mol}}{2\ \text{mol} + 50\ \text{mol}}$$

$$= \frac{1}{26} = 0.039 \quad \textbf{(02)}$$

R: $\text{Amount of sucrose} = \frac{171\ \text{g}}{342\ \text{g mol}^{-1}} = 0.5\ \text{mol}$ **(02)**

$$\text{Amount of water} = \frac{171\ \text{g}}{18\ \text{g mol}^{-1}} = 9.5\ \text{mol} \quad \textbf{(02)}$$

$$\text{Moles fraction of sucrose} = \frac{0.5\ \text{mol}}{0.5\ \text{mol} + 9.5\ \text{mol}} = 0.05 \quad \textbf{(02)}$$

Q: $\text{Amount of glucose} = \frac{180\ \text{g}}{180\ \text{g mol}^{-1}} = 1\ \text{mol}$ **(02)**

$$\text{Amount of water} = \frac{162\ \text{g}}{18\ \text{g mol}^{-1}} = 9\ \text{mol} \quad \textbf{(02)}$$

$$\text{Mole fraction of glucose} = \frac{1\ \text{mol}}{1\ \text{mol} + 9\ \text{mol}} = \frac{1}{10} = 0.1 \quad \textbf{(02)}$$

(iii) Arrange the solutions **P**, **Q** and **R** in the order of their **increasing** vapour pressures, according to Raoult's law.

If there is mathematical mistake in (ii) / mark (iii) independently
Then the order would be according to the calculated answer

Q < R < P **(08)**

(iv) Write the Raoult's law as an equation for a mixture consisting of glucose, sucrose and water where the masses of these are known.

$p = p^\circ$ (1 - mole fraction of glucose - mole fraction of sucrose) **(08)**

[Part marks : Mole fraction of solutes in solution = sum of mole fractions of glucose and sucrose **(04)**]

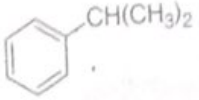
50

4. (a) (i) State the characteristic type of reaction that benzene undergoes.

Electrophilic substitution **(04)**

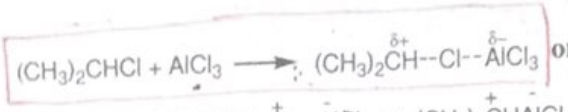
Total 4(a)i = 04 mark

(ii) Give the structure of the product and the mechanism, for the reaction between benzene and $(CH_3)_2CHCl$ in the presence of anhydrous $AlCl_3$.



(04)

mechanism

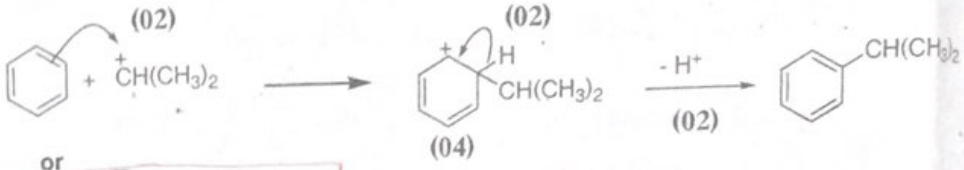


or $(CH_3)_2\overset{+}{C}H\text{---}\overset{-}{AlCl_4}$

or $(CH_3)_2CH\text{—}\overset{+}{Cl}\text{—}\overset{-}{AlCl_3}$ **or** $(CH_3)_2\overset{+}{C}H\overset{-}{AlCl_4}$ **or** $(CH_3)_2\overset{+}{C}H\ \overset{-}{AlCl_4}$ **(04)**

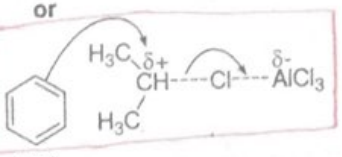
structures with -ve sign on Cl (e.g. $(CH_3)_2\overset{+}{C}HAlCl_4^-$) accepted.

(02) **(02)**



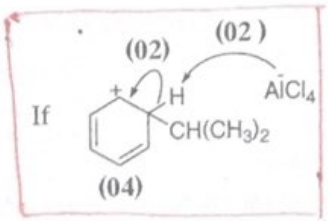
(04) **(02)**

or



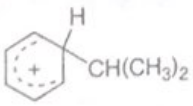
(02)

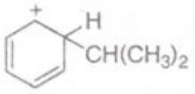
Total 4(a)ii = 18 marks

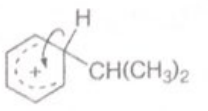


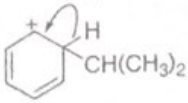
(02) **(02)** **(04)**

If given award **(08)** marks



is accepted for  award only **(04)** marks

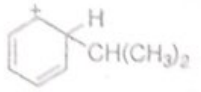


is accepted for  award only **(06)** marks

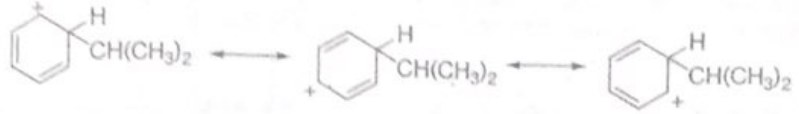
(02)

(04)

(iii) Explain the stability of the intermediate formed from benzene in the above reaction.

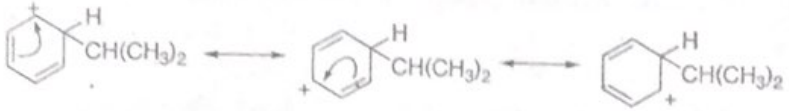


is stabilized by resonance as shown below. (03)



(03) (03) (03)

or

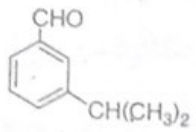


(03) (03) (03)

Could ignore the arrows in the structures

Total 4(a)iii = 12 marks

(iv) Draw the structure of the expected major product when benzaldehyde (C_6H_5CHO) is reacted with $(CH_3)_2CHCl$ in the presence of anhydrous $AlCl_3$.



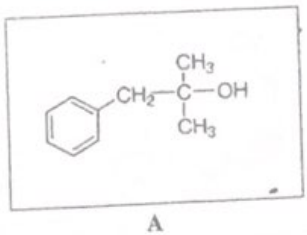
(06)

Total 4(a)iv = 06 marks

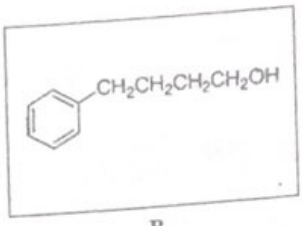
(*b*) A, B and C are isomeric, optically inactive, monosubstituted aromatic compounds with the molecular formula $C_{10}H_{14}O$.

- A reacts readily with conc. HCl in the presence of anhydrous $ZnCl_2$ to give the corresponding halide, while B and C do not react with the same reagent at an appreciable rate.
- B and C when reacted with pyridinium chlorochromate give compounds D and E, respectively. D undergoes aldol type condensation in the presence of dil. NaOH while E does not.

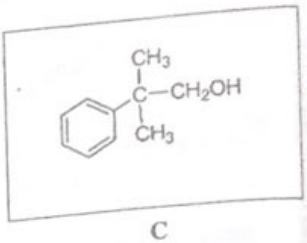
(i) Draw the structures of A, B, C, D and E in the relevant boxes given below.



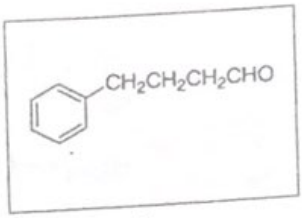
A



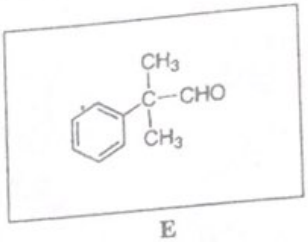
B



C



D

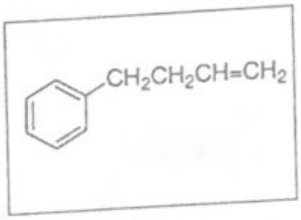


E

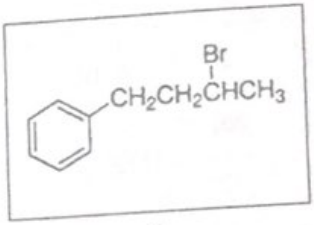
(05)

- B when heated with conc. H_2SO_4 gives F.
- F when reacted with HBr gives G.

(ii) Draw the structures of F and G in the relevant boxes given below.

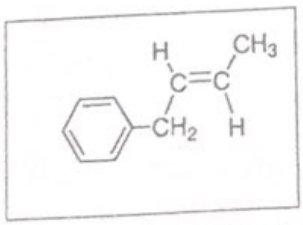


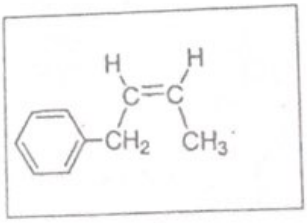
F

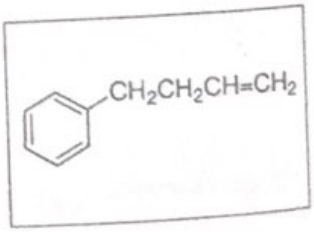


G

(iii) Draw the structures of the three products formed, in the boxes given below, when G is reacte with alcoholic KOH.







If $C_6H_5CH_2CH{=}CHCH_3$ given and cis/trans not shown in the structure by drawing give 05 ma

(iv) State whether G could exist in stereoisomeric forms. Yes

(v) Explain your answer in (iv) above.

G has a carbon atom joined to four different groups or chiral centre or asymmetric carbon atom.

5 a) Amount of $O_2 = \frac{3.2\ g}{32\ g\ mol^{-1}} = 0.10\ mol$ (02+01)

$pV = nRT$ (03)

Before addition of X,

$(1.0 \times 10^5\ Pa)\ V = 0.10\ mol \times R \times 300\ K$ ..... (1) (02+01)

After addition of X,

Let M = molar mass of X

Amount of $X = \frac{8.8\ g}{M}$ (02+01)

Total number of moles of gases = $\left(0.10\ mol + \frac{8.8\ g}{M}\right)$ (02+01)

$(2.0 \times 10^5\ Pa)\ 2V = \left(0.10\ mol + \frac{8.8\ g}{M}\right) \times R \times 400\ K$ ..... (2) (02+01)

$\frac{(2)}{(1)}$ $\frac{(2.0 \times 10^5\ Pa)\ 2V}{(1.0 \times 10^5\ Pa)\ V} = \frac{\left(0.10\ mol + \frac{8.8\ g}{M}\right) \times R \times 400\ K}{0.1\ mol \times R \times 300\ K}$ (02+01)

$1.2\ mol = 0.40\ mol + \frac{8.8\ g \times 4}{M}$ (03)

$M = \frac{8.8\ g \times 4}{(1.2 - 0.40)\ mol}$ (03)

$M = 44\ g\ mol^{-1}$

OR Rel. mol. mass of X = 44 (02+01)

Note: molar mass of X can also be defined with units (as M g mol^{-1}). Then the total number of moles of gases is $\left(0.10\ mol + \frac{8.8\ g}{M\ g\ mol^{-1}}\right) = \left(0.10 + \frac{8.8}{M}\right) mol$. The molar mass of X will appear as 44.

Alternative answer for 5a

Before addition of X,

Volume is doubled; Pressure is halved.

$p_1 = 5.0 \times 10^4\ Pa$ (02+01)

To calculate pressure at 400 K,

$\frac{p_1}{T_1} = \frac{p_2}{T_2}$ (03)

$\frac{5.0 \times 10^4\ Pa}{300\ K} = \frac{p_2}{400\ K}$ (02+01)

$$p_2 = \frac{4}{3} \times 5.0 \times 10^4 \text{ Pa}$$ (02+01)

After addition of X,

$$p \propto n$$

Initially, $n = \frac{3.2 \text{ g}}{32 \text{ g mol}^{-1}} = 0.10 \text{ mol}$ (02+01)

$$\frac{4}{3} \times 5.0 \times 10^4 \text{ Pa} \propto 0.10 \text{ mol}$$ (03)

$$2.0 \times 10^5 \text{ Pa} \propto n$$ (03)

$$\frac{\frac{4}{3} \times 5.0 \times 10^4 \text{ Pa}}{2.0 \times 10^5 \text{ Pa}} = \frac{0.10 \text{ mol}}{n}$$

$$n = 0.30 \text{ mol}$$ (02+01)

Moles of X added = 0.30 mol – 0.10 mol = 0.20 mol (03)

Molar mass of X $= \frac{8.8 \text{ g}}{0.20 \text{ mol}} = 44 \text{ g mol}^{-1}$

OR Rel. mol. mass= 44 (02+01)

Total for 5(a) *30 marks*

---

b) i) Partition coefficient between **A** and **B** $= \frac{[S]_A}{[S]_B} = \frac{1}{9}$ (04)

Note: $\frac{[S]_B}{[S]_A} = 9$ is also accepted.

Total for 5b(i) *04 marks*

ii) Partition coefficient between **A** and **C** $= \frac{[S]_A}{[S]_C} = \frac{1}{4}$ (04)

Note: $= \frac{[S]_C}{[S]_A} = 4$ is also accepted.

Total for 5b(ii) *04 marks*

iii) Let C = concentration of **S** in phase **A** after partition equilibrium in mol dm^{-3}

Concentration of S in phase **B** = (0.10 – C) mol dm^{-3} (04)

Since the volumes of the two phases are equal,

$$\frac{C}{0.10 - C} = \frac{1}{9}$$ (04)

$$0.10 - C = 9C$$

$$C = 0.010$$ (04)

Concentration of S remained in A = 0.01 mol dm^{-3} (03+01)

Total for 5b(iii) *16 marks*

Alternative answer for 5b(iii)

After partition equilibrium, let

n_1 = Mol of S in phase A

n_2 = Mol of S in phase B

Since the volumes of the two phases are equal,

$$\frac{n_1}{n_2} = \frac{1}{9} \quad (04)$$

$$\frac{n_1}{n_1 + n_2} = \frac{1}{10} \quad (04)$$

Concentration of S remained in A $= \frac{1}{10} \times 0.10$ mol dm^{-3} (03+01)

$= 0.010$ mol dm^{-3} (03+01)

Total for 5b(iii) *16 marks*

iv) Partition begins having 0.010 mol dm^{-3} of S in phase A.

Let x = Number of mol of S remained in phase A

After equilibrium is reached,

$$\text{Concentration of S in phase C} = \frac{0.010 \text{ mol dm}^{-3} \times \frac{10.00}{1000} \text{ dm}^3 - \text{x mol}}{\frac{20.00}{1000} \text{ dm}^3} \quad (03+01)$$

$$= \frac{0.10 - 1000\,\text{x}\ \cancel{\text{mol}}}{20.00} \text{ mol dm}^{-3} \quad (03+01)$$

$$\text{Concentration of S in phase A} = \frac{\text{x mol}}{\frac{10.00}{1000} \text{ dm}^3} \quad (03+01)$$

$$= \frac{1000\,\text{x}}{10.00} \text{ mol dm}^{-3} \quad (03+01)$$

$$\frac{\left(\frac{1000\,\text{x}}{10.00} \text{ mol dm}^{-3}\ \cancel{\text{mol dm}^{-3}}\right)}{\left(\frac{0.10 - 1000\,\text{x}\ \cancel{\text{mol}}}{20.00} \text{ mol dm}^{-3}\right)} = \frac{1}{4} \quad (04)$$

$$\left(\frac{0.10 - 1000\,\text{x}}{20.00}\right) = \frac{4000\,\text{x}}{10.00} \quad (04)$$

$$0.10 - 1000\,\text{x} = 8000\,\text{x}$$

$$9000\,\text{x} = 0.10$$

$$\text{x} = 1.1 \times 10^{-5} \quad (04)$$

Concentration of S remained in phase **A** $= \dfrac{1.1\times10^{-5}\ \text{mol}}{\frac{10.00}{1000}\ \text{dm}^3}$ **(03+01)**

$= 1.1 \times 10^{-3}\ \text{mol dm}^{-3}$ **(03+01)**

Total for 5b(iv) *36 marks*

Alternative answer for 5b(iv)

After equilibrium is reached, let

n_1' = Mol of S in phase **A**

n_2' = Mol of S in phase **C**

Concentration of S in phase **A** $= \dfrac{n_1'\ \text{mol}}{\frac{10.00}{1000}\ \text{dm}^3}$ **(03+01)**

$= \dfrac{1000\ n_1'}{10.00}\ \text{mol dm}^{-3}$ **(03+01)**

Concentration of S in phase **C** $= \dfrac{n_2'\ \text{mol}}{\frac{20.00}{1000}\ \text{dm}^3}$ **(03+01)**

$= \dfrac{1000\ n_2'}{20.00}\ \text{mol dm}^{-3}$ **(03+01)**

$$\frac{\frac{1000\ n_1'}{10.00}\ \text{mol dm}^{-3}}{\frac{1000\ n_2'}{20.00}\ \text{mol dm}^{-3}} = \frac{1}{4} \quad \textbf{(04)}$$

$$\frac{2\ n_1'}{n_2'} = \frac{1}{4} \quad \textbf{OR} \quad \frac{n_1'}{n_2'} = \frac{1}{8} \quad \textbf{(04)}$$

$$\frac{n_1'}{n_1' + n_2'} = \frac{1}{9} \quad \textbf{(04)}$$

Concentration of S remained in **A** $= \dfrac{1}{9} \times 0.010\ \text{mol dm}^{-3}$ **(03+01)**

$= 0.0011\ \text{mol dm}^{-3}$ **(03+01)**

Total for 5b(iv) *36 marks*

Total for 5(b) *60 marks*

c) i) $2P(g) \rightleftharpoons 2Q(g) + R(g)$

Partial pressure of R = 2.0×10^4 Pa (given) **(03+01)**

Partial pressure of **Q** = 4.0×10^4 Pa

Partial pressure of **P** = total pressure – p. pressure of **Q** –p. pressure of **R** **(03+01)**

= 1.2×10^5 Pa - 2.0×10^4 Pa - 4.0×10^4 Pa **(03+01)**

= 6.0×10^4 Pa

Total for 5c(i) *12 marks*

(04)

ii) $pV = nRT$ **(03+01)**

$(1.2 \times 10^5 \text{ Pa}) \times (1.0 \times 10^{-3} \text{ m}^3) = n \times 4.0 \times 10^3 \text{ J mol}^{-1}$ **(03+01)**

$n = 0.030$ mol

Mol of each component = Total no. of mol × fractional pressure

$n_P = 0.030 \text{ mol} \times \frac{6.0 \times 10^4}{1.2 \times 10^5} = 0.015 \text{ mol}$ **(04)**

$n_Q = 0.030 \text{ mol} \times \frac{4.0 \times 10^4}{1.2 \times 10^5} = 0.010 \text{ mol}$ **(04)**

$n_R = 0.030 \text{ mol} - 0.015 \text{ mol} - 0.030 \text{ mol} = 0.005 \text{ mol}$ **(04)**

Note: If the calculations are INCORRECT (OR NOT GIVEN), award **(04)** marks for correct identification of the partial pressure – number of moles relationship.

At equilibrium,

Concentration of **P** = 0.015 mol dm^{-3} **(03+01)**

Concentration of **Q** = 0.010 mol dm^{-3} **(03+01)**

Concentration of **R** = 0.005 mol dm^{-3} **(03+01)**

Total for 5c(ii) *36 marks*

Alternative answer for 5c(ii)

$p = CRT$ **OR** $C = p/RT$ **(06)**

$C_P = \frac{6.0 \times 10^4 \text{ Pa}}{4.0 \times 10^3 \text{ J mol}^{-1}}$ **(05+01)**

= 15.0 mol m^{-3} = 0.015 mol dm^{-3} **(03+01)**

$C_Q = \frac{4.0 \times 10^4 \text{ Pa}}{4.0 \times 10^3 \text{ J mol}^{-1}}$ **(05+01)**

= 10.0 mol m^{-3} = 0.010 mol dm^{-3} **(03+01)**

$C_R = \frac{2.0 \times 10^4 \text{ Pa}}{4.0 \times 10^3 \text{ J mol}^{-1}}$ **(05+01)**

= 5.0 mol m^{-3} = 0.005 mol dm^{-3} **(03+01)**

Total for 5c(ii) *36 marks*

iii) $K_C = \dfrac{[Q]^2\,[R]}{[P]^2}$ **(04)**

$= \dfrac{(0.010\ \text{mol dm}^{-3})^2\,(0.005\ \text{mol dm}^{-3})}{(0.015\ \text{mol dm}^{-3})^2}$ **(03+01)**

$= 2.2 \times 10^{-3}$ mol dm^{-3} **(03+01)**

Total for 5c(iii) *12 marks*

Alternative answer for 5c(iii)

$K_p = \dfrac{p_Q^2\,p_R}{p_P^2}$ **(03)**

$= \dfrac{(4.0\times10^4\ \text{Pa})^2\,(2.0\times10^4\ \text{Pa})}{(6.0\times10^4\ \text{Pa})^2}$

$= \dfrac{8}{9} \times 10^4$ Pa **(02+01)**

$K_C = \dfrac{K_p}{RT}$ **(03)**

$= \dfrac{(8/9)\times10^4\ \text{Pa}}{4.0\times10^3\ \text{J mol}^{-1}}$

$= 2.2$ mol m^{-3} **OR** 2.2×10^{-3} mol dm^{-3} **(02+01)**

Total for 5c(iii) *12 marks*

Note: Award full marks for the calculation of concentrations and K_c in mol m^{-3} units.

Total for 5(c) *60 marks*

6) a) i) $HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)$ **(03)**

Initially,	0.100	--	--	mol dm^{-3}
At eqm.,	0.100 – x	x	x	mol dm^{-3} **(02+01)**

$K_a = \dfrac{[H_3O^+(aq)]\,[A^-(aq)]}{[HA(aq)]}$ **(03)**

$= \dfrac{x^2}{0.100 - x}$ mol dm^{-3} **(03)**

Note: Award **no** marks for the chemical equation and for the expression of K_a if physical states are **not** given.

Assumption: x is negligible compared to 0.100 **OR** $0.100 - x \approx 0.100$ **(03)**

$\dfrac{x^2}{0.100} = 1.0 \times 10^{-5}$ **(03)**

$x^2 = 1.0 \times 10^{-6}$ (03)

$x = 1.0 \times 10^{-3}$

$[H_3O^+] = 1.0 \times 10^{-3}$ mol dm^{-3} (03)

pH = -log (1.0×10^{-3}) = 3.00

Total for 6a(i) *24 marks*

ii) $K_a = \dfrac{[H_3O^+(aq)][A^-(aq)]}{[HA(aq)]}$

$\dfrac{[HA(aq)]}{[A^-(aq)]} = \dfrac{[H_3O^+(aq)]}{K_a}$ (06)

Note: Award **no** marks if physical states are **not** given

Total for 6a(ii) *06 marks*

iii) pH = 4.0; $[H_3O^+] = 1 \times 10^{-4}$ mol dm^{-3} (02+01)

$[HA] + [A^-] = 0.100$ mol dm^{-3} ⟶ (1) (02+01)

$\dfrac{[HA]}{[A^-]} = \dfrac{1.0 \times 10^{-4} \text{ mol dm}^{-3}}{1.0 \times 10^{-5} \text{ mol dm}^{-3}} = 10$

$[HA] = 10\,[A^-]$ (2) (03)

From (1) and (2),

$10\,[A^-] + [A^-] = 0.100$ mol dm^{-3}

$[A^-] = (1/11) \times 0.100$ mol dm^{-3} (03)

$[A^-] = 9.09 \times 10^{-3}$ mol dm^{-3}. (02+01)

$[HA] = 9.09 \times 10^{-2}$ mol dm^{-3} (02+01)

Total for 6a(iii) *18 marks*

iv) $\dfrac{[HA(aq)]}{[A^-(aq)]} = \dfrac{[H_3O^+(aq)]}{K_a}$

When [HA] = [A-],

$\dfrac{[H_3O^+]}{K_a} = 1$ (03)

$[H_3O^+] = K_a = 1.0 \times 10^{-5}$ mol dm^{-3} (02+01)

pH = -log (1.0×10^{-5}) = 5.00 (03)

Total for 6a(iv) *09 marks*

v) $pH = pK_a + \log \dfrac{[A^-]}{[HA]}$ (03)

After reaction between HA and NaOH,

$$\text{concentration of HA} = \frac{5.00\ \text{cm}^3 \times 0.0500\ \text{mol dm}^{-3}}{105.00\ \text{cm}^3} \quad \textbf{(02+01)}$$

$$\text{concentration of A-} = \frac{50.00\ \text{cm}^3 \times 0.0500\ \text{mol dm}^{-3}}{105.00\ \text{cm}^3} \quad \textbf{(02+01)}$$

15

$$\text{pH} = -\log(1.0\times10^{-5}) + \log\frac{[50.00\ \text{cm}^3 \times 0.0500\ \text{mol dm}^{-3}/105.00\ \text{cm}^3]}{[5.00\ \text{cm}^3 \times 0.0500\ \text{mol dm}^{-3}/105.00\ \text{cm}^3]} \quad \textbf{(02+01)}$$

$$\text{pH} = 5.00 + \log 10.0$$
$$= 6.00 \quad \textbf{(03)}$$

Alternative answer for 6a(v)

After reaction between HA and NaOH,

$$\text{concentration of HA} = \frac{5.00\ \text{cm}^3 \times 0.0500\ \text{mol dm}^{-3}}{105.00\ \text{cm}^3} \quad \textbf{(02+01)}$$

$$= 2.38 \times 10^{-3}\ \text{mol dm}^{-3}$$

$$\text{concentration of A-} = \frac{50.00\ \text{cm}^3 \times 0.0500\ \text{mol dm}^{-3}}{105.00\ \text{cm}^3} \quad \textbf{(02+01)}$$

$$= 2.38 \times 10^{-2}\ \text{mol dm}^{-3}$$

$$K_a = \frac{[H_3O^+(aq)][A^-(aq)]}{[HA(aq)]} \quad \textbf{OR} \quad [H_3O^+(aq)] = \frac{K_a\,[HA(aq)]}{[A^-(aq)]} \quad \textbf{(03)}$$

$$[H_3O^+(aq)] = \frac{[1.0\times10^{-5}\ \text{mol dm}^{-3}][2.38\times10^{-3}\ \text{mol dm}^{-3}]}{[2.38\times10^{-2}\ \text{mol dm}^{-3}]} \quad \textbf{(02+01)}$$

$$= 1.0 \times 10^{-6}\ \text{mol dm}^{-3}$$

$$\text{pH} = -\log 1.0 \times 10^{-6}$$
$$= 6.00 \quad \textbf{(03)}$$

Assumption: Concentrations of HA and A^- after reaction ≈ their equilibrium concentrations of ionisation of HA is negligible **(03)**

Total for 6a(v) ***18 marks***

Total for 6(a) ***75 marks***

b) i) $CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$ **(05)**

Amount of $CaCO_3$ $= 4.00\ \text{g} / 100\ \text{g mol}^{-1} = 0.040\ \text{mol}$ **(04+01)**

Amount of HCl $= 0.30\ \text{mol dm}^{-3} \times 0.500\ \text{dm}^3 = 0.15\ \text{mol}$ **(04+01)**

Excess amount of HCl $= 0.15\ \text{mol} - 2 \times 0.040\ \text{mol}$
$= 0.07\ \text{mol}$ **(04+01)**

Concentration of H^+ $= 0.07\ \text{mol} / 0.500\ \text{dm}^3$
$= 0.14\ \text{mol dm}^{-3}$ **(04+01)**

Total for 6b(i) ***25 marks***

ii) 250 cm^3 of 0.14 mol dm^{-3} H^+ + 250 cm^3 of 0.16 mol dm^{-3} NaOH

$$[Ca^{2+}(aq)] = \frac{0.020\ mol}{0.500\ dm^3} = 0.040\ mol\ dm^{-3}$$ **(04+01)**

$$[OH^-(aq)] = \frac{0.16\ mol\ dm^{-3} \times 0.250\ dm^3 - 0.14\ mol\ dm^{-3} \times 0.250\ dm^3}{0.500\ dm^3}$$

$$= 0.01 mol\ dm^{-3}$$ **(04+01)**

.....

$$[Ca^{2+}(aq)]\ [OH^-(aq)]^2 = 0.040\ mol\ dm^{-3} \times (0.01 mol\ dm^{-3})^2$$ **(05)**

(05 = 02 for physical states +02 for substitution + 01 for units)

$$= 4 \times 10^{-6}\ mol^3\ dm^{-9}$$ **(04+01)**

$< K_{sp}$ ($= 6.5 \times 10^{-6}\ mol^3\ dm^{-9}$). No precipitation occurs. **(05)**

OR

$[OH^-(aq)]$ required to precipitate $= (K_{SP} / [Ca^{2+}(aq)])^{1/2}$

(02 for physical states only)

$$= \left(\frac{6.5 \times 10^{-6}\ mol^3\ dm^{-9}}{0.040\ mol\ dm^{-3}}\right)^{1/2}$$ **(02+01)**

$$= 1.3 \times 10^{-2}\ mol\ dm^{-3}$$ **(04+01)**

Concentration of $[OH^-(aq)]$ in solution $< 1.3 \times 10^{-2}$ mol dm^{-3}. No precipitation occurs. **(05)**

.....

Total for 6b(ii) ***25 marks***

iii) $[OH^-(aq)] = 0.01$ mol dm^{-3}

Concentration of Ca^{2+} required to precipitate $Ca(OH)_2$

$$= \frac{K_{sp}}{[OH^-(aq)]^2}$$

$$= \frac{6.5 \times 10^{-6}\ mol^3\ dm^{-9}}{(0.01\ mol\ dm^{-3})^2}$$ **(04+01)**

$$= 6.5 \times 10^{-2}\ mol\ dm^{-3}$$

Concentration of Ca^{2+} added for precipitation [as $Ca(NO_3)_2$]

$= 6.5 \times 10^{-2}$ mol dm^{-3} – 0.04 mol dm^{-3} **(04+01)**

$= 0.025$ mol dm^{-3}

Molar mass of $Ca(NO_3)_2 = 164$ g mol^{-1} **(05)**

Mass of $Ca(NO_3)_2$ to be added = 0.025 mol dm^{-3} × 0.500 dm^3 × 164 g mol^{-1} **(05)**

$= 2.05$ g **(04+01)**

Total for 6b(iii) ***25 marks***

Alternative answer for 6b(iii)

Molar mass of $Ca(NO_3)_2 = 164\ g\ mol^{-1}$ **(05)**

Let x = Mass of $Ca(NO_3)_2$ to be added for precipitation

Concentration of Ca^{2+} in solution $= 0.040\ mol\ dm^{-3} + \frac{x/(164\ g\ mol^{-1})}{0.500\ dm^3}$ **(04+01)**

$[OH^-]$ does not change.

$$\left(0.040\ mol\ dm^{-3} + \frac{x/(164\ g\ mol^{-1})}{0.500\ dm^3}\right)(0.01\ mol\ dm^{-3})^2 = 6.5 \times 10^{-6}\ mol^3\ dm^{-9}$$

(04+01)

$$\left(0.040\ mol\ dm^{-3} + \frac{x/(164\ g\ mol^{-1})}{0.500\ dm^3}\right) = 0.065\ mol\ dm^{-3}$$ **(05)**

$x = 0.025\ mol\ dm^{-3} \times 0.500\ dm^3 \times 164\ g\ mol^{-1}$

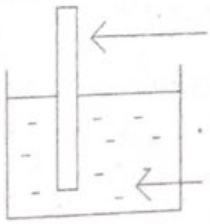
$= 2.05\ g$

Minimum mass of $Ca(NO_3)_2$ to be added for precipitation = 2.05 g **(04+01)**

Total for 6b(iii) ***25 marks***

Total for 6b ***75 marks***

7) a) i) Diagram of the Mg electrode



electrode completely in solution no marks

OR $MgCl_2(aq)$ OR $MgSO_4(aq)$ OR $Mg(NO_3)_2(aq)$

4 answers × 03 marks (12)

Total for 7a(i) ***12 marks***

Note: Award no marks for different diagrams even if labelling is correct.

ii)

- Potential develops on an electrode as a result of accumulation of charges on the electrode and the adjacent layer of solution. **(02)**
- One terminal of the potential measuring device must be connected to the electrode and the other terminal is partially immersed in the solution. **(02)**
- The charge accumulated on the second terminal immersed in solution too develops an electrical potential on the surface. **(02)**

- Potential measured of the first electrode is the potential with respect to that of the second electrode. (Therefore, the potential measured is not the absolute potential of the electrode concerned). (02)

OR

What can be measured is the potential of an electrode with respect to the potential of another electrode (04)

(04)

iii) I. (Porous) C electrode

II.

$$E^{\ominus}_{cell} = E^{\ominus}_{cathode} - E^{\ominus}_{anode}$$

$$= 0.40\ V - (-2.37\ V) \quad (03+01)$$

$$= 2.77\ V \quad (01)$$

(04)

III. Anode: $Mg(s) \rightarrow Mg^{2+}(aq) + 2e$ (04)

Cathode: $O_2(g) + 2H_2O(l) + 4e \rightarrow 4OH^-(aq)$ (04)

Overall: $2Mg(s) + O_2(g) + 2H_2O(l) \rightarrow 2Mg^{2+}(aq) + 4OH^-(aq)$ (04)

(11 no marks)

Note: Award **no** marks if physical states are **not** given.
Award **no** marks for equilibrium reactions.

iv) Change in potential of the Mg electrode **OR** Change in e.m.f. (04)

Comment: Electrolyte is changed. **OR** Mg^{2+} is not present (04)

v) **Award a maximum of (16) marks for any two of the following answers.**

(04)

1. Replace the Mg electrode with a new electrode (04)
   Comment: Mg is used up in the cell reaction. (04)

2. Add water **OR**
   Comment: H_2O is used up in the cell reaction. (04)
   To maintain the initial water level (04)

3. Replace/Clean the porous C electrode
   Comment: To remove $Mg(OH)_2$ precipitate deposited on the porous C electrode (04)

Total for 7(a) *65 marks*

b) i) Initial rate: (Average) rate for a small change in time from the starting point of a reaction (05)

Average rate: The average value of individual rates determined over a certain period of time during the course of a reaction (05)

Total for 7b(i) *10 marks*

ii) I. rate $\propto [A]^a[B]^b[C]^c$ **(04)**

II. 8.0×10^{-4} mol dm^{-3} s^{-1} $\propto$ [0.10 mol dm^{-3}]^a[0.10 mol dm^{-3}]^b[0.10 mol dm^{-3}]^c (1) **(03+01)**

1.6×10^{-3} mol dm^{-3} s^{-1} $\propto$ [0.20 mol dm^{-3}]^a[0.10 mol dm^{-3}]^b[0.10 mol dm^{-3}]^c (2) **(03+01)**

3.2×10^{-3} mol dm^{-3} s^{-1} $\propto$ [0.20 mol dm^{-3}]^a[0.20 mol dm^{-3}]^b[0.10 mol dm^{-3}]^c (3) **(03+01)**

3.2×10^{-3} mol dm^{-3} s^{-1} $\propto$ [0.10 mol dm^{-3}]^a[0.10 mol dm^{-3}]^b[0.20 mol dm^{-3}]^c (4) **(03+01)**

(2)/(1) $2 = 2^a$

$a = 1$ **OR** order with respect to A = 1 **(04)**

(3)/(2) $2 = 2^b$

$b = 1$ **OR** order with respect to B = 1 **(04)**

(4)/(1) $4 = 2^c$

$c = 2$ **OR** order with respect to C = 2 **(04)**

Note: Award only **(04)** × **3** = **12** marks for valid qualitative arguments to show that a = 1, b = 1 and c = 2.

III. rate $\propto [A][B][C]^2$ **(04)**

IV. Increased by a factor of $3^2 = 9$ **(03+04)**

(**Note**: Mark the two answers independently.)

Total for 7b(ii) *43 marks*

iii) Slow step **OR** $Y + B \rightarrow Z$ **(04)**

Rate $\propto [Y]\,[B]$ **(08)**

$$K_1 = \frac{[X]}{[A][C]} \quad \textbf{(04)}$$

$$K_2 = \frac{[Y]}{[X][C]} \quad \textbf{(04)}$$

$$K_1K_2 = \frac{[X]}{[A][C]}\,\frac{[Y]}{[X][C]} = \frac{[Y]}{[A][C]^2} \quad \textbf{(04)}$$

$$[Y] = K_1\,K_2\,[A]\,[C]^2 \quad \textbf{(04)}$$

Rate $\propto K_1\,K_2\,[A]\,[B]\,[C]^2$ OR

$\propto [A]\,[B]\,[C]^2$ **(04)**

Total for 7b(iii) *32 marks*

Total for 7(b) *85 marks*

Part C - ESSAY

8. (a)(i)

Observation	Inference	
1. brown gas	→ presence of nitrates (of certain metals)	(03)
2. red litmus turns blue	→ presence of $NO_3^-/NO_2^-/NH_4^+$	(01 x3)
3. black precipitate	→ PbS /CuS/HgS /Bi_2S_3/Ag_2S/CoS/NiS (any three)	(01 x 3)
4. white precipitate	→ $PbCl_2$ or AgCl	(02 + 01)
5. white precipitate dissolved	→ $PbCl_2$	(03)
6. white needles	→ $PbCl_2$	(03)
7. white precipitate insoluble in dil. HCl & dil. HNO_3	→ presence of SO_4^{2-}	(03)
8. I. dirty green precipitate II. blood red colour	} presence of Fe^{2+}	(03)

A – $Pb(NO_3)_2$ **B** – $FeSO_4$ (10 + 10)

(ii) $2Pb(NO_3)_2 \xrightarrow{\Delta} 2PbO + 4NO_2 + O_2$ (04)

$3NO_3^- + 2H_2O + 8Al + 5OH^- \rightarrow 3NH_3 + 8AlO_2^-$ (04)

$Pb(NO_3)_2 + H_2S \rightarrow PbS\downarrow + 2HNO_3$

or

$Pb^{2+} + H_2S \rightarrow PbS\downarrow + 2H^+$ (04)

$Pb(NO_3)_2 + 2HCl \rightarrow PbCl_2\downarrow + 2HNO_3$

or

$Pb^{2+} + 2HCl \rightarrow PbCl_2\downarrow + 2H^+$ (04)

(iii) **C** – $PbSO_4$ (05)

(iv) For Pb^{2+}

(1) Add K_2CrO_4 to a solution of **A**	yellow precipitate (soluble in NaOH)
(2) Add dil. H_2SO_4 to a solution of **A**	white precipitate which dissolves in conc. NH_4OAc
(3) Add dil. NaOH to a solution of **A**	white precipitate which dissolves in excess NaOH

(4) Add KI to a solution of **A**	Yellow precipitate which dissolves on boiling and precipitates as golden spangles on cooling **(any one)** **(03 + 02)**

only yellow ppt
give
03 + 02

For NO_3^-

(1) Add conc. H_2SO_4 to solid **A** and heat.	Reddish-brown/ brown fumes
(2) To a solution of **A**, add a freshly prepared solution of $FeSO_4$ followed by conc. H_2SO_4 slowly down the sides of the test-tube **or** Brown ring test	brown ring
(3) Add conc. H_2SO_4 to solid **A** followed by Cu turnings and warm	reddish-brown/brown gas with a blue solution

(any one) **(03 + 02)**

(**N.B.** – All these tests may not be in the syllabus. However, students may give these as answers.)

Total 8(a) =75 marks

8. (b) 1.

Weight of $BaSO_4$	= 2.335 g	
Molar mass of $BaSO_4$	= 233 g mol^{-1}	**(02)**
Moles of $BaSO_4$	= 2.335/233 = 0.010	**(03)**
Therefore, moles of SO_4^{2-}	= 0.010	**(02)**
$[SO_4^{2-}]$	= 0.010 x 1000/25 mol dm^{-3} = 0.40 mol dm^{-3}	**(03)** **(03 + 02)**

(15 marks)

2. $5Fe^{2+} + MnO_4^- + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$ ---------(1) **(05)**

$5CuS + 6MnO_4^- + 28H^+ \rightarrow 6Mn^{2+} + 5Cu^{2+} + 5SO_2 + 14H_2O$ ---(2) **(05)**

or

$5S^{2-} + 6MnO_4^- + 28H^+ \rightarrow 6Mn^{2+} + 5SO_2 + 14H_2O$ **(03)**

Moles of Fe^{2+} $= 0.1/1000 \times 10.5$ (02)
$= 1.05 \times 10^{-3}$ (01)

From eq.(1), moles of MnO_4^- remaining $= 1/5(1.05 \times 10^{-3})$ (02)
$= 2.1 \times 10^{-4}$ (01)

Moles of $KMnO_4$ added $= 30.00/1000 \times 0.28$ (02)
$= 8.4 \times 10^{-3}$ (01)

Moles of MnO_4^- reacted with CuS $= (8.4 \times 10^{-3}) - (2.1 \times 10^{-4})$
$= 8.2 \times 10^{-3}$ (02)

From eq.(2), moles of CuS $= 5/6 \times 8.2 \times 10^{-3}$ (05)
$= 6.8 \times 10^{-3}$ **or** 7×10^{-3} (03)

Therefore, moles of Cu^{2+} in 25.00 cm^3 $= 6.8 \times 10^{-3}$ **or** 7×10^{-3} (03)

$[Cu^{2+}] = (6.8 \times 10^{-3})/25 \times 1000$ **or** $(7 \times 10^{-3})/25 \times 1000$ mol dm^{-3} (03)

$[Cu^{2+}] = 0.27$ mol dm^{-3} **or** 0.28 mol dm^{-3} (03 + 02)

N.B. Here we have assumed that the SO_2 formed did not react with excess $KMnO_4$.

(40 marks)

If SO_2 formed reacts with excess $KMnO_4$

$5Fe^{2+} + MnO_4^- + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$ ---------(1) (05)

$5CuS + 6MnO_4^- + 28H^+ \rightarrow 6Mn^{2+} + 5Cu^{2+} + 5SO_2 + 14H_2O$ ---(2) (05)

or

$5S^{2-} + 6MnO_4^- + 28H^+ \rightarrow 6Mn^{2+} + 5SO_2 + 14H_2O$ (03)

Moles of Fe^{2+} $= 0.1/1000 \times 10.5$ (02)
$= 1.05 \times 10^{-3}$ (01)

From eq.(1), moles of MnO_4^- remaining $= 1/5(1.05 \times 10^{-3})$ (02)
$= 2.1 \times 10^{-4}$ (01)

Moles of $KMnO_4$ added $= 30.00/1000 \times 0.28$ (02)
$= 8.4 \times 10^{-3}$ (01)

Moles of MnO_4^- reacted with CuS $= (8.4 \times 10^{-3}) - (2.1 \times 10^{-4})$
$= 8.2 \times 10^{-3}$ **(02)**

$5SO_2 + 2H_2O + 2MnO_4^- \rightarrow 5SO_4^{2-} + 2Mn^{2+} + 4H^+$ ----------(3) **(05)**

Combining eqs. (2) & (3), $5CuS \equiv 8MnO_4^-$ ----------(4) **(03)**

From relationship (4), moles of CuS $= 5/8 \times 8.2 \times 10^{-3}$ **(03)**
$= 5.1 \times 10^{-3}$ **(01)**

Therefore, moles of Cu^{2+} in 25.00 cm^3 $= 5.1 \times 10^{-3}$ **(01)**

$[Cu^{2+}] = 5.1 \times 10^{-3}/25 \times 1000$ mol dm^{-3} **(01)**

$[Cu^{2+}] = 0.20$ mol dm^{-3} **(03 + 02)**

(40 marks)

3. $IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O$
$3(I_2 + 2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 2I^-)$
$IO_3^- + 6S_2O_3^{2-} + 6H^+ \rightarrow I^- + 3S_4O_6^{2-} + 3H_2O$ ----------(5) **(06)**
For first two reactions only, award (02) + (02) marks

Moles of $S_2O_3^{2-} = 0.4/1000 \times 25$ **(03)**
From eq.(5), moles of H^+ in 25.00 $cm^3 = 0.4/1000 \times 25$ **(03)**

$[H^+] = 0.4/1000 \times 25 \times 1000/25$ mol dm^{-3} **(03)**

$[H^+] = 0.4$ mol dm^{-3} **(03 + 02)**

(20 marks)

($[H^+_{ini}]$ came from ~~H2S~~ was not included in this calculation)

Total 8(b) = 75 marks

9. (a) (i) NO, NO_2, HNO_3, N_2O **(03 x 3)**
(No marks for N_2O_4)

(ii) NO_2^-, NO_3^-, NH_4^+ (NH_3) **(03 x 3)**

(iii) Biological fixation, Industrial fixation, Atmospheric fixation, Combustion of fossil fuels **(any three) (03 x 3)**

(iv) Most of the NH_3 produced by Haber process is used to manufacture fertilizers which are potential water pollutants. **(03)**

Total 9(a) =30 marks

(b) (i) volatile hydrocarbons and nitrogen oxides (NOx) produced by vehicles and industries react in the atmosphere in the presence of sunlight (uv) to form photochemical oxidants (secondary pollutants), which also combine with primary emissions to form photochemical smog.

or

volatile hydrocarbons and nitrogen oxides (NOx) produced by vehicles and industries react in the atmosphere in the presence of sunlight (uv) to form photochemical oxidants (e.g. ozone, atomic oxygen). These contribute to the formation of photochemical smog.

(01 x 8)

(ii)

- reduced visibility (around noon due to formation of aerosols)
- brownish or yellowish or yellow-brown haze formed (during the middle of the day)
- breathing difficulties

(any two) (03 + 03)

(iii) O_3, short chain aldehydes (HCHO, CH_3CHO, CH_2=CH-CHO), peroxyacetyl nitrate (PAN), peroxobenzonitrate (PBN), and alkylnitrates(e.g. CH_3ONO_2)

(any four) (03 x 4)

$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ **(02)**

$NO_2(g) \xrightarrow{h\nu} NO(g) + O(g)$ **(02)**

$O_2(g) + O(g) + M \rightarrow O_3(g) + M^*$ **(02)**

(M is a third body (N_2) which absorbs energy)

(iv) Adverse effects

(1) Affects human health –
- Affects respiratory system and causes coughing, wheezing, asthma etc.
- Can cause eye and nose irritation

(2) Damage to materials – O_3 causes rubber to deteriorate through fission of double bonds and also reduces quality of fabrics and bleaches dyes.

(3) Toxic to plants – shortage of food world wide

(4) Affects the atmosphere – aerosols reduce visibility

(any three) (03 x 3)

(v) (1) Fix catalytic converters in vehicles (to convert CO and unburnt hydrocarbons to CO_2 & H_2O, and NOx to $N_2(g)$ & $O_2(g)$).

(2) Reduce industrial emissions

(3) Use of alternative fuels (in hybrid cars, electric cars)

(any one) **(04)**

Total 9(b) = 45 marks

(c) (i) (1) Copper pyrites ($CuFeS_2$) is roasted in air **(02)**

$$2CuFeS_2(s) + 4O_2(g) \rightarrow Cu_2S(s) + 2FeO(s) + 3SO_2(g)$$ **(04)**

or

$$4CuFeS_2(s) + 9O_2(g) \rightarrow 2Cu_2S(s) + 2Fe_2O_3(s) + 6SO_2(g)$$

(2) The products are then heated with silica to form a molten slag which floats on molten Cu_2S **(02)**

$$FeO(s) + SiO_2(s) \rightarrow FeSiO_3(l)$$ **(03)**

or

$$Fe_2O_3(s) + 3SiO_2(s) \rightarrow Fe_2(SiO_3)_3(l)$$

The slag is then separated. **(01)**

(3) The impure $Cu_2S(s)$ is heated in air so that part of it reacts to form Cu_2O **(02)**

$$Cu_2S(s) + 3O_2(g) \rightarrow 2Cu_2O(g) + 2SO_2(g)$$ **(04)**

(4) The remaining Cu_2S is now mixed with Cu_2O and heated in the absence of air. **(02)**

$$Cu_2S(s) + Cu_2O(s) \rightarrow 6Cu + SO_2(g)$$ **(04)**

(Blister Cu – 2-3% impure) **(02)**

(5) Impure blister Cu is purified by electrolysis using $CuSO_4$ solution. **(04)**

Note: Award full marks even if physical states are not given.

(ii) Add NH_4OH **(02)** – gives a blue precipitate, $Cu(OH)_2$ **(01)**
Dissolves in excess NH_4OH **(01)** to give a dark blue solution of $[Cu(NH_3)_4]^{2+}$ **(01)**

or

Add potassium ferrocyanide, $K_4[Fe(CN)_6]$, to the neutral or acidic solution. **(03)**. A reddish-brown precipitate is formed. **(02)**

or

Make solution basic with NaOH (or Fehlings-B), and add glucose or an aldehyde and heat the solution **(03)**. A brick red precipitate is formed **(02)**

Total 9(c) = 35 marks

(d) (i) (1) Large flat land with water impervious clay soil close to the ocean or lagoon

(2) Strong sunlight should prevail during most of the year

(3) Area that has dry, fast moving winds

(4) Area with low rainfall **(01 x 10)**

(ii) (1) Sea water is pumped into the first tank (large), **(01)** water evaporated by sunlight **(01)**, solution becomes concentrated **(01)** $CaCO_3$ precipitates **(03)** and settles down.

(2) Remaining solution is transferred to another tank (medium) **(01)**, water evaporates by sunlight **(01)**, solution becomes concentrated **(01)** $CaSO_4$ precipitates **(03)** and settles down.

(3) Remaining solution is pumped to another tank (small) **(01)**, water evaporates by sunlight **(01)**, NaCl precipitates **(03)**.
This contains Mg^{2+}, Ca^{2+} and SO_4^{2-} as impurities **(01)**

(4) NaCl collected is stored outside the tank for about six months **(02)**. Ca^{2+} and Mg^{2+} salts absorb moisture from air and forms a solution **(02)** whereas NaCl remains as a solid **(02)**.

or

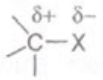
NaCl obtained is washed with the mother liquor to obtain purified NaCl (washed salt) **(06)**

(iii) Metal – Mg **(03)** Non-metal – Br_2 **(03)**

Total 9(d) = 40 m

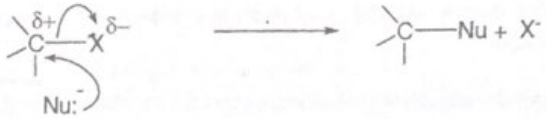
10 (a) **Complete answer**

(i) The C-X bond is polarized **(03)** because of the higher electronegativity of X **(04)** to create a partial positive charge on C **(03)**



A nucleophile carrying a pair of electrons available **(02)** to form a bond (to carbon) will be attracted (reacts readily) to the carbon atom. **(02).**

The C-X bond will break **(02)** with the bonding electrons leaving with X and carbon forms a new bond with the nucleophile **(02).**



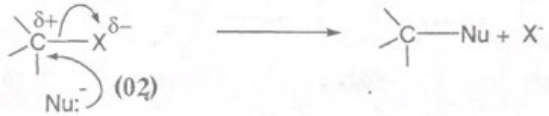
Thus nucleophile substitutes X **(02)**

N.B. If points underlined are given without the diagram award full marks.

Part marks

- If explained only with the diagram as shown below award **(12)** marks.
  Allocated as follows

(02) **(02)**

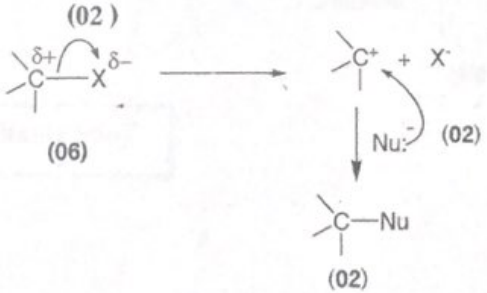


(02)

(06)

or

(02)



(06) **(02)** **(02)**

Justification for the allocation of marks are as follows.

(i) Showing polarized structure **(06)** marks. i.e.



(ii) Arrow showing breakage of C-X bond. **(02)**

(iii) Attack of nucleophile **(02)**

(iv) Showing nucleophilic substituted product **(02)**

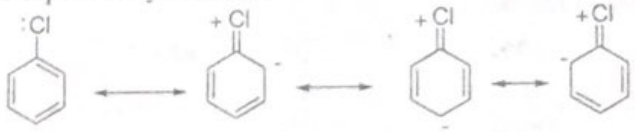
- If only  is given award only **06** marks

N.B. *The tail of the arrow should start from the lone pair or negative sign or the bond which is being broken.*

Total 10(a)i = 20 marks

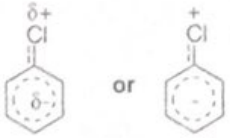
(a)(ii) The C-Cl bond has a double bond character **(04)** and is more difficult to break **(04)** due to delocalization of a pair of electrons on the chlorine atom **(04)** with the benzene ring.

This can be explained by resonance



(02) **(02)** **(02)** **(02)**

or

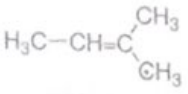


(08) **(06)**

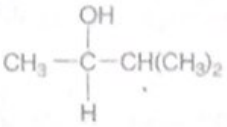
accepted

Total 10(a)ii = 20 marks

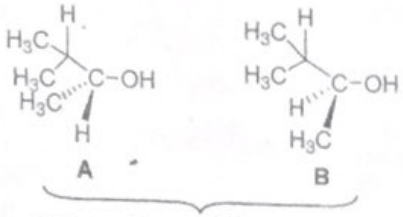
(b)







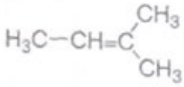
- Alcohol could be represented as two optical isomers i.e. two structures as shown below.



A **B**

or any other valid representation with the stereochemistry at the asymmetric centre shown.

Then the required answer is

 and **A** and **B**

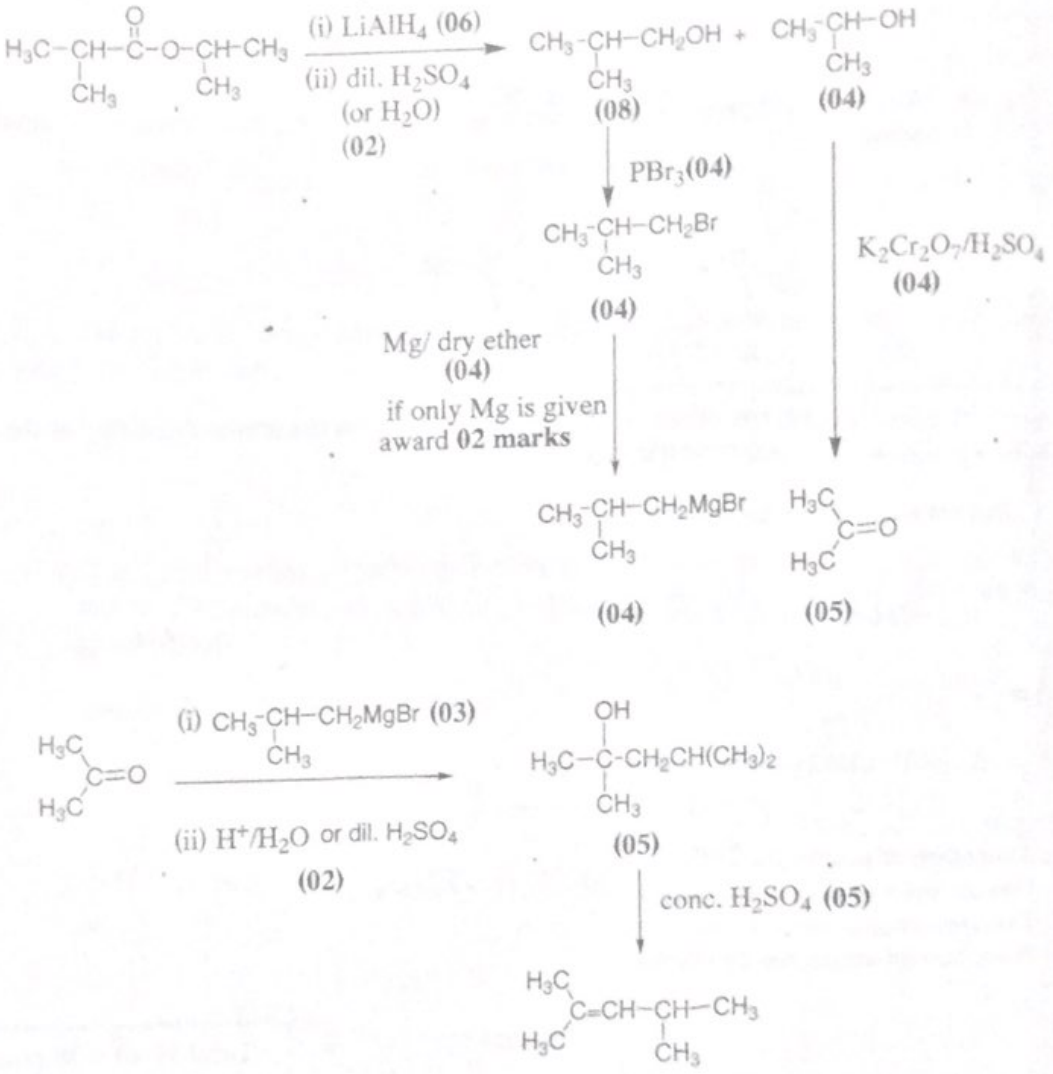
or

$H_2C{=}CH{-}CH(CH_3)_2$ and **A** and **B**

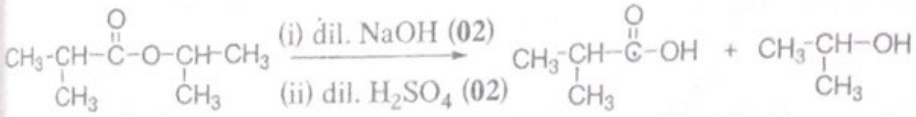
Allocation of marks for 10(b)
One correct structure **07 marks**
Two correct structures **14 marks**
Three correct structures **20 marks.**

Total 10(b) = 20 marks

10(c) **Method 1: Total 60 marks**

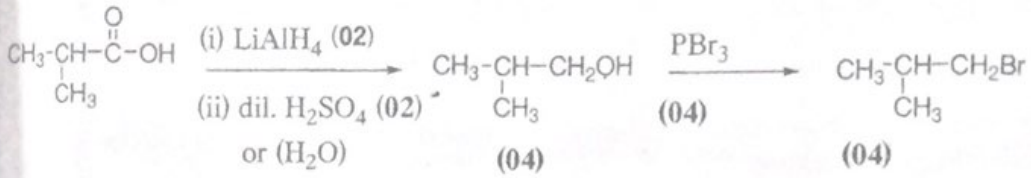


Method 2: Total 60 marks

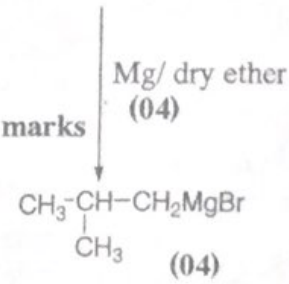


(04) (04)

- If acid hydrolysis is given **(04)**
- H^+, H^+/H_2O could be given instead of H_2SO_4

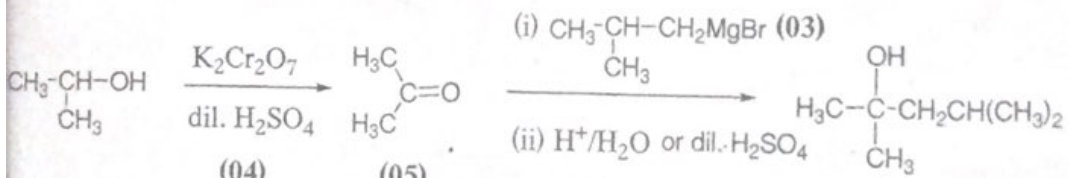


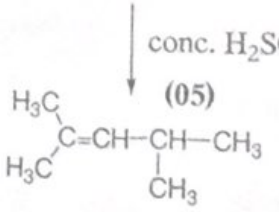
H^+, H^+/H_2O could be given instead of H_2SO_4



if only Mg is given give **02 marks**

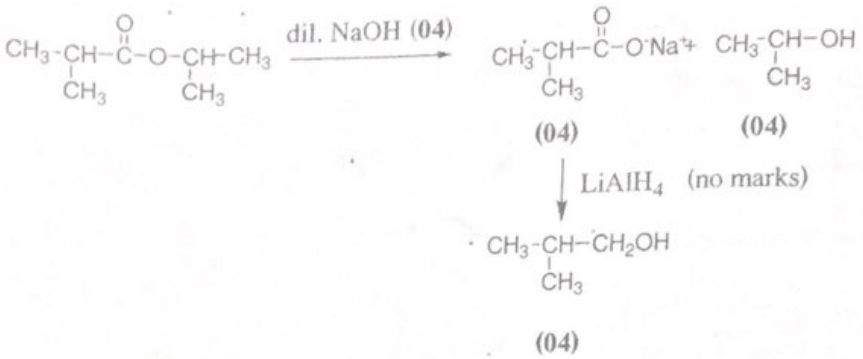
(04)





Total 10(c) = 60 marks

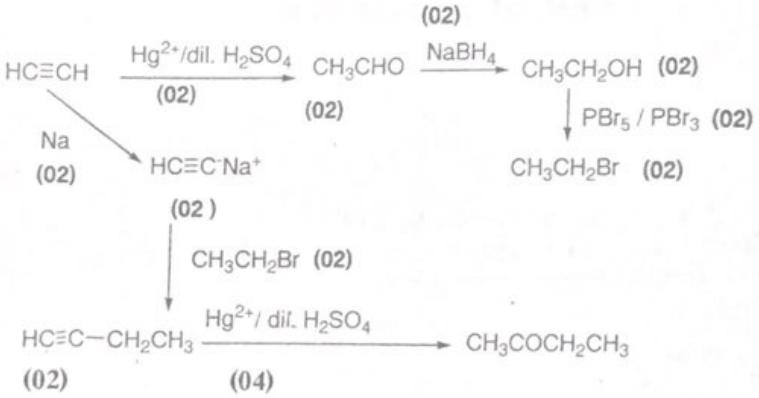
Method 3: Full marks cannot be awarded. Marks could be allocated to a maximum of 56 marks.



Part marks: After obtaining isobutyl alcohol (**Y**) give marks for the conversion as in method 2.**or** any other valid method.

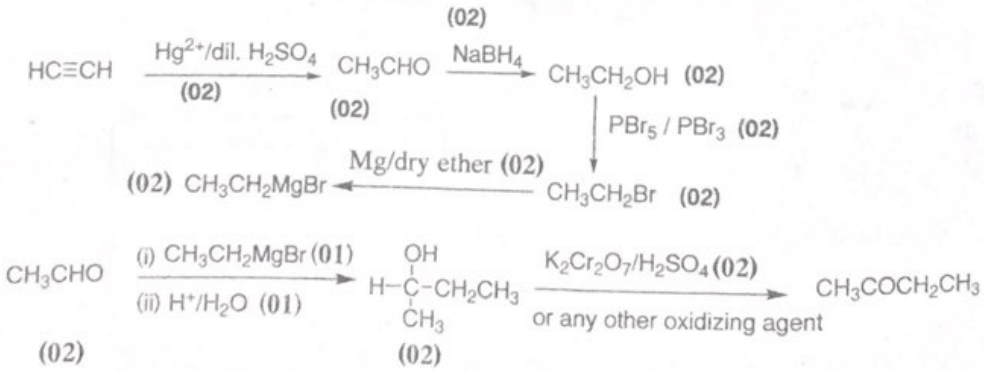
10(d)(i)

Method 1: Total 24 marks

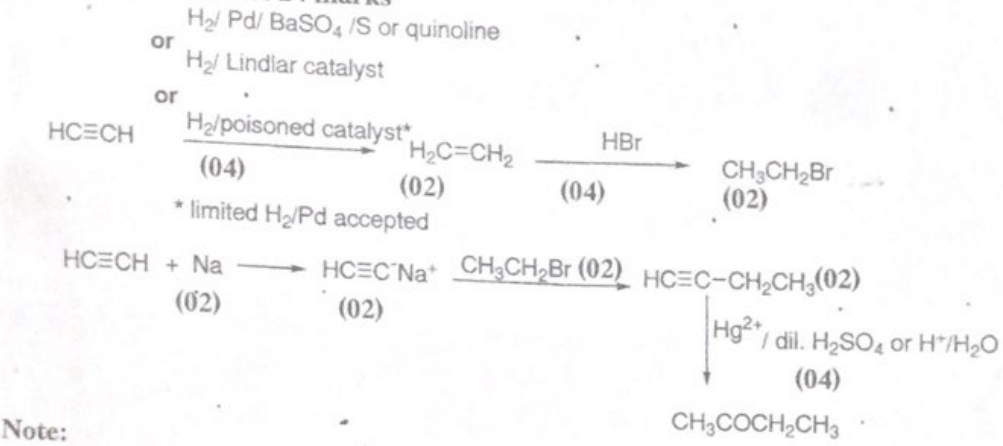


Note: Dilute has to be specified in the reaction with Hg^{2+}/ dil. H_2SO_4.

Method 2: Total 24 marks

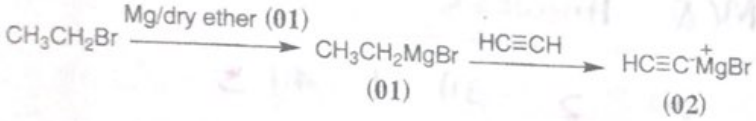


Method 3: Total of 24 marks

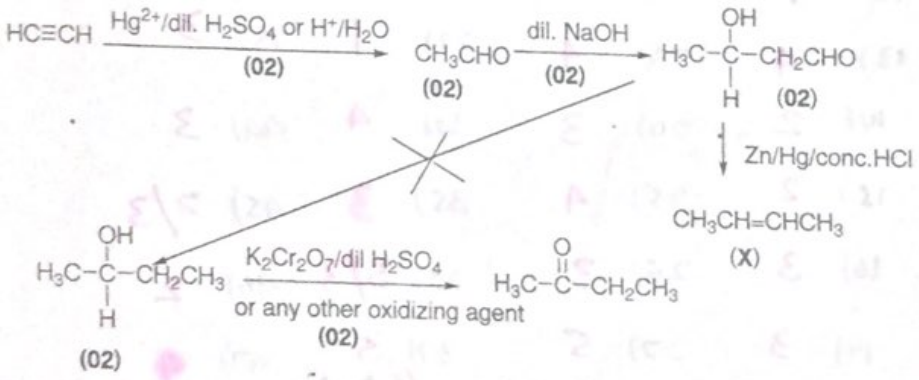


Note:

- In method 1 and 3 $HC\equiv C^{-}\overset{+}{M}gBr$ can be used instead of $HC\equiv C^{-}Na^{+}$ by the following scheme
  First obtain CH_3CH_2Br as given in the scheme and then



- The following conversion is not correct but part marks can be given to a total of **12 marks.**



Justification for awarding marks

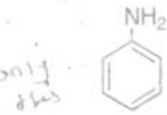
- obtaining a linear 4 carbon chain
- a plausible retrosynthetic final step

N.B. If the alkene **X** is converted to the ketone by any other method award full marks for the conversion.

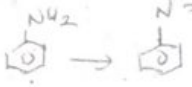
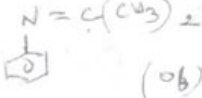
Total 10(d)(i) = 24 marks

React with aniline (06)

(ii)



~~(06)~~ 04

(02) CH_3, CH_3 >C=O +  →  (06)

Total 10(d)(ii) = 06 marks

Total 10(d) = 30 marks

N.B.

- For the hydrolysis dilute HCl can be used instead of dil. H_2SO_4.
- For the conversions the product(s) should be correct to award the mark allocated to the reagent.

MCQ Answers

1)	4	11)	2	21)	2	31)	1	41)	5
2)	5	12)	1	22)	1	32)	3	42)	2
3)	1	13)	4	23)	4	33)	1	43)	3
4)	1	14)	2	24)	3	34)	4	44)	3
5)	3	15)	2	25)	4	35)	3	45)	2/3
6)	2	16)	3	26)	3	36)	5/3	(46)	2
7)	5	17)	3	27)	5	37)	5 (a,b,d)	47)	4
8)	3	18)	4	28)	2	38)	4	48)	1
9)	3/4	19)	1	29)	5	39)	1/5	49)	5
10)	5	20)	3/5	30)	3	40)	5 (c)	(50)	5