Thalatha 765

Confidential

(18)/2014

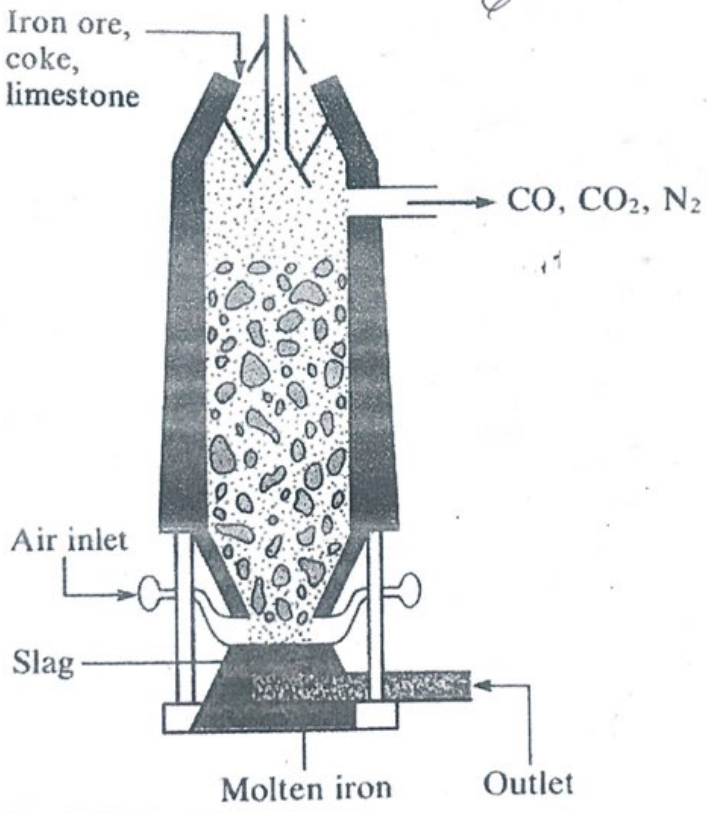
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Department of Examinations - Sri Lanka

G.C.E. (A/L) Examination - 2014

02 - Chemistry

Marking Scheme



This has been prepared for the use of marking examiners. Some changes would be made according to the views presented at the chief examiner's Meeting.

Amendments to be included

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MCQ – Answer

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

PART A – STRUCTURED ESSAY

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

1. (*a*) Arrange the following in the **decreasing** order of the property indicated in parenthesis.

(i) Li, Na, Mg, Al, Si (first ionization energy)

Si > Mg > Al > Li > Na

(ii) C, O, F, Cl (first electron affinity)

Cl > F > O > C

(iii) $BeCl_2$, $CaCl_2$, $BaCl_2$ (melting point)

$BaCl_2$ > $CaCl_2$ > $BeCl_2$

(iv) NCl_3, $SiCl_4$, ICl_4^- (bond angle)

$SiCl_4$ > NCl_3 > ICl_4^-

(v) H_2O, H_3O^+, OH^- (electronegativity of oxygen atom)

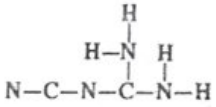
H_3O^+ > H_2O > OH^-

(vi) NO^+, FNO_2, ClNO, NH_2OH (N–O bond length)

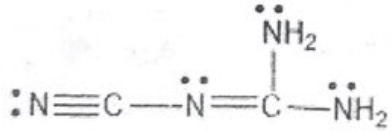
NH_2OH > FNO_2 > ClNO > NO^+

(05 x 6 = 30 marks)

(*b*) 2–Cyanoguanidine ($C_2H_4N_4$) is a widely used chemical in agriculture. The following questio (i) to (v) are based on 2–Cyanoguanidine. Its skeleton is given below.

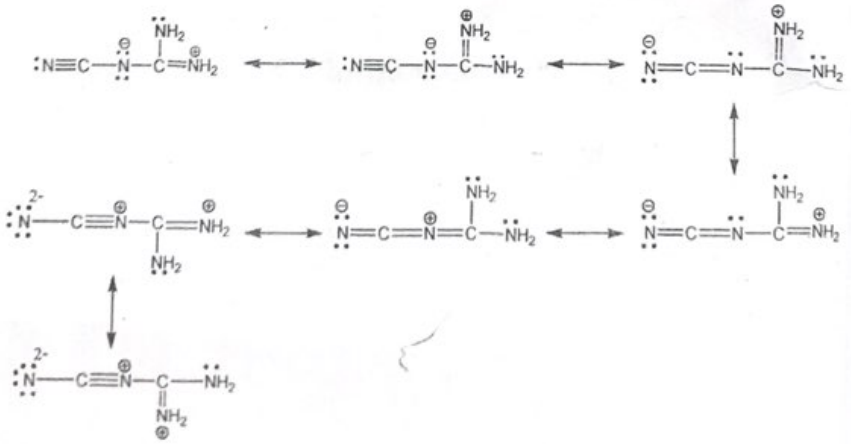


(i) Draw the **most acceptable** Lewis structure for this molecule.



(08 marks)

(ii) Draw **four** resonance structures (excluding the structure drawn in (i) above) for this molecule

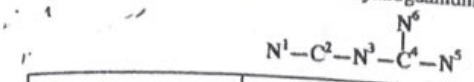


Note : Any four. If more than four are given consider the first four. Even if b(i) is incorrect, mark b(ii) independently.

(04 x 4 = 16 marks)

(iii) State the following regarding the C and N atoms given in the table below:
I. electron pair geometry (arrangement of electron pairs) around the atom
II. shape around the atom
III. hybridization of the atom

The carbon and nitrogen atoms of 2–Cyanoguanidine are labelled as follows:

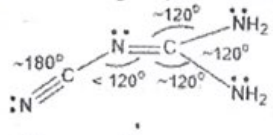


		C^2	N^3	C^4	N^5 or N^6
I.	electron pair geometry	linear	trigonal planar	trigonal planar	tetrahedral
II.	shape	linear	angular	trigonal planar	pyramidal
III.	hybridization	sp	sp^2	sp^2	sp^3

(01 x 12 = 12 marks)

Note : Even if b(i) is incorrect, if environment around an atom is correct, award marks accordingly.

(iv) Sketch the shape of the Lewis structure drawn in part (i) above indicating approximate values of the bond angles (show all bond angles other than those involving N—H bonds).



Sketch (03 marks)
angles (01 x 5 = 05 marks)

$< 120^0$ - till 115^0 is accepted.

$\sim 180^0 \pm 2$, $\sim 120^0 \pm 2$ is accepted.

If b(i) is incorrect, do not award marks for b(iv).

(08 marks)

(v) Identify the atomic / hybrid orbitals involved in the formation of the following σ–bonds in the Lewis structure drawn in part (i) above (numbering of atoms as in part (iii)).

I. $N^1—C^2$ N^1 ...(2*p* a.o or *sp* h.o)..., C^2 ...(*sp* h.o.)...

II. $C^2—N^3$ C^2 ...(*sp* h.o.),..., N^3 ...(sp^2 h.o.)...

III. $N^3—C^4$ N^3 ...(sp^2 h.o.)..., C^4 ...(sp^2 h.o.)...

Note: a.o / h.o. need not be mentioned. Even if b(i) is incorrect, if environment around an atom is correct, award marks accordingly.

(01 x 6 = 06 marks)

c) Consider the two chemical substances CH_3Cl (boiling point 249 K) and CH_3I (boiling point 316 K).

(i) Which substance has the larger dipole moment?
CH_3Cl

(ii) Which substance has the stronger London dispersion forces?
CH_3I

(iii) Which substance has the stronger total intermolecular attractive forces?
CH_3I

(iv) Which type of intermolecular force is dominant in comparing these two substances?
London dispersion forces or London forces or dispersion forces

(electronegativity : H = 2.1, C = 2.5, I = 2.5, Cl = 3.0)

(05 x 4 = 20 marks)

2. (*a*) **X** is an element in the third period of the Periodic Table. Its first five successive ionization energies in kJ mol^{-1}, are respectively, 577, 1816, 2744, 11577 and 14842. **X** reacts with both dilute HCl and dilute NaOH separately, liberating the same colourless and odourless diatomic gas.

Note : If metal has not been identified correctly as Al, NO marks for parts (i)-(viii)

(i) Identify element X. Al or aluminium (05)

(ii) Write the ground state electronic configuration of **X**. $1s^2 2s^2 2p^6 3s^2 3p^1$ (05)

(iii) Give the most stable positive oxidation state of **X**. (+)3 or (+)III (05)

(iv) Give balanced chemical equations for the reaction of element **X** with

I. dilute HCl $2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2$ or $2Al + 6HCl \rightarrow 2Al^{3+} + 6Cl^- + 3H_2$ (05)

II. dilute NaOH $2Al + 2H_2O + 2NaOH \rightarrow 2NaAlO_2 + 3H_2$ or $2Al + 6H_2O + 2NaOH \rightarrow 2NaAl(OH)_4 + 3H_2$ (05)

Note: $NaAl(OH)_4$ can be given as $NaAlO_2.2H_2O$

(v) **X** burns readily in air or O_2 to form an oxide. Write the formula of the oxide.
Al_2O_3 (05)

(vi) Write the balanced chemical equation for the reaction of **X** when heated with $NaNO_3$ and dilute NaOH.

$NO_3^-(aq) + 6H_2O(l) + 8e \rightarrow NH_3(g) + 9OH^-(aq)$

$Al(s) + 4OH^-(aq) \rightarrow AlO_2^- + 2H_2O + 3e$

$3NO_3^-(aq) + 2H_2O(l) + 8Al(s) + 5OH^-(aq) \rightarrow 3NH_3(g) + 8AlO_2^-(aq)$ (05)

Note : If only correct half reactions are given award 02+02 marks

(vii) Write the formula of the chemical species that the ion of X having the most stable oxidation state forms in an **aqueous** medium. Predict what you would expect to observe when a small amount of solid Na_2CO_3 is added to an aqueous solution of this ion.

$[Al(H_2O)_6]^{3+}$ or $[Al(H_2O)_5(OH)]^{2+}$ (Al^{3+} ion solution is acidic) (05)

Evolution of gas bubbles (H^+ release) (05)

(viii) Give **one** use of element **X**.

To make aircraft bodies, cooking utensils, cans for drinks, electrical power cables, alloys, aluminium paints (any **one**) (05)

(05 x 10 = 50 marks)

(*b*) Test tubes labelled **A** to **E** contain solutions of $Mg(NO_3)_2$, Na_2CO_3, KCl, $ZnSO_4$ and $Pb(NO_3)_2$ (not in order). $BaCl_2$ and dilute NH_4OH solutions are added separately to portions of each solution. The observations are given in the table below.

Solution	$BaCl_2$ solution	dilute NH_4OH solution
A	a white precipitate soluble in hot water	a white precipitate
B	a white precipitate insoluble in dil. HCl	a white precipitate soluble in excess NH_4OH
C	a white precipitate soluble in dil. HCl	a clear solution
D	a clear solution	a clear solution
E	a clear solution	a gelatinous white precipitate

(i) Identify solutions **A** to **E**.

A = $Pb(NO_3)_2$ (04)

B = $ZnSO_4$ (04)

C = Na_2CO_3 (04) 20

D = KCl (04)

E = $Mg(NO_3)_2$ (04)

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

i. All the reactions forming precipitates (indicate the precipitates with an arrow (↓) in the equations). $Pb^{2+} + 2Cl^- \longrightarrow PbCl_2\downarrow$ — 02 ionic form.

$Pb(NO_3)_2 + BaCl_2 \rightarrow PbCl_2\downarrow + Ba(NO_3)_2$ **(04)**

$Pb(NO_3)_2 + 2NH_4OH \rightarrow Pb(OH)_2\downarrow + 2NH_4NO_3$ **(04)**

$ZnSO_4 + BaCl_2 \rightarrow BaSO_4\downarrow + ZnCl_2$ **(04)**

$ZnSO_4 + 2NH_4OH \rightarrow Zn(OH)_2\downarrow + (NH_4)_2SO_4$ **(04)**

$Na_2CO_3 + BaCl_2 \rightarrow BaCO_3\downarrow + 2NaCl$ **(04)**

$Mg(NO_3)_2 + 2NH_4OH \rightarrow Mg(OH)_2\downarrow + 2NH_4NO_3$ **(04)**

ionic forms accepted.

Note : Deduct 01 mark per reaction if ↓ is not shown

24

II. All the reactions involving dissolution of precipitates.

$PbCl_2(s) \triangleq Pb^{2+}(aq) + 2Cl^-(aq)$ or $PbCl_2(aq)$ **(01)**

$Zn(OH)_2 + 4NH_4OH \rightarrow [Zn(NH_3)_4](OH)_2 + 4H_2O$ or

$Zn(OH)_2 + 4NH_3 \rightarrow [Zn(NH_3)_4](OH)_2$ or

$Zn(OH)_2 + 6NH_4OH \rightarrow [Zn(NH_3)_6](OH)_2 + 6H_2O$ or

$Zn(OH)_2 + 6NH_3 \rightarrow [Zn(NH_3)_6](OH)_2$ **(03)**

$BaCO_3 + 2HCl \rightarrow BaCl_2 + CO_2 + H_2O$ **(02)**

6

Note : Award marks for correct balanced equations even if A - E are not correctly identified. ***(30 marks)***

3. **Y** is a 1.00 M solution of a weak acid HA with a pH = 3.0 at 25 °C. A 100.0 cm³ sample of this solution was placed in a shaking bottle and 100.0 cm³ of an organic solvent was added. After shaking the bottle it was placed in a water bath at 25 °C for 30 minutes. Thereafter, the two layers were separated and the aqueous layer was labelled as solution **Z**. A 25.00 cm³ sample of solution **Z** was titrated with 0.50 M NaOH using phenolphthalein as the indicator. The volume of NaOH required was 40.00 cm³.

(i) Calculate the degree of dissociation, α, of the weak acid in solution **Y** at 25 °C.

Consider solution Y

$HA(aq) \rightleftharpoons H^+(aq) + A^-(aq)$ **(05)**

OR $HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)$

Concentrations (mol dm^{-3}) $c(1-\alpha)$ $c\alpha$ $c\alpha$ **(04+01)**

(or in any other acceptable form)

pH = 3.0

$pH = -\log [H^+(aq)]$ **(05)**

$[H^+] = 1.0 \times 10^{-3}$ mol dm^{-3} **(04+01)**

$[H^+] = c\alpha$

$\alpha = [H^+]/c = 1.0 \times 10^{-3}$ mol dm^{-3} / 1.0 mol dm^{-3} $= 1.0 \times 10^{-3}$ **(04+01)**

for not writing the unit -

(25 marks)

(ii) Calculate the dissociation constant (K_a) of the acid HA at 25 °C.

Acid dissociation constant, $K_a = \frac{[H^+(aq)][A^-(aq)]}{[HA(aq)]}$ **(05)**

$K_a = \frac{c\alpha \times c\alpha}{c(1-\alpha)}$

Assuming $1-\alpha \approx 1$, **(05)**

$K_a = c\alpha^2 = 1.0$ mol dm^{-3} x $(1.0 \times 10^{-3})^2$

$K_a = 1.0 \times 10^{-6}$ mol dm^{-3} **(04+01)**

(15 marks)

Note : Final answer must be in simplified form.

(iii) Calculate the degree of dissociation, α', of the acid HA in solution **Z** at 25 °C.

Concentration of HA in solution z,

$[HA]_z = \frac{0.50\ mol\ dm^{-3} \times 40.00\ cm^3}{25.00\ cm^3}$

$[HA]_z = 0.80$ mol dm^{-3} (04+01

Using $K_a = c\alpha'^2$

$\alpha' = 1.118 \times 10^{-3}$ or 1.12×10^{-3} or 1.1×10^{-3} (04+01

(10 marks

Note : Final answer must be in simplified form.

(iv) Using the values of α and α' calculated above, comment on the relationship between the degree dissociation and concentration of the acid HA at 25 °C.

When the concentration of the acid is decreased its amount (degree) of dissociation is increased. (10

(10 marks

(v) Calculate the partition coefficient at 25 °C of the acid HA between water and the organic solve (The weak acid HA, does not associate or dissociate in an organic solvent. Disregard the dissociati of HA in aqueous medium.)

Partition coefficient $K = \frac{[HA]_{aq}}{[HA]_{org}}$ OR $K = \frac{[HA]_{org}}{[HA]_{aq}}$ (05

$K = \frac{0.8\ mol\ dm^{-3}}{(1.0-0.8)\ mol\ dm^{-3}} = 4$ OR $K = \frac{(1.0-0.8)\ mol\ dm^{-3}}{0.8\ mol\ dm^{-3}} = \frac{1}{4} = 0.25$ (04+01

(10 marks

(vi) Calculate the pH of a mixture containing 25.00 cm^3 of solution Y and 25.00 cm^3 of 0.50 M NaO solution.

When NaOH is added,

Concentration of HA in the mixture = $\frac{1.0\ mol\ dm^{-3} \times 25.00\ cm^3 - 0.50\ mol\ dm^{-3}\ 25.00\ cm^3}{50.00\ cm^3}$ (04+0

$= 2.5 \times 10^{-1}$ mol dm^{-3} (04+0

Concentration of A^-, Assuming that NaA is completely ionized,

$[A^-] = \frac{0.50\ mol\ dm^{-3} \times 25.00\ cm^3}{50.00\ cm^3}$ (04+0

$= 2.50 \times 10^{-1}$ mol dm^{-3} (04+0

H^+ concentration

$[H^+] = \frac{K_a [HA]}{[A^-]} = \frac{1.0 \times 10^{-6}\ mol\ dm^{-3} \times 2.5 \times 10^{-1}\ mol\ dm^{-3}}{2.50 \times 10^{-1}\ mol\ dm^{-3}} = 1.00 \times 10^{-6}$ mol dm^{-3} (04+0

$pH = -\log[H^+] = 6.0$ (04+0

Note : Correct argument showing that [HA] = [A$^-$] , award full marks. Use of Henderson equation with correct argument to show that [HA] = [A$^-$] is also accepted.

(30 mar

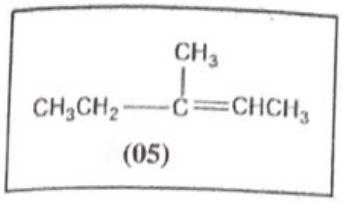
$[A^-] = [HA]$

$pH = pK_a + \log \frac{[A^-]}{[HA]} =$

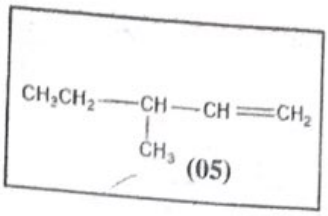
$pH = pK_a$

A.A.

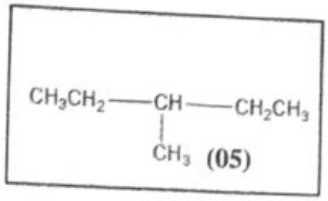
4. (a) **A** and **B** are structural isomers of methylpentene with the molecular formula C_6H_{12}. **A** exhibits geometric isomerism while **B** exhibits optical isomerism. On hydrogenation, **A** and **B** yield the same compound **C** with the molecular formula C_6H_{14}. **C** does not exhibit optical isomerism. Draw the structures of **A**, **B** and **C** in the boxes given below (It is **not necessary** to draw the stereoisomeric forms).


(05)

A


(05)

B


(05)

C

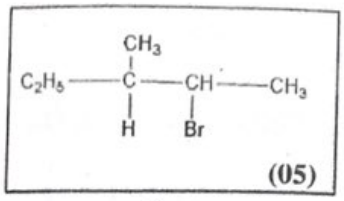
If A correct only, mark DEF

(15 marks)

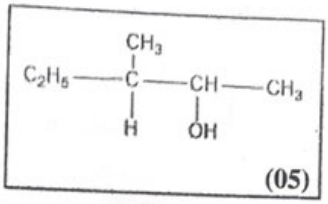
(b) (i) Consider the following two reaction sequences (I and II) and draw the structures of the products **D**, **E**, **F**, **G**, **H** and **I** in the boxes given below.

I. **A** $\xrightarrow[H_2O_2]{HBr}$ **D** $\xrightarrow{aq.\,KOH}$ **E** $\xrightarrow{PCC}$ **F**

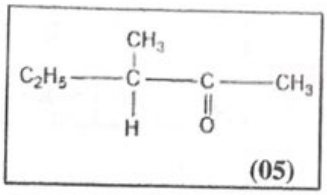
II. **B** $\xrightarrow[H_2O_2]{HBr}$ **G** $\xrightarrow{aq.\,KOH}$ **H** $\xrightarrow{PCC}$ **I**


(05)

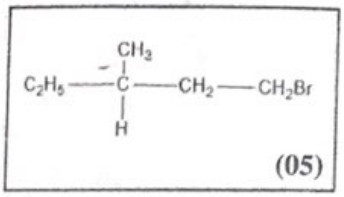
D


(05)

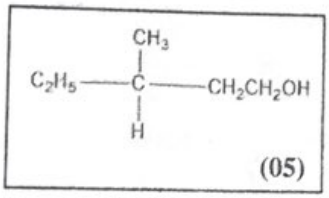
E


(05)

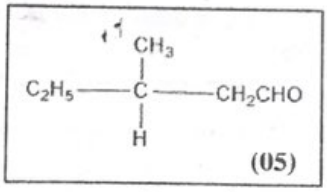
F


(05)

G


(05)

H


(05)

I

If B correct only, mark GHI

(30 marks)

(ii) Give a chemical test with the relevant observations to distinguish between **F** and **I**.

Silver mirror test/Tollens reagent/Ammoniacal Silver nitrate } **(02)**

I gives a Silver mirror (but not F) } **(01 + 02)** without not give if all wrong

OR Fehling test } **(02)**

I gives a Brick red precipitate (but not F) } **(01 + 02)**

OR Acidic $KMnO_4$ } **(02)**

I decolorizes the solution (but not F) } **(01 + 02)**

OR Acidic $K_2Cr_2O_7$ } **(02)**

I turns the solution green (but not F) } **(01 + 02)**

(05 marks)

Iodoform.

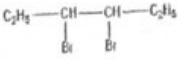
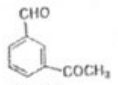
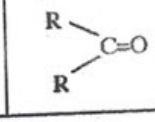
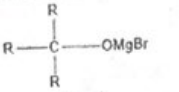
(iii) Compound **E** is a structural isomer of **H**. Name the type of structural isomerism that is found between these two compounds.

Position isomerism **(05)**

If E, H position isomers (for wrong structures) mark (iii) (05 marks)

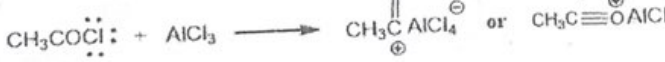
(c) Draw the structures of the major products of the reactions given in the table below. Classify each of the reactions as nucleophilic addition (A_N), electrophilic addition (A_E), nucleophilic substitution (S_N), electrophilic substitution (S_E) or elimination (E), by writing A_N, A_E, S_N, S_E, E in the appropriate cages.

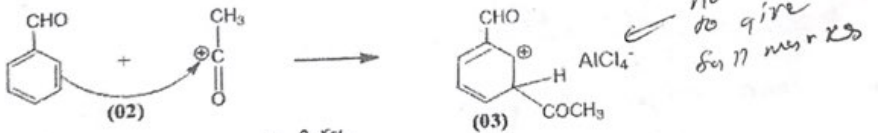
only the product is correct mark R.t.

Reaction number	Reactant	Reagent	Major product	Reaction type
1	$C_2H_5CH{=}CHC_2H_5$	Br_2/CCl_4	 (03)	A_E (02)
2		CH_3COCl/ anhydrous $AlCl_3$	 (03)	S_E (02)
3	ROH	PCl_3	RCl (03)	S_N (02)
4	RCH_2CH_2OH	anhydrous Al_2O_3/Δ	$RCH{=}CH_2$ (03)	E (02)
5		RMgBr	 (03)	A_N (02)

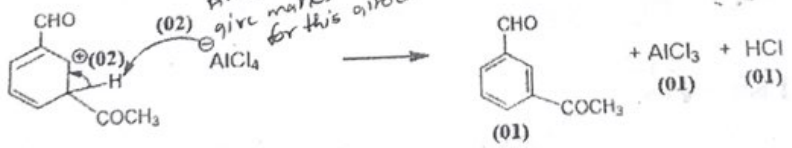
15 10 (25 marks)

(d) Write the mechanism for **Reaction No. 2.** Explain why the intermediate formed from benzalde is stable in this reaction.

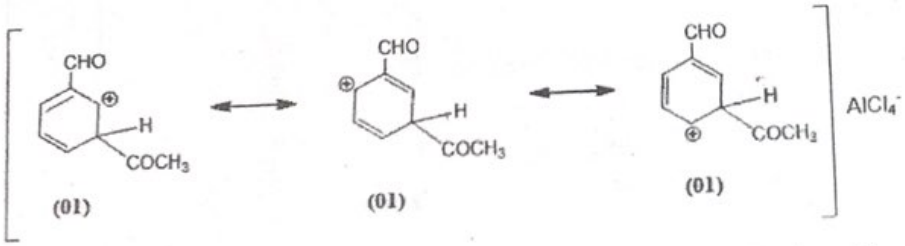
(i)  (03)

(ii)  (02) (03)

not necessary to give for 11 marks

(iii)  (02) (01) (01) (01)

Although para gives marks for this arrow

 (01) (01) (01)

Intermediate carbocation formed is stabilized by delocalization of the positive charge or resonance. (02)

(20 marks)

Note : Full marks can be awarded for the correct answer even if $AlCl_4^-$ is not given.

(a) (i) State Raoult's law.

In an (ideal) solution (at equilibrium with its vapour), the vapour pressure of a component is equal to its saturated vapour pressure times its mole fraction in solution.

$(P_A = X_A \cdot P^0_A)$

OR

In an (ideal) binary solution (at equilibrium with its vapour), the relative depression of the vapour pressure of one component is equal to the mole fraction of the other component in the solution

$\left(\frac{P^0_A - P_A}{P^0_A}\right) = X_B$ ← for Binary solution

OR

In the form of an equation with all the terms defined.

OR

The vapour pressure of a component in an ideal solution (in equilibrium with its vapour) is proportional to its mole fraction in the solution. $(P_A \propto X_A)$

OR

Other acceptable answers.

(15)

Ideal gas behavior in gas phase is assumed.

(ii) A and B form an ideal solution. This solution is in equilibrium with its vapour phase in a rigid container. The amounts of A and B in moles in the liquid phase are n_A and n_B respectively. The saturated vapour pressures of A and B at the temperature T are P^0_A and P^0_B respectively.

I. Calculate the partial pressure of A given that $n_A = 0.10$ mol, $n_B = 0.20$ mol, $P^0_A = 1.00 \times 10^4$ Pa and $P^0_B = 3.50 \times 10^4$ Pa.

II. Calculate the total pressure of the system.

I. $P_A = P^0_A x_A$

$$X_A = \frac{0.1\ (mol)}{(0.1 + 0.2)(mol)}$$ (04+01)

$$P_A = \frac{1.00 \times 10^4\ Pa \times 0.1\ (mol)}{(0.1+0.2)(mol)}$$ (04+01)

$P_A = 3.33 \times 10^3\ Pa$ (04+01)

05 15

II.

$$X_B = \frac{0.2\ (mol)}{(0.1 + 0.2)(mol)}$$ (04+01)

$$P_B = \frac{3.50 \times 10^4\ Pa \times 0.2\ (mol)}{(0.1+0.2)(mol)} = 2.33 \times 10^4 Pa$$ (simplification not necessary) (04+01)

$P_{total} = P_A + P_B$ (05)

$P_{total} = 2.66 \times 10^4\ Pa$ (04+01)

05 20

5(a) 50 marks

(*b*) The gas **C** dissociates into gases **D** and **E** according to the reaction given below.

$$C(g) \rightleftharpoons 2D(g) + E(g)$$

1.00 mol of **C** was introduced into a rigid container and allowed to reach equilibrium at tempera T_1. It was observed that 0.20 mol of **C** has dissociated at equilibrium and the pressure in the conta was 1.00×10^5 Pa.

(i) Calculate the equilibrium constant in terms of partial pressures, K_p, for the above equilibrium wri the relevant expressions.

C (g)	$\rightleftharpoons$ 2D (g)	+ E (g)		
(1-α	2α	α) mol	at equilibrium	(05)
OR (1.0-0.2) mol	2x0.2 mol	0.2 mol		

Note : Award **05** marks, only if unit is given.

$$K_p = \frac{P_D^2 \times P_E}{P_C} \qquad \textbf{(10)}$$

Partial pressures,

$P_c = P_{total} \times X_c$, $P_D = P_{total} \times X_D$, $P_E = P_{total} \times X_E$ **(05 x 3)**

OR

$P_c = \frac{P_{total} \times 0.8 \text{ mol}}{1.4 \text{ mol}}$ $P_D = \frac{P_{total} \times 0.4 \text{ mol}}{1.4 \text{ mol}}$ $P_E = \frac{P_{total} \times 0.2 \text{ mol}}{1.4 \text{ mol}}$ (with mol)

$$K_p = \frac{\left(1.00 \times 10^5 Pa \times \frac{0.4}{1.4}\right)^2 \left(1.00 \times 10^5 Pa \times \frac{0.2}{1.4}\right)}{\left(1.00 \times 10^5 Pa \times \frac{0.8}{1.4}\right)} \qquad \textbf{(04 + 01)}$$

$K_p = 2.04 \times 10^8 \text{ Pa}^2$ OR $2.0 \times 10^8 \text{ Pa}^2$ **(04 + 01)**

40

Note : Steps can be combined.

(ii) Calculate the equilibrium constant in terms of concentrations, K_c, if T_1 = 500 K.

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

$K_p = K_c (RT)^2$ OR for the recognition of $\Delta n=2$ **(05)**

$$K_c = \frac{K_p}{(RT)^2} = \frac{2.04 \times 10^8 Pa^2}{(8.314 \ J \ mol^{-1} \ K^{-1} \times 500 \ K)^2} \qquad \textbf{(04 + 01)}$$

$K_c = 1.18 \times 10^1 \text{ mol}^2 \text{ m}^{-6}$ (1·2) OIC. **(04 + 01)**

20

Note : Final answer must be in simplified form.

(iii) When the temperature of the system was lowered to T_2 (T_2 = 300 K), it was observed that **D** is partially liquefied and is in equilibrium with its vapour. **C** and **E** remain as gases and are insoluble in the liquid phase of **D**. The saturated vapour pressure of **D** at 300 K is 5.00×10^2 Pa. The amount of **C** dissociated at T_2 is 0.10 mol. Calculate K_p.

C (g)	$\rightleftharpoons$	2D (g&l)	+	E (g)
(1-α		2α		α) mol at equilibrium
(1.0-0.1) mol		2x0.1 mol (liq. & vap.)		0.1 mol

Total number of moles in gas phase = n **(05)**

15

New partial pressures,

$P_C = P_{total} \times X_C$. $P_E = P_{total} \times X_E$ for D ✗ **(05 x 2)**

OR

$P_C = \frac{P'_{total} \times 0.9 \text{ mol}}{n \text{ mol}}$ $P_E = \frac{P'_{total} \times 0.1 \text{ mol}}{n \text{ mol}}$

$P_D = P^0_D$ (For the recognition that P_D is equal to saturated vapour pressure of D) **(15)**

Note : For detailed calculation of partial pressures,
Award **10** marks for stating that the volume of the liquid phase is negligible.

If the partial pressures have been calculated, award **04 + 01** for each $P_C = 3.86 \times 10^4$ Pa and $P_E = 4.28 \times 10^3$ Pa.

If the ratio $P_E/P_C = 1/9 = 0.111$ is directly calculated, award **08 + 02** marks.

If saturated vapour pressure of D is not used for P_D do not award marks beyond this step.

15 give here if P_D has been substituted correctly.

$$K_p = \frac{(5.00 \times 10^2\ Pa)^2 \left(P_{total} \times \frac{0.9}{n}\right)}{\left(P_{total} \times \frac{0.9}{n}\right)}$$ **(04 + 01)**

$$K_p = \frac{(5.0 \times 10^2\ Pa)^2}{9}$$

$K_p = 2.78 \times 10^4$ Pa^2 **(04 + 01)**

Note : Final answer must be in simplified form. Fractions are not accepted

5(b) 100 marks

Dhammika

6. (a) Gas **A** decomposes according to the elementary reaction given below.

$A(g) \longrightarrow B(g) + C(g)$

(i) Write the rate law for the reaction.

Rate = k [A] / $\frac{\Delta[A]}{\Delta t}$ or stated - (10)

(ii) The above reaction was started by introducing 1.0 mol of **A** into a rigid container at 300 K, initial pressure of 30 kPa increased to 32 kPa in 10 s. When the experiment was repeated at 400 K using the same amount of **A**, the initial pressure of 40 kPa increased to 45 kPa in 10 s. Rate constants of the reaction at 300 K and 400 K are k_1 and k_2 respectively.

I. Calculate the amount of **A** decomposed in 10 s at 300 K.

	A →	B +	C		
At t = 0 s	n	-	-	mol	(02)
At t = 10 s	n(1-α)	nα	nα	mol	(03)

Note : Amounts can be given as concentrations, mol dm^{-3}

Ideal gas behavior in gas phase is assumed.

At 300 K

Total amount of gases after 10 s = n(1 + α) mol

Initially, $P = \frac{n}{V}RT$

$30 \times 10^3 Pa = \frac{n}{V}RT$ --(1) (02)

After 10 s $32 \times 10^3 Pa = \frac{n(1+\alpha)}{V}RT$ --(2) (03)

From (2)/(1); $\frac{32}{30} = 1 + \alpha$

α=1/15 OR nα=1/15 mol (04 + 01)

for no unit

II. Calculate the amount of **A** decomposed in 10 s at 400 K.

AT 400 K

Total amount of gases after 10 s = n(1 + α') mol

Initially

$40 \times 10^3 Pa = \frac{n}{V}RT'$ --(3) (02)

After 10 s $45 \times 10^3 Pa = \frac{n(1+\alpha')}{V}RT'$ --(4) (03)

From (4)/(3); $\frac{45}{40} = 1 + \alpha'$

α' = 1/8 nα'=1/8 mol (04 + 01)

III. Giving reasons show that $k_2 > k_1$

Rate at 300 K, using initial concentration of A (rate constant at 300 K is k_1)

$$Rate_{300K} = \frac{\Delta[A]}{\Delta t} = k_1[A]$$

$$\frac{\frac{n}{15V}}{t} = k_1\left(\frac{n}{V}\right) \qquad \text{--(5)}$$

05 ← Formula writing units.

~~(04 + 01)~~

Rate at 400 K, Using initial concentration of A (Rate constant at 400 K is k_2

$$Rate_{400K} = \frac{\Delta[A]}{\Delta t} = k_2[A]$$

$$\frac{\frac{n}{8V}}{t} = k_2\left(\frac{n}{V}\right) \qquad \text{--(6)}$$

05

~~(04 + 01)~~

15/15

From (6)/(5);

$k_2/k_1 = 15/8$; $k_2 > k_1$ **(05)**

Award full marks for (III) if correct arguments are used to show that $k_2 > k_1$
For the same initial concentration, the concentration change of A in 10 s (or in constant time) is large at 400 K (high temperature) compared to that at 300 K (low temperature). Therefore k_2 must be greater than k_1.
Full marks (**15**) can be awarded for mentioning all these facts and arguing correctly as above.

For correct argument without all the facts, e.g. Rate is increased when the temperature is increased. Therefore, $k_2 > k_1$.
Award only **05** marks.

6(a) 50 marks

(*b*) Enthalpy and entropy data for the dissociation of the weak acid HA are given below.

	Enthalpy change kJ mol^{-1}	Entropy change J K^{-1} mol^{-1}
$HA(aq) \rightarrow A^-(aq) + H^+(aq)$	$\Delta H_1 =$ 1.0	$\Delta S_1 =$ 95.0
$A^-(g) \rightarrow A^-(aq)$	$\Delta H_2 =$ –200.0	$\Delta S_2 =$ –2000.0
$H^+(g) \rightarrow H^+(aq)$	$\Delta H_3 =$ –1100.0	$\Delta S_3 =$ –1200.0
$HA(g) \rightarrow HA(aq)$	$\Delta H_4 =$ –150.0	$\Delta S_4 =$ –100.0

(i) Write the balanced chemical equation for the dissociation of HA in gas phase.

$HA(g) \rightarrow H^+(g) + A^-(g)$ (gas phase, no water molecule) **(05)**

Physical states are required, equilibrium arrows are accepted.

(ii) Calculate the following for the dissociation of HA in gas phase.

I. Enthalpy change

$$\begin{array}{ccc} HA(g) & \xrightarrow{\Delta H_5} & H^+(g) + A^-(g) \\ \downarrow \Delta H_4 & & \downarrow \Delta H_3 \quad \downarrow \Delta H_2 \\ HA(aq) & \xrightarrow{\Delta H_1} & H^+(aq) + A^-(aq) \end{array}$$

(04

$\Delta H_5 = \Delta H_4 + \Delta H_1 - \Delta H_2 - \Delta H_3$

$= (-150.0 + 1.0 + 200.0 + 1100.0)$ kJ mol^{-1} **(03 + 01)** x

Note : If the above step is not present or incorrect award **03+01** for each correct step in the thermochemical cycle (with physical states). If only the symbols are used in the thermochemical cycle, award **03** marks for each correct step. If an enthalpy diagram is used, award marks accordingly

$= 1151.0$ kJ mol^{-1} **(04 + 01**

II. Entropy change

$$\begin{array}{ccc} HA(g) & \xrightarrow{\Delta S_5} & H^+(g) + A^-(g) \\ \downarrow \Delta S_4 & & \downarrow \Delta S_3 \quad \downarrow \Delta S_2 \\ HA(aq) & \xrightarrow{\Delta S_1} & H^+(aq) + A^-(aq) \end{array}$$

(04

$\Delta S_5 = \Delta S_4 + \Delta S_1 - \Delta S_2 - \Delta S_3$

$= (-100.0 + 95.0 + 2000.0 + 1200.0)$ J K^{-1} mol^{-1} **(03 + 01) x**

Note : If the above step is not present or incorrect award **03+01** for each correct step in the thermochemical cycle (with physical states). If only the symbols are used in the thermochemical cycle, award **03** marks for each correct step. If an entropy diagram is used, award marks accordingly)

$= 3195$ J K^{-1} mol^{-1} or 3.195 kJ K^{-1} mol^{-1} **(04 + 0**

III. Gibbs energy change at 300 K.

For a closed system at constant pressure,

$\Delta G = \Delta H - T\Delta S$ (0

$= 1151.0$ kJ mol$^{-1} - 300$ K 3.195 kJ K^{-1} mol^{-1} **(04 + 0**

$= 192.5$ kJ mol^{-1} **(04 + 0**

Note : Do not award marks for $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$

(iii) Comment on the spontaneity of the dissociation of HA in the gas phase at 300 K.

Gibbs energy change for the dissociation of HA in gas phase at 300 K is positive. Therefore, dissociation of HA in gas phase at 300 K is not spontaneous. (1

Note : Award marks based on answer in III. If calculation is not given in III, do not awards.

(iv) **Calculate the Gibbs energy change for the dissociation of HA in the aqueous phase at 300 K.**

For the dissociation of HA in aqueous phase at 300 K,

$\Delta H_1 = 1.0 \text{ kJ mol}^{-1}$ and $\Delta S_1 = 95.0 \text{ J K}^{-1} \text{ mol}^{-1}$

$\Delta G_1 = 1.0 \text{ kJ mol}^{-1} - 300 \text{ K } 95 \times 10^{-3} \text{ kJ K}^{-1} \text{ mol}^{-1}$ **(04 + 01)** 10

$= -27.5 \text{ kJ mol}^{-1}$ **(04 + 01)**

(v) **At what temperature does the Gibbs energy change of dissociation of HA in gas phase become equal to its Gibbs energy change of dissociation in the aqueous phase?**

Note : Assume that ΔH and ΔS are independent of temperature.

Let T be the temperature at which the free energy change of dissociation of HA in gas phase become equal to the free energy change of dissociation of HA in aqueous phase.

$\Delta G_{gas} = \Delta G_{aq}$

$T = \dfrac{\Delta H_5 - \Delta H_1}{\Delta S_5 - \Delta S_1}$

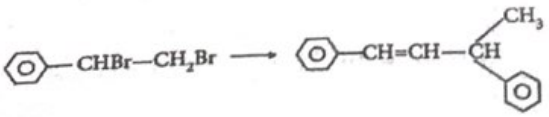
10

$$T = \frac{(1151.0 - 1.0)\ kJ\ mol^{-1}}{(3.195 - 0.095)\ kJ\ mol^{-1} K^{-1}}$$ **(04 + 01)**

$T = 370.9\ K$ *or* $97.96\ ^{o}C$ **(04 + 01)**

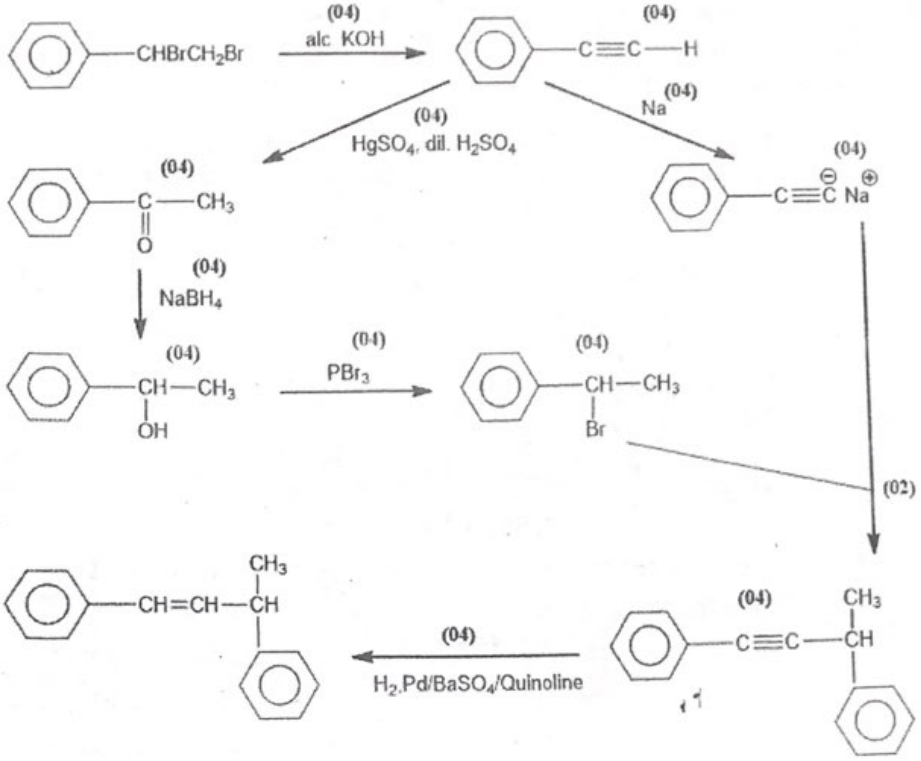
6(b)100 marks

7. (a) Using **only** the chemicals given in the list, show how you would carry out the following conversion



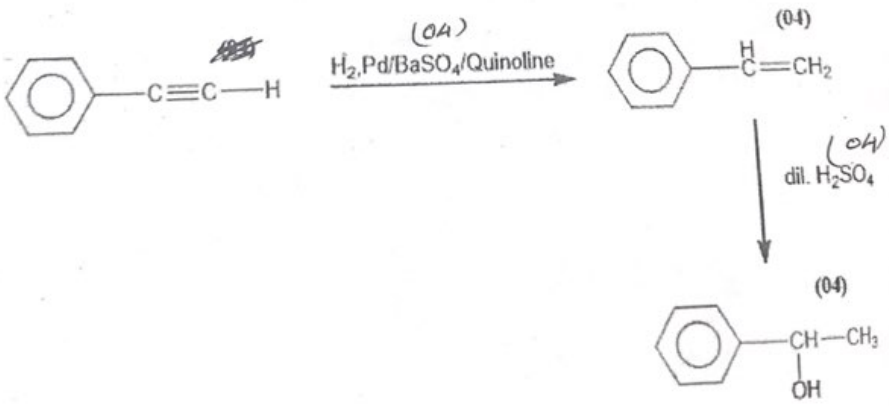
List of chemicals

H_2, Pd / $BaSO_4$ / Quinoline, $NaBH_4$
Na, alcoholic KOH, $HgSO_4$
dil. H_2SO_4, PBr_3



7(a) 50 marks

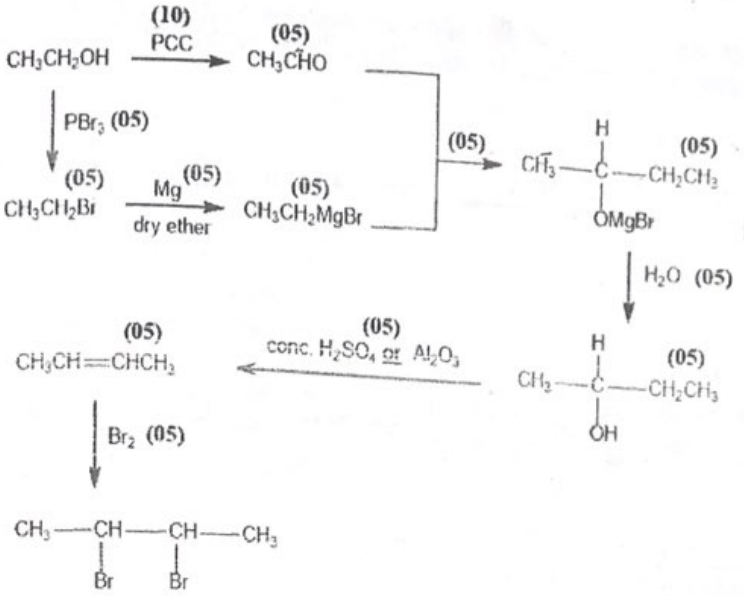
Alternative method for synthesis of $PhCH(OH)CH_3$



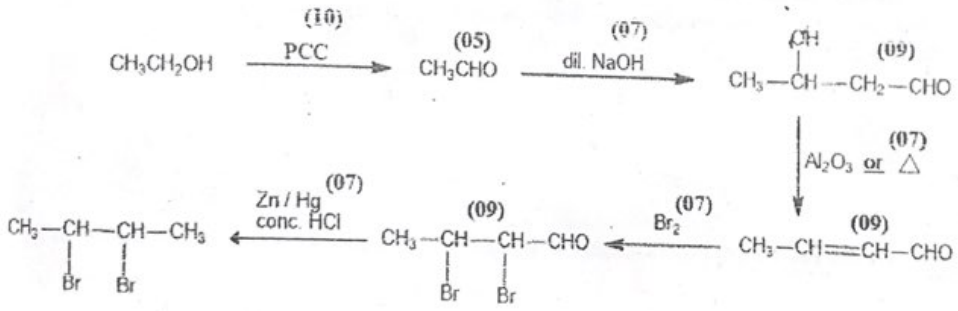
(16)

(b) Show how you would synthesize compound **B** using compound **A** as the **only** organic starting material.

CH_3CH_2OH **A** $\qquad$ $CH_3CHBrCHBrCH_3$ **B**



The following may be accepted for assigning marks based on the A/L syllabus content

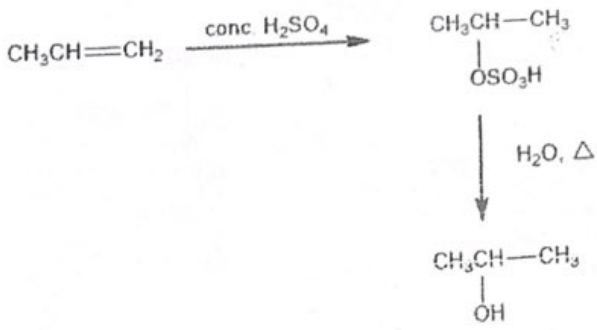


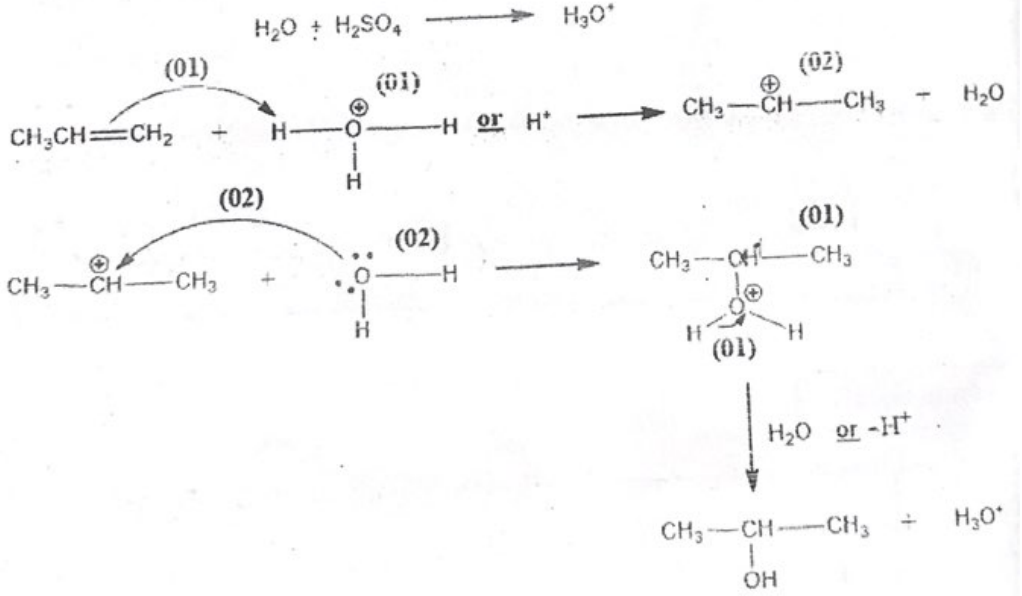
7(b) 70 marks

(c) Draw the structures of the compounds **C** and **D** in the reaction sequence given below.

$$CH_3CH{=}CH_2 \xrightarrow{\text{conc. } H_2SO_4} \mathbf{C} \xrightarrow[\Delta]{H_2O} \mathbf{D}$$

It is observed that the same product **D** can be obtained directly by the reaction of $CH_3CH{=}CH_2$ with **dilute H_2SO_4**. Explain this observation by taking into account the fact that H_2O can act as a nucleophile.





Statement only

The water in dilute H_2SO_4 can act as a nucleophile and react with the (04)

$CH_3—\overset{\oplus}{C}H—CH_3$ carbocation and form the alcohol.

should be to give marks

Note: If structure of carbocation is not given, NO marks for statement.

7(c) 30 marks

PART C — ESSAY

8. (a) The following question is based on the *s* and *p* block elements in the Periodic Table. Identify the chemical species **P**, **Q**, **R**, **S**, **T**, **U**, **V**, **W**, **X** and **Y** in the reaction scheme given below.

P (white solid) $\xrightarrow{\Delta}$ **Q** (white solid) + **R** (colourless gas)

Q $\xrightarrow{\text{dil. HCl}}$ **S** (reddish brown gas) + other products

Q + $NH_4Cl(s)$ $\xrightarrow{\Delta}$ **T** (white residue that gives a bright yellow colour in the flame test) + **U** (colourless gas) + water vapour

R + **V** (colourless gas) $\xrightarrow[\text{temperature}]{\text{high}}$ **U** + water vapour

$Ca(s)$ + **U** $\xrightarrow{\Delta}$ **W** (white solid)

W + $H_2O(l)$ $\longrightarrow$ **V** + another product

$Mg(s)$ + **R** $\xrightarrow{\Delta}$ **X** (white solid)

X + $H_2O(l)$ $\longrightarrow$ **Y** (turns phenolphthalein pink)

P = $NaNO_3$	**Q** = $NaNO_2$	**R** = O_2	**S** = NO_2
T = $NaCl$	**U** = N_2	**V** = NH_3	**W** = Ca_3N_2
X = MgO	**Y** = $Mg(OH)_2$		

(05 x 10)

8(a) 50 marks

(b) Tests (1), (2) and (3) were carried out with an **aqueous solution** containing an inorganic covalent compound **Z**. The tests and observations are given below.

Test	Observation
(1) Added an acidified suspension of MnO_2 to the **aqueous solution.**	a pale pink solution with evolution of O_2 gas
(2) Passed H_2S gas through the **aqueous solution.**	a pale yellow (sometimes white) turbidity
(3) Passed SO_2 gas through the **aqueous solution.** Removed excess SO_2 and added a solution of $BaCl_2$.	a white precipitate insoluble in dilute HCl

(i) Identify **Z**.

Z = H_2O_2 **(10)**

(ii) Give balanced chemical equations for the reactions that occur in tests (1), (2) and (3).

$MnO_2 + 4H^+ + 2e \rightarrow Mn^{2+}\ 2H_2O$ **(03)**

$H_2O_2 \rightarrow 2H^+ + O_2 + 2e$ **(03)**

or

$MnO_2 + H_2O_2 + 2H^+ \rightarrow Mn^{2+} + 2H_2O + O_2$ **(08)**

$H_2S \rightarrow S + 2H^+ + 2e$ **(03)**

$H_2O_2 + 2H^+ + 2e \rightarrow 2H_2O$ **(03)**

or

$H_2O_2 + H_2S \rightarrow S + 2H_2O$ **(08)**

$SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^+ + 2e$ **(03)**

$H_2O_2 + 2H^+ + 2e \rightarrow 2H_2O$ **(03)**

or

$H_2O_2 + SO_2 \rightarrow 2H^+ + SO_4^{2-}$ (**or** H_2SO_4) **(08)**

$H_2SO_4 + BaCl_2 \rightarrow BaSO_4\downarrow + 2HCl$ **(05)**

(iii) Give two uses of Z.

as an antiseptic, bleaching agent, oxidizing agent, reducing agent, fuel

(03 + 0

(iv) What is the most important intermolecular force that is present in Z?

hydrogen bonding (0

8(b) 50 mark

(c) The following procedure was used to determine the thickness of a layer of chromium coated o surface of a rectangular sheet of an inert material.

Procedure:

A dilute acid was used to dissolve the chromium in a 8.0 cm × 5.0 cm rectangular sample of the sheet. The resulting Cr^{3+}, was oxidized with $S_2O_8^{2-}$ (peroxydisulfate ion) in neutral medium as given

$$S_2O_8^{2-}(aq) + Cr^{3+}(aq) + H_2O(l) \longrightarrow Cr_2O_7^{2-}(aq) + H^+(aq) + SO_4^{2-}(aq)$$

After removal of excess $S_2O_8^{2-}$, the solution was acidified and an excess of ferrous ammonium $(Fe(NH_4)_2(SO_4)_2.6H_2O)$ 3.10 g was added. The unreacted Fe^{2+} was then titrated with 0.05 M $K_2Cr_2O_7$ solution. The volume required was 8.50 cm^3.

(i) Give balanced chemical equations for the reactions of

I. $Cr^{3+}(aq)$ with $S_2O_8^{2-}(aq)$

II. $Fe^{2+}(aq)$ with $Cr_2O_7^{2-}(aq)$.

$$2Cr^{3+} + 3S_2O_8^{2-} + 7H_2O \rightarrow Cr_2O_7^{2-} + 6SO_4^{2-} + 14H^+$$ (0

$$6Fe^{2+} + Cr_2O_7^{2-} + 14H^+ \rightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$$ (0

(ii) Calculate the thickness of the chromium layer on the sample.

(Density: Cr = 7.2 g cm^{-3}; Relative atomic mass: Fe = 56, Cr = 52, S = 32, O = 16, N = 14,

Let the thickness of the chromium layer be **y cm** (

Area of the rectangular sample = 8.0 × 5.0

$= 40.0\ cm^2$ (01 +

Volume of chromium layer $= 40.0 \times y\ cm^3$ (01 +

Mass of chromium layer $= 40.0 \times y \times 7.2\ g$ (01 +

Moles of chromium in the layer $= \frac{40.0 \times y \times 7.2}{52}$

Molar mass of $Fe(NH_4)_2(SO_4)_2.6H_2O = 392\ g\ mol^{-1}$ (

Therefore, moles of Ferrous $(Fe^{2+}) = \frac{3.10}{392}$

Moles of $K_2Cr_2O_7$ used to titrate excess $Fe^{2+} = \frac{0.05}{1000} \times 8.5$

Moles of excess Fe^{2+} $= 6 \times \frac{0.05}{1000} \times 8.5$ **(03)**

Therefore, moles of Fe^{2+} reacted with $Cr_2O_7^{2-}$ formed as a result of dissolution of chromium layer in the sample

$= \left(\frac{3.10}{392}\right) - \left(6 \times \frac{0.05}{1000} \times 8.5\right)$ **(03)**

$= (7.91 \times 10^{-3}) - (2.60 \times 10^{-3})$
$= 5.31 \times 10^{-3}$ **(03)**

Therefore, moles of $Cr_2O_7^{2-}$ due to dissolution of chromium layer
$= \frac{1}{6} \times 5.31 \times 10^{-3}$ **(03)**

Therefore, moles of Cr^{3+} $= 2 \times \frac{1}{6} \times 5.31 \times 10^{-3}$ **(03)**

$= 1.77 \times 10^{-3}$ **(03)**

$\frac{40.0 \times y \times 7.2}{52} = 1.77 \times 10^{-3}$ **(03)** 4

$y = 3.2 \times 10^{-4}$ **(cm)** **(05)**

Note : Steps could be combined. Marks should be awarded accordingly.

Alternative Answer

Let the thickness of the chromium layer be **y cm** **(01)**

Molar mass of $Fe(NH_4)_2(SO_4)_2.6H_2O = 392$ g mol^{-1} **(02)**

Initial moles of Ferrous $(Fe^{2+}) = \frac{3.10}{392}$ **(02)**

Moles of $K_2Cr_2O_7$ used to titrate excess $Fe^{2+} = \frac{0.05}{1000} \times 8.5$ **(03)**

$Fe^{2+} : Cr_2O_7^{2-} = 6 : 1$

Moles of excess (unreacted) $Fe^{2+} = 6 \times \frac{0.05}{1000} \times 8.5$ **(03)**

Therefore, moles of Fe^{2+} reacted with $Cr_2O_7^{2-}$ formed as a result of dissolution of chromium layer in the sample

$= \left(\frac{3.10}{392}\right) - \left(6 \times \frac{0.05}{1000} \times 8.5\right)$ **(03)**

$= (7.91 \times 10^{-3}) - (2.60 \times 10^{-3})$

$= 5.31 \times 10^{-3}$ **(03)**

Initial moles of $Cr_2O_7^{2-}$ due to dissolution of chromium layer
$= \frac{1}{6} \times 5.31 \times 10^{-3}$ **(03)**

Therefore, moles of Cr^{3+} $= 2 \times \frac{1}{6} \times 5.31 \times 10^{-3}$ **(03)**

$= 1.77 \times 10^{-3}$ **(03)**

Mass of Cr^{3+} $= 1.77 \times 10^{-3} \times 52$ g (0

Therefore, volume of Cr^{3+} layer $= \frac{1.77 \times 10^{-3} \times 52}{7.2}$ cm^3 (0

$y \times 8.0\ cm \times 5.0\ cm = \frac{1.77 \times 10^{-3} \times 52}{7.2}$ cm^3 (0

$y = \frac{1.77 \times 10^{-3} \times 52}{7.2 \times 40}$ cm (0

$= 3.2 \times 10^{-4}$ (cm) (0

8(c) 50 mark

availability high Fe_2O_3

9. (a) The following questions are based on the extraction of iron using the Blast Furnace.

(i) Give the common names along with their chemical formulae of the iron ore and other raw materials used in the extraction of iron.

hematite – Fe_2O_3 **or** Magnetite - Fe_3O_4 **(02 + 02)**

coke – C **(02 + 02)**

limestone – $CaCO_3$ **or** dolomite – $CaCO_3.MgCO_3$ **(02 + 02)** 12

Note : If more than one ore is given, the correct answer (Fe_2O_3 **or** Fe_3O_4) must be written within the first two

(ii) Discuss briefly the function of each of the raw materials, except the iron ore. Use balanced chemical equations where applicable.

Coke

(coke acts as a fuel)

(1) Coke burns in air to give CO_2 **(01)** with liberation of a large amount of heat **(01)**. This helps to keep the temperature of the blast furnace very high **(01)** at the bottom **(01)**. 5

$C + O_2 \rightarrow CO_2$ + heat **(01)**

(2) The CO_2 formed reacts with C to give CO **(01)** which is the main reducing agent **(01)** in the conversion of iron oxide to iron. 3

$CO_2 + C \rightarrow 2CO$ **(01)**

(3) To reduce FeO directly by C **(01)**

$2FeO + C \rightarrow 2Fe + CO_2$ **(02)** 3

$CaCO_3$

This is used to remove impurities **(01)** such as sand / silicates **(01)**, alumina **(01)** from the ore by slag formation **(01)**. 4

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

$CaO + SiO_2 \rightarrow CaSiO_3$ (slag) **(02)** $CaCO_3 + SiO_2 \rightarrow CaSiO_3 + CO_2$

$CaO + Al_2O_3 \rightarrow Ca(AlO_2)_2$ (slag) **(02)** full marks

Also accepted

$CaO + P_2O_5 \rightarrow Ca_3(PO_4)_2$

Slag is obtained in the molten state **(01)** and is less dense than the molten iron **(01)**. Therefore, slag floats on top of the iron **(01)** and prevents atmospheric oxidation **(01)**, mainly due to the hot air blown at the bottom. 4

(iii) Write balanced chemical equations to show the stepwise conversion of iron ore to iron in the Furnace.

no marks for Fe_3O_4

$3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2$ -------- (1)

$Fe_3O_4 + CO \rightarrow 3FeO + CO_2$ -------- (2)

$FeO + CO \rightarrow Fe + CO_2$ -------- (3)

$2FeO + C \rightarrow 2Fe + CO_2$ -------- (4)*

(ii) 3 → If this is expected no marks

*Note: Marks to be awarded only once

(iv) Write the name given to the molten iron formed at the bottom of the Blast Furnace and its approximate composition.

Pig iron

Composition: Fe **(01)**; 3 – 4% C **(01)**; Si, P, S, Mn (any **three**)

5

(v) Indicate the changes in composition required to convert the iron obtained from the Blast Furnace to stainless steel. State briefly how this is done.

(1) Reduce carbon content

(2) Remove Si, Mn, P as slag

(3) Add alloying elements **or** adding Cr / Ni

Heat with air or O_2 **or** Blow hot air **or** O_2 to molten iron

(vi) Calculate the mass of the gas, (identified in part (iii)) in kg used in the stepwise conversion of iron ore to produce 2000 kg of iron.

From part (iii), Add eq. (1) + (2) x 2 + (3) x 6 **or** otherwise to give

$Fe_3O_4 + 4CO \rightarrow 3Fe + 4CO_2$

$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

To produce 2 moles of Fe, require 3 moles of CO

3×59 4×28

To produce 2×56 g of Fe, require 3×28 g of CO

Therefore, to produce 2000 kg of Fe, require $\frac{3 \times 28 \times 2000}{2 \times 56}$ kg of CO

$= 1500$ kg 1333 kg

(vii) The waste gas mixture that travels up and comes out of the Blast Furnace is known as blast furnace gas or flue gas. State the principal gases present in the mixture and identify the predominant species.

(Relative atomic mass: **Fe = 56, O = 16, C = 12**)

CO_2, CO, N_2 **(01 + 01 +**

5

Predominant species: N_2

9(a) 75 m

(b) (i) State **two** major carbon species found in each of the following.

I. atmosphere

II. lithosphere (earth's crust)

III. hydrosphere

atmosphere – CO_2, CH_4, volatile hydrocarbons (other than CH_4), carbon particles, CO

(02 + 02)

lithosphere – fossil fuels, minerals containing carbonates, graphite, coke, diamond

(02 + 02)

hydrosphere – (dissolved) CO_2 **or** $CO_2(aq)$ **or** H_2CO_3, carbonates, bicarbonates

(02 + 02)

12

(ii) State **five** natural processes that provide and remove carbon species to and from the atmosphere.

at least one for each

- Photosynthesis (removes CO_2 from atmosphere)
- Respiration by plants and animals (all living organisms) (add CO_2 to atmosphere)
- Dissolution of CO_2 in water (removes CO_2 from atmosphere)
- Ruminant animals produce CH_4 (in their digestive systems due to fermentation by anaerobic bacteria)
- Natural combustion (eruption of volcanoes and natural fires) (gives out carbon species to atmosphere)
- Bacterial decomposition of organic matter (releases CO_2 & CH_4)
- Microorganisms can get the carbon species in dead plants & animals back into the atmosphere

(Any **five**. Other valid answers are accepted) **(04 x 5)**

(iii) Explain how human activities increase the carbon content in the atmosphere.

- Burning of fossil fuels in large amounts release CO_2 and other hydrocarbons to the atmosphere
- Wetland based agriculture (Paddy cultivation) and livestock release CH_4 to the atmosphere
- During synthesis of halogenated hydrocarbons, these can enter the atmosphere
- Deforestation

(Any **three**. Other valid answers are accepted) **(04 x 3)**

(iv) State **two** global environmental issues that are caused by the elevation of carbon content in the atmosphere.

global warming
ozone layer depletion
photochemical smog

(any **two**) **(05 x 2)**

(v) Name the chemical species/class of chemical species that are responsible for the envir issues you mentioned in part (iv).

check all and give marks not 1st three

CO_2, CH_4, hydrocarbons, NO_2 (NO_x), halogenated hydrocarbons **or** CFC, HCFC, HFC, PBN, PAN aldehyde, Ketone

(Any **three**) (03 x 3)

(vi) Write **two** detrimental effects caused by **each** of the environmental issues stated in par global climate/human health.

global warming

- Shifts in rainfall pattern
- Rise in mean sea level (melting of polar ice caps / glaciers)
- Heavy snowfalls
- Frequent cyclones
- Desertification (productive land into deserts)
- Droughts lasting long periods
- Frequent heat waves
- Drying of freshwater reservoirs
- Extinction of species
- Epidemic diseases
- Increase in global temperature

ozone layer depletion

- Skin cancer
- Cataract
- Respiratory diseases
- Heat strokes resulting in death

photochemical smog

- Respiratory diseases
- Eye irritation
- Visibility problem

Note: Two from any **two** issues

(03 x 2) + (03 x 2)

9(b) 75 mar

10. (a) (i) A domestic bleaching agent (hereafter referred to as bleaching solution) contains equal mole amounts of sodium hypochlorite (NaOCl) and Cl^-. The amount of Cl_2 gas liberated by the action of excess dilute acids on a sample of bleaching solution is called the 'available chlorine' of that sample. This is shown by the reaction below.

$$ClO^-(aq) + 2H^+(aq) + Cl^-(aq) \longrightarrow Cl_2(g) + H_2O(l)$$

Generally, the 'available chlorine' of a bleaching solution is expressed as the amount of Cl_2 gas liberated from 100 g of the bleaching solution. The following procedure was used to determine the 'available chlorine' in a bleaching solution.

Procedure:

A 25.0 cm^3 sample of the bleaching solution was diluted to 250.0 cm^3 in a volumetric flask with distilled water. To a 25.0 cm^3 sample of the diluted solution, acetic acid and excess KI were added. The I_2 liberated was then titrated with 0.30 M $Na_2S_2O_3$ solution using starch as the indicator. The volume required was 19.0 cm^3.

I. Write balanced chemical equations for the reaction of $ClO^-(aq)$ with $I^-(aq)$ and the reaction of I_2 with $Na_2S_2O_3$.

$ClO^-(aq) + 2H^+ + Cl^-(aq) \rightarrow Cl_2(g) + H_2O$ (given)

$Cl_2 + 2I^- \rightarrow I_2 + 2Cl^-$ **(02)**

or

$ClO^- + 2H^+ + 2I^- \rightarrow I_2 + Cl^- + H_2O$ **(06)**

Alternative Answer

$ClO^-(aq) + 2H^+ + 2e \rightarrow Cl^- + H_2O$ **(02)**

$2I^- \rightarrow I_2 + 2e$ **(02)**

or

$ClO^- + 2H^+ + 2I^- \rightarrow I_2 + Cl^- + H_2O$ **(06)**

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

II. Calculate the percentage of 'available chlorine' by mass in the bleaching solution. (Density of the bleaching solution = 1.2 g cm^{-3}, Relative atomic mass: Cl = 35.5)

Moles of $S_2O_3^{2-}$ $= \frac{0.3}{1000} \times 19.0$ **(02)**

Moles of I_2 $= \frac{1}{2} \times \frac{0.3}{1000} \times 19.0$ **(02)**

Moles of ClO^- $= \frac{1}{2} \times \frac{0.3}{1000} \times 19.0$ **(02)**

$= 2.85 \times 10^{-3}$ **(02)**

Moles of ClO^- in 250.0 cm^3 $= 2.85 \times 10^{-3} \times 10$ **(02)**

$= 2.85 \times 10^{-2}$ **(02)**

Therefore, moles of available Cl_2 $= 2.85 \times 10^{-2}$ **(02)**

Mass of available Cl_2 in 250.0 cm^3 $= 2.85 \times 10^{-2} \times 71$ g **(02)**

$$\% \text{ of available } Cl_2 = \frac{\text{mass of available } Cl_2 \text{ in } 250.0\ cm^3}{\text{mass of bleaching solution}} \times 100$$ **(03)**

Mass of bleaching solution $= 25.0 \times 1.2$ **(02)**

$= 30$ g **(01)**

$$\text{Available } Cl_2 = \frac{2.85 \times 10^{-2} \times 71}{30} \times 100\ \%$$ **(01)**

$= 6.8\ \%$ **(04)**

Note: Answers between 6.7 - 6.8 % can be accepted

(ii) The following questions are based on the transition metal Fe and its compounds.

I. Write the ground state electronic configuration of Fe.

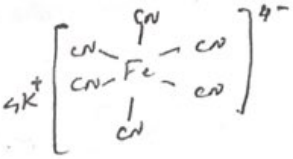
$1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$ **or** $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$

II. State the **two** most common positive oxidation states of Fe.

(+)2, (+)3 **or** (+)II, (+)III (05

III. Aqueous $FeSO_4$ reacts with excess KCN to give a yellow octahedral ionic complex, **G** does not contain the elements H, O and S. Write the structural formula of **G**.

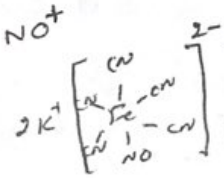
$K_4[Fe(CN)_6]$ **or** $[Fe(CN)_6]^{4-}\ 4K^+$



IV. Give the IUPAC name of **G**.

potassium hexacyanoferrate(II)
or
potassium hexacyanidoferrate(II)

V. **G** reacts with 30% aqueous HNO_3 to give a red-brown octahedral ionic complex, **oxidation state of Fe remains unchanged during this reaction. The molecular formula** $FeK_2C_5N_6O$. **Write the structural formula of L.**



$K_2[Fe(CN)_5(NO)]$ **or** $K_2[Fe(NO)(CN)_5]$ **or**

$[Fe(CN)_5(NO)]^{2-}\ 2K^+$ **or** $[Fe(NO)(CN)_5]^{2-}\ 2K^+$

VI. The reaction taking place in part (V) above can be described as a ligand substitution r an octahedral complex. From the list given below, identify the entering group and th group, with their correct charges, in this substitution reaction.

N_2, NO, NO^+, NO_2^-, NO_3^-, CN^-, CO

entering group NO^+
leaving group CN^-

10(a) 75 m

(b) Waste water generated in an industrial process (pH = 7.0) contains a coloured compound **D**. A treatment plant is designed to remove the colour by electrochemically oxidizing this compound. Electrochemical oxidation of compound **D** in the aqueous medium takes place as follows.

$$D(aq) \longrightarrow A^{2+}(aq) + B(aq) + 2e$$

$$2H_2O(l) + 2e \longrightarrow H_2(g) + 2OH^-(aq)$$

The concentration of compound **D** in the waste water was found to be 0.001 mol dm^{-3}.

(i) Calculate the time required for complete electrochemical oxidation of compound **D** in a 1.0 dm^3 sample of the waste water by an electrolytic cell consisting of two Pt electrodes, using a constant current of 100 mA.

(charge of 1.0 mol of electrons = 96500 C)

Amount of D in 1.0 dm^3 of waste water = 0.001 mol dm^{-3} x 1.0 dm^3 **(04 + 01)**

= 0.001 mol **(04 + 01)**

Amount of electrons released when the above amount of D is oxidized,

= 0.001 mol x 2

= 0.002 mol **(04 + 01)**

Amount of electricity (charge) needed,

= 96500 C mol^{-1} x 0.002 mol **(04 + 01)**

Time required for complete oxidation of D in 1.0 dm^3 of waste water

$$= \frac{96500 \text{ C mol}^{-1} \times 0.002 \text{ mol}}{100 \times 10^{-3} \text{ C s}^{-1}} \quad \textbf{(04 + 01)}$$

= 1.93×10^3 s **or** 32.16 min **or** 0.536 h **(04 + 01)**

30

(ii) If $A(OH)_2$ is completely ionized in the aqueous medium, calculate the pH of the waste water sample after the electrochemical oxidation.

At 25 °C,

During the electrochemical process OH^- is produced.

$[OH^-]$ = 0.001 mol dm^{-3} x 2 **(04 + 01)**

pOH = -log (0.002) **(04 + 01)**

= 2.698

pH = 14.0 – 2.698 **(04 + 01)**

(if concentrations are used, award marks)

pH = 11.3 **(04 + 01)** for no unit

20

(iii) If the above industry releases waste water containing compound **D** at a rate of 10 dm^3 s^{-1}, calculate the minimum current that must be supplied to the electrolytic cell in order to completely oxidize compound **D**.

When waste water is released continuously, current must be supplied to the cell continuously. **(05)**

Current needed to be supplied = 0.001 mol dm^{-3} x 2 x 96500 C mol^{-1} x 10.0 dm^3 s^{-1}

(04 + 01) x 3

= 1930 C s^{-1} **or** 1930 A

(04 + 01)

25

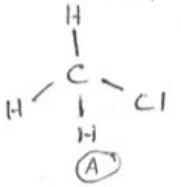
10(b) 75 marks

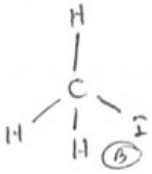
C - 2.5 Cl - 3.0 I - 2.5 H - 2.1

Note

CH_3Cl CH_3I.

249 K 316 K.



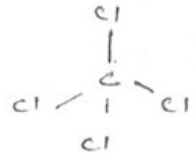


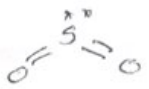
dipole - dipole + London forces

strongest dipole (A)

strongest intermolecular forces in (B) as its Mr is high. ∴ predominant intermolecular force is London forces.

eg:- CCl_4 SO_2.





non polar. P. dipole.

London forces dipole-dipole.

high B.P Low B.P.

Instantaneous dipole - induced dipole

6 - a ii) $P \propto n$ $P_1 = Kn_1$

$\Delta P = K \Delta n$.

$\frac{\Delta P}{P} = \frac{K \Delta n}{K n}$.

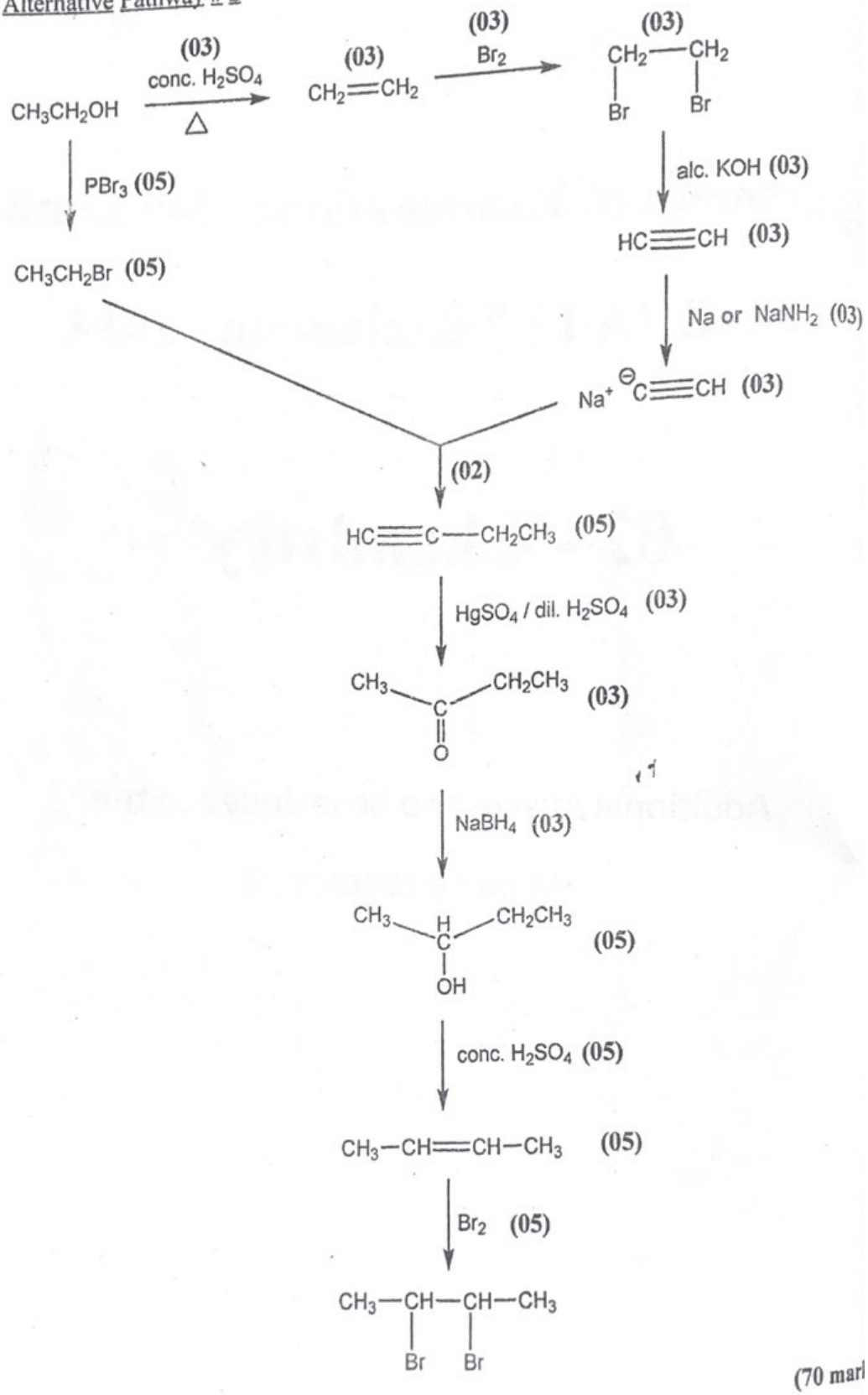
$\frac{\Delta P}{P} = \frac{\Delta n}{n}$.

10 - b $m = \frac{It}{eF}$ $n = \frac{Il}{eF}$

$n = \frac{It}{eF}$ $cv = \frac{It}{eF}$

$t = \frac{neF}{I}$ $I = \frac{cv}{t} eF$

7 (b) Alternative Pathway # 2



(70 mar

9. (a) (vi)

If Fe_3O_4 is used as the iron ore, part (vi) should be marked as follows:

From part (iii), Add eq. (2) + (3) x 3 **or** otherwise to give

$Fe_3O_4 + 4CO \rightarrow 3Fe + 4CO_2$ **(05)**

To produce 3 moles of Fe, require 4 moles of CO **(01)**

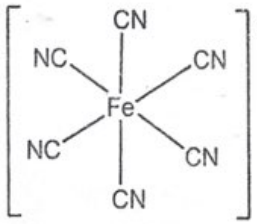
To produce 3×56 g of Fe, require 4×28 g of CO **(01)**

Therefore, to produce 2000 kg of Fe, require $\frac{4 \times 28 \times 2000}{3 \times 56}$ kg of CO

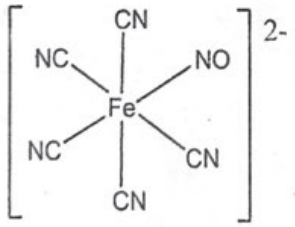
= 1333 kg **(04)**

10. (a) (ii) The following can also be accepted.

III. $4K^+$ $[Fe(CN)_5(NC)]^{4-}$

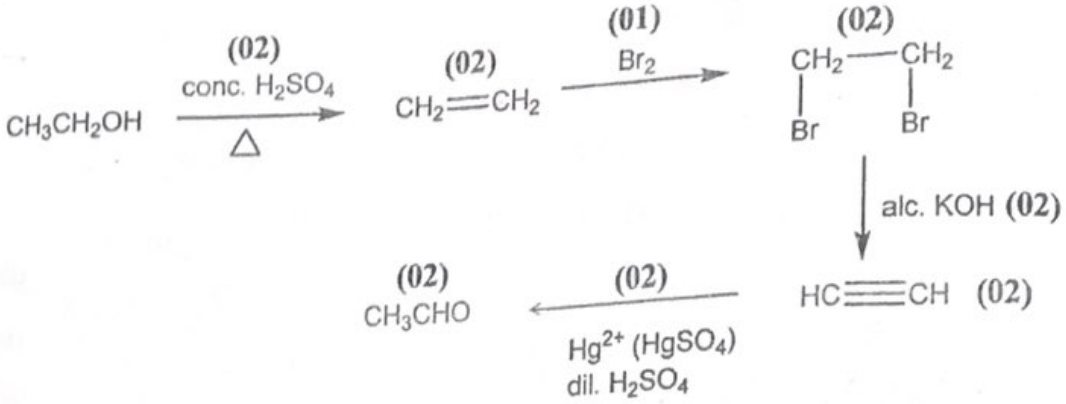


V. $2K^+$ $[Fe(CN)_5(NO)]^{2-}$



Note: The K^+ ions can be written either before the negtively charged species or after it.

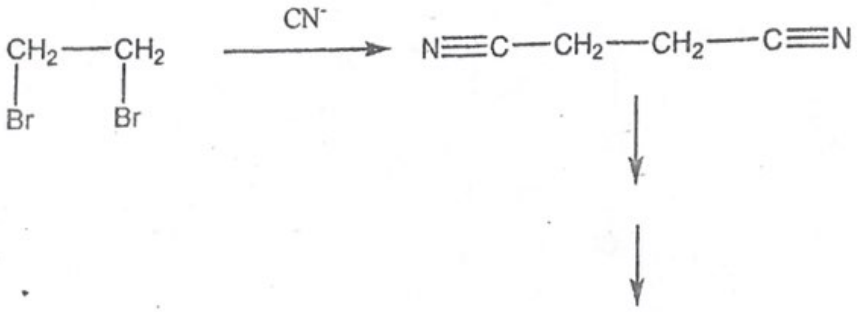
7(b) Alternative pathway to make CH_3CHO



lote:

(1) Only a total of (15) marks can be assigned for synthesizing CH_3CHO from CH_3CH_2OH. Therefore, the marks assigned for the same reactions are different from each other in the two alternative pathways proceeding through $HC\equiv CH$

(2)



is ~~not~~ acceptable as two of the C atoms in the final product have not come from A However, upto **12** marks can be assigned for the synthesis of CH_2Br-CH_2Br as given in Alternative pathway #2.

(3) The following can be used in place of PCC :

- Cu / 300 °C
- $KMnO_4$ **or** chromic acid under conditions where the aldehyde is distilled off as it forms.

  ($KMnO_4$ **or** chromic acid under controlled conditions is not accepted)