2.1.3 Expected answers and the marking scheme for Paper I

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

Each correct answer carries 02 marks, amounting the total to 100.

2.2.3 Expected answers, marking scheme and observations and conclusions related to paper II

★ **The observations related to the answers for Paper II have been presented by the graphs 2, 3, 4.1, 4.2 and 4.3.**

PART A — STRUCTURED ESSAY

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

Question 1

1. (*a*) You are provided with the following list of some *p*-block elements in the Periodic Table.

B	**C**	**N**	**O**	**F**	**Ne**
Al	**Si**	**P**	**S**	**Cl**	**Ar**

From the list,

(i) identify the non-metallic element that forms a homoatomic covalent lattice of high hardness. ..... C .....

(ii) identify the element that exhibits the widest range of oxidation states. ..... N/S/P/Cl/C .....

(iii) identify the element that has the highest first ionization energy. ..... Ne .....

(iv) identify the element that exhibits amphoteric properties. ..... Al .....

(v) identify the element that has two gaseous allotropes. ..... O .....

(vi) identify the element that is considered to be the strongest oxidizing agent. ..... F .....

(04 × 6 = 24 marks)

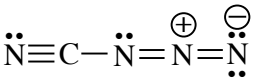
Note : If more than one answer is given for a question, award zero marks for that question.

1(*a*) : 24 marks

(*b*) The following parts (i) to (v) are based on the molecule CN_4. It has the following skeleton.

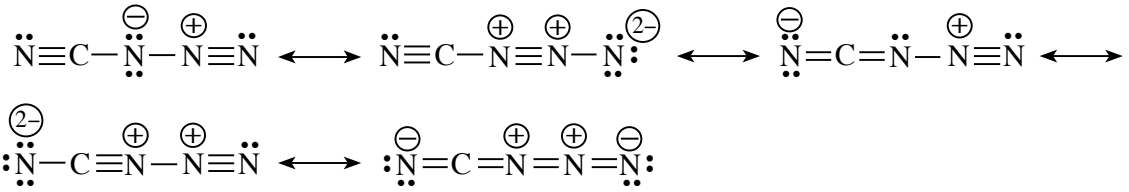
N—C—N—N—N

(i) Assuming that N—N bond lengths are approximately equal, draw the **most acceptable** Lewis structure for this molecule.



(10 marks)

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



Note : Consider first three responses.

(05 × 3 = 15 marks)

(iii) Based on the Lewis structure drawn in (i) above, state the following regarding the C and N atoms given in the table below.

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

The nitrogen atoms of CN_4 are numbered as follows:

$N^1—C—N^2—N^3—N^4$

		C	N^2	N^3
I.	VSEPR pairs	2	3	2
II.	Electron pair geometry	Linear	trigonal planar	Linear
III.	Shape	Linear	Angular / V	Linear
IV.	Hybridization	*sp*	sp^2	*sp*

(01 × 12 = 12 marks)

(iv) In the Lewis structure drawn in part (i) above, indicate whether N^2 or N^3 has the **higher** electronegativity. Give reasons for your choice. [Numbering of atoms is as in part (iii).]

$N^3 > N^2$ **or** N^3 has higher electronegativity than N^2 **(05)**

N^3 – *sp* and carries a positive charge **or** Oxidation state is +1 **(01 + 01)**

N^2 - sp^2 and carries zero charge **or** Oxidation state is –1 **(01 + 01)**

Higher the positive charge/higher the electronegativity/Higher the positive oxidation state **(01)**

Higher the *s*– character, higher the electronegativity **(01)**

(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 is as in part (iii).]

I. $N^1—C$ N^1 ..*sp* **or** *2p*.., C..*sp*..

II. C—N^2 C ..*sp*.., N^2..sp^2..

III. $N^2—N^3$ N^2..sp^2.., N^3..*sp*..

IV. $N^3—N^4$ N^3..*sp*.., N^4..sp^2 **or** *2p*..

(01 × 8 = 08 marks)

Note : Even if the Lewis structure drawn in (*b*)(i) is wrong, award marks for pair geometry in central atom/around the atom are given.

1(*b*) : 56 marks

(*c*) State whether the following statements are **true** or **false**. (Reasons are **not** required.)

(i) SF_6 and OF_6 are both stable molecules. ..False..

(ii) Although the electron pair geometry of $SiCl_4$, NCl_3 and SCl_2 is tetrahedral, their bond angles are different. ..True..

(iii) The boiling point of Kr is greater than that of Xe. ..False..

(iv) The solubility of group II sulphates decreases down the group primarily due to decrease in hydration enthalpy of the cations. ..True..

(05 × 4 = 20 marks)

1(*c*) : 20 marks

Total for 1 : 100 marks

Question 2

2. (*a*) **X** and **Y** are *s*-block elements of the Periodic Table. They react with water to form hydroxides. The hydroxide of **X** is more basic than that of **Y**. The hydroxide of **X** is used in the manufacture of baby soap. The hydroxide of **Y** is commonly used to identify the gas **Z** that is one of the main gases responsible for global warming.

(i) Identify **X** and **Y**.

K **or** potassium	Ca **or** calcium

(03 + 03)

(ii) Write the electronic configurations of **X** and **Y**.

X = $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^1$

Y = $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2$ **(03 + 03)**

(iii) Write the colour of the flame given by salts of **X** and **Y** in the flame test.

X : lilac/violet/reddish-violet

Y : brick red/yellow-red/orange red

Note : Marks could be awarded for 'orange' colour **(03 + 03)**

(iv) Indicate the relative magnitudes of the following in respect of **X** and **Y**.

I. Atomic size	X > Y
II. Density	Y > X
III. Melting point	Y > X
IV. First ionization energy	Y > X

(03 × 4)

Note : If <u>one</u> answer in (*a*)(i) is correct, award marks for the respective correct answers of (*a*)(ii) and (*a*)(iii). Award marks for (*a*)(iv) only if both X and Y are correctly identified.
If answer is given as X = KOH, Y = $Ca(OH)_2$ do not award marks for (*a*)(i) and (*a*)(iv). However, award marks for correct answers of (*a*)(ii) and (*a*)(iii).

(v) Identify **Z**.

CO_2 **(03)**

(vi) Using balanced chemical equations **only**, indicate how the hydroxide of **Y** could be used to identify **Z**.

Note: Indicate precipitates, if any, using "↓" and colours of precipitates/solutions used in the identification.

$CO_2 + Ca(OH)_2 \longrightarrow CaCO_3\downarrow + H_2O$ **(01 + 01 + 01)**
(white/milky white)

$CaCO_3 + CO_2 + H_2O \longrightarrow Ca(HCO_3)_2$ **(02 + 01)**
(colourless)

Note : If Y has been identified correctly, Y could be used instead of Ca.

(vii) A natural source of **Y** in which it is present as a carbonate is used as a raw material in the manufacture of a disinfectant.

I. Name the natural source. limestone/marble/oyster shells **(03)**

II. Identify the disinfectant. $Ca(OCl)_2$. $Ca(OH)_2$ $CaCl_2$ $2H_2O(s)$/$Ca(OCl)_2$/ Bleaching powder **(03)**

III. Write the steps in the manufacturing process of the disinfectant, using balanced chemical equations **only**.

$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$ **(02)**

$CaO(s) + H_2O(l) \longrightarrow Ca(OH)_2(s)$ **(02)**

$3Ca(OH)_2(s) + 2Cl_2(g) \longrightarrow Ca(OCl)_2$. $Ca(OH)_2$ $CaCl_2$ $2H_2O(s)$ **(01)**

Note : Physical states are not required.

2(*a*) : 50 marks

(*b*) (i) Complete the reactions given below by selecting the appropriate solution from the given list and writing in the box.

List of solutions (not in order)

$Na_2S_2O_3(aq)$, $AgNO_3(aq)$, $K_2SO_4(aq)$, $(NH_4)_2CO_3(aq)$, $BaCl_2(aq)$, $KI(aq)$

Note: A solution should be used **only once**.

I. $BaCl_2(aq)$ + $(NH_4)_2CO_3$ ⟶ **A** (White precipitate that dissolves in dil. HCl to give a clear solution)

II. $Pb(NO_3)_2(aq)$ + KI ⟶ **B** (Yellow precipitate that dissolves in hot water)

III. $AgNO_3(aq)$ + $Na_2S_2O_3$ ⟶ **C** (White precipitate that turns black on standing)

IV. $K_2SO_3(aq)$ + $BaCl_2$ ⟶ **D** (White precipitate that dissolves in dil. HCl)

V. NaBr(aq) + $AgNO_3$ ⟶ **E** (Pale yellow precipitate that dissolves completely in conc. ammonia)

VI. $Ba(NO_3)_2(aq)$ + K_2SO_4 ⟶ **F** (White precipitate that does **not** dissolve in dil. HCl)

(04 × 6 = 24 marks)

(ii) Write the chemical formulae of the precipitates **A** to **F**.

A $BaCO_3$ **B** PbI_2

C $Ag_2S_2O_3$ **D** $BaSO_3$

E $AgBr$ **F** $BaSO_4$

(03 × 6 = 18 marks)

(iii) Write balanced chemical equations for the dissolution of precipitates **A**, **D** and **E** in (b)(i) above.

(A) $BaCO_3 + 2HCl \longrightarrow BaCl_2 + H_2O + CO_2$ (or H_2CO_3) **(03)**

(D) $BaSO_3 + 2HCl \longrightarrow BaCl_2 + H_2O + SO_2$ (or H_2SO_3) **(03)**

(E) $AgBr + 2NH_3 \longrightarrow [Ag(NH_3)_2]Br$ or $[Ag(NH_3)_2]^+ + Br^-$ **(02)**

Note : Mark (*b*)(iii) independently.

2(b) : 50 marks

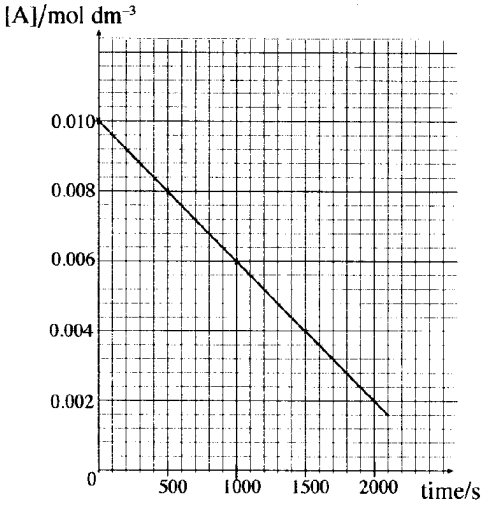
Total for 2 : 100 marks

Question 3

3. (*a*) When 0.010 moles of gas **A** is placed in a 1.0 dm^3 evacuated closed rigid container in the presence of a small amount of a solid catalyst, at 227 °C, it decomposes as shown below.

$$\mathbf{A}(g) \longrightarrow \mathbf{B}(g) + \mathbf{C}(g)$$

The concentration of **A**(g) was measured over time. The results are shown in the following graph.



(i) Taking the order and the rate constant of the reaction as **a** and ***k***, respectively, write the rate expression for the above reaction.

Rate = $k[A]^a$ **or** **(10)**

$\left[-\frac{\Delta[A]}{\Delta t} = k[A]^a \text{ or } -\frac{d[A]}{dt} = k[A]^a \right.$ if (–) sign is not included do not award marks$\left.\right]$

(ii) Giving reasons, determine the value of **a**.

Rate = $k[A]^0$ **or** order = a = 0 **(10)**

Rate = constant (gradient is constant) **or** Rate is independent of concentration **(05)**

(iii) Calculate the rate constant, ***k*** at 227 °C.

Rate constant, $k = |\text{Rate}|$ **(05)**

$k = \left|\frac{(0.002 - 0.01)\,\text{mol dm}^{-3}}{2000\,\text{s}}\right|$ **or** any two points **(04 + 01)**

$k = 4.0 \times 10^{-6}\,\text{mol dm}^{-3}$ **(04 + 01)**

(iv) Calculate the pressure in the container when half the initial amount of **A**(g) has decomposed. Assume that the volume of the catalyst can be neglected.

Volume of the container = 1.0 dm^3

A ⟶ B + C

After 50% completion

$0.01(1-x)$ $0.01x$ $0.01x$ [concentrations in mol dm^{-3}]

Amount of gas $t = 0$ = 0.01 mol

Amount of gas after 50% is decomposed = (0.005 + 0.005 + 0.005) mol

= 0.015 mol **(05)**

Assuming ideal gas behaviour, aaplyPV = nRT

$$\text{Pressure} = \frac{0.015\,\text{mol}\ \ 8.314\,\text{J K}^{-1}\,\text{mol}^{-1}\ 500\,\text{K}}{10^{-3}\,\text{m}^3} \quad \textbf{(08 + 02)}$$

$$= 6.\ 23 \times 10^{4}\,\text{Pa} \quad \textbf{(04 + 01)}$$

3(a) : 60 marks

(*b*) In the presence of a solid catalyst, the gas **X** decomposes according to the following chemical equation.

$$\mathbf{X}(g) \xrightarrow[\Delta]{\text{Catalyst}} 2\mathbf{Y}(g) + \mathbf{Z}(g)$$

1.0 mole of gas **X** was introduced to an evacuated container. The initial volume of the gas was measured to be $\mathbf{V_0}$. The reaction was initiated by introducing a small amount of catalyst (volume is negligible). The rate constant of the catalysed reaction is $\boldsymbol{k_1}$ and order of the reaction with respect to **X** is **b**. The initial rate of the reaction was measured as $\mathbf{R_0}$. The pressure of the system was maintained at a constant value by allowing the container to expand. The temperature of the system was also maintained at a constant value.

(i) Write an expression for $\mathbf{R_0}$ using the terms **b**, $\boldsymbol{k_1}$ and $\mathbf{V_0}$.

Initial rate, $R_0 = k_1[X]^b$

$$R_0 = k_1\left(\frac{1.0\,\text{mol}}{V_0}\right)^b \quad \text{——— (1)} \quad \textbf{(10)}$$

(Units are not required)

(ii) It was observed that the rate of the reaction was $0.25\mathbf{R_0}$ and the volume of the container was doubled when 50% of **X**(g) was consumed. Calculate the order **b** of the reaction.

After 50% decomposition,

$$[X] = \frac{0.5\,\text{mol}}{2V_0} \quad \textbf{(05)}$$

At this stage, $\text{Rate} = 0.25R_0$

$$0.25R_0 = k_1\left(\frac{0.5\,\text{mol}}{2V_0}\right)^b \quad \text{——— (2)} \quad \textbf{(10)}$$

From (2)/(1),

$$\frac{0.25\,R_0}{R_0} = \frac{k_1\left(\frac{0.5\,\text{mol}}{2V_0}\right)^b}{k_1\left(\frac{1.0\,\text{mol}}{V_0}\right)^b} \quad \textbf{(10)}$$

$$0.25 = 0.25^b$$

$$b = 1 \quad \textbf{(05)}$$

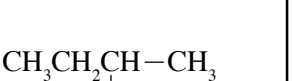
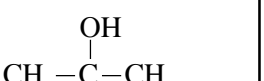
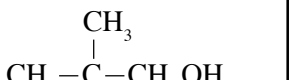
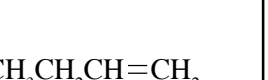
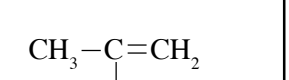
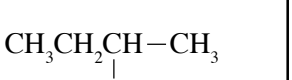
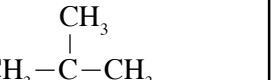
(Units are not required)

3(b) : 40 marks

Total for 3 : 100 marks

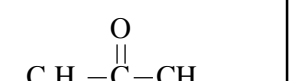
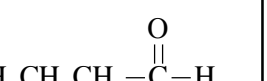
Question 4

4. (*a*) (i) **A**, **B**, **C** and **D** are structural isomers with the molecular formula $C_4H_{10}O$. All four isomers reacted with metallic sodium to evolve H_2 gas. Of the four isomers, only **A** exhibited optical isomerism. When **B**, **C** and **D** were added separately to conc. HCl, containing $ZnCl_2$, the mixture containing **B** became turbid very rapidly. The development of turbidity with **C** and **D** was very slow. When **C** and **D** were heated with conc. H_2SO_4, **E** and **F** were respectively obtained. **E** and **F** are structural isomers with the molecular formula C_4H_8. Neither **E** nor **F** exhibited geometric isomerism. When **E** and **F** were treated with HBr, **G** and **H** were respectively obtained. Only **G** exhibited optical isomerism. Draw the structures of **A**, **B**, **C**, **D**, **E**, **F**, **G** and **H** in the boxes given below. (It is **not necessary** to draw stereoisomeric forms.)

		
A	**B**	**C**
		
D	**E**	**F**
		**Note : If A is incorrect, no marks for I. If C is incorrect, no marks for J.**
G	**H**	

(05 × 8 = 40 marks)

(ii) When **A** and **C** were reacted with PCC, **I** and **J** were respectively obtained. Draw the structures of **I** and **J** in the boxes given below. (PCC = Pyridinium chlorochromate)

	
I	**J**

(05 × 2 = 10 marks)

4(a) : 50 marks

(*b*) Draw the structure of the **major** organic products **K**, **L**, **M**, **N**, **O**, **P**, **Q**, **R**, **S** and **T** of the following reactions in the relevant boxes given on page **8**.

(i) $CH_3CH{=}CH_2 \xrightarrow[\text{Peroxide}]{\text{HBr}}$ **K**

(ii) $C_6H_5CHO \xrightarrow[\text{② dehydration}]{\text{① 2, 4 – DNP}}$ **L**

(iii) $C_6H_5N_2^+Cl^- \xrightarrow[\text{0 – 5° C}]{\text{NaOH}}$ **M**

(iv) $C_6H_5COCl \xrightarrow{NH_3}$ **N**

(v) $C_6H_5CO_2H \xrightarrow[\text{conc. } H_2SO_4]{\text{conc. } HNO_3}$ **O**

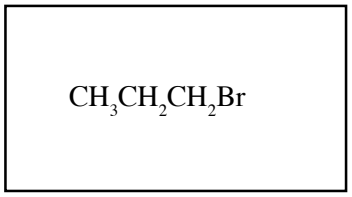
(vi) $CH_3COC_2H_5 \xrightarrow[\text{conc. HCl}]{\text{Zn | Hg}}$ **P**

(vii) $CH_3CHO \xrightarrow{Ag(NH_3)_2^+OH^-}$ **Q**

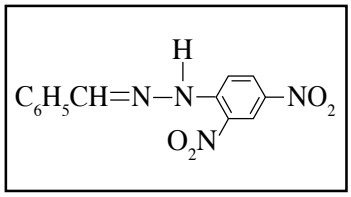
(viii) $CH_3C{\equiv}CH \xrightarrow{NaNH_2}$ **R**

(ix) $CH_3C{\equiv}CCH_3 \xrightarrow{H_2 \mid Pd}$ **S**

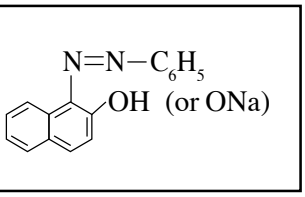
(x) $C_6H_5OH \xrightarrow{Br_2}$ **T**



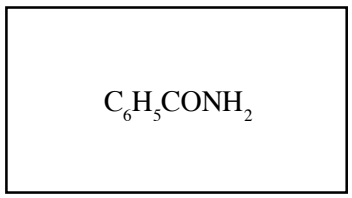
K



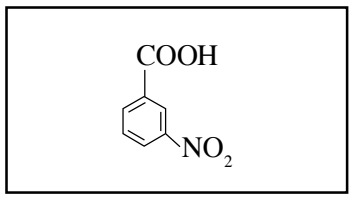
L



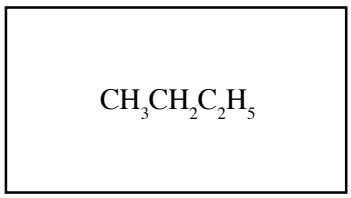
M



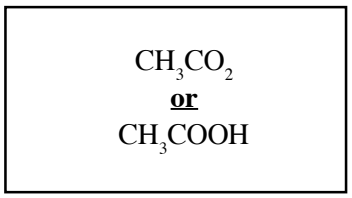
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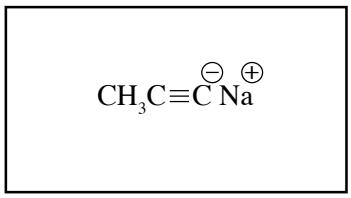
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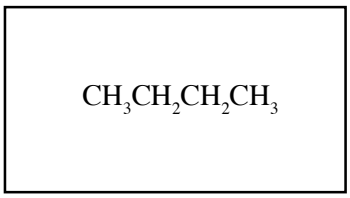
P



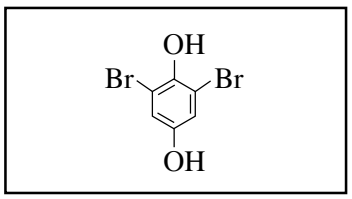
Q



R



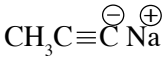
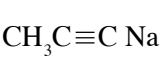
S



T

Note : Q : Disregard cation

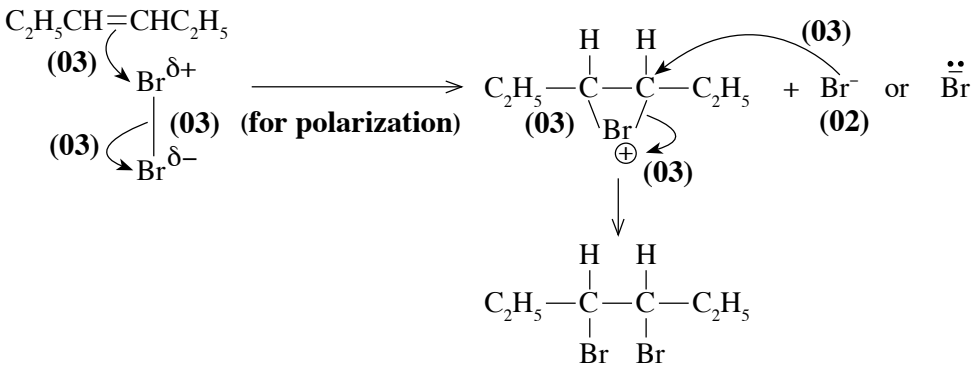
R : Do not award marks for the following structures

 or 

(03 × 10 = 30 marks)

4(b) : 30 marks

(*c*) Write the mechanism for the reaction between $C_2H_5CH{=}CHC_2H_5$ and $Br_2(CCl_4)$.



Nate : If cyclic intermediate is not drawn, do not award 06 marks

4(c) : 20 marks

Total for 4 : 100 marks

Question 5

5. (*a*) The procedure given below was followed to determine the partition coefficient, K_D of butanedioic acid (BDA, $HOOCCH_2CH_2COOH$) between ether and water at 25 °C.

Initially, 20 g of solid BDA was shaken well with a mixture of approximate volumes of 100 cm^3 of ether and 100 cm^3 of water in a reagent bottle and the layers were allowed to separate. At this stage, some undissolved BDA was seen remaining at the bottom of the reagent bottle. Thereafter, a 50.00 cm^3 volume of ether layer and a 25.00 cm^3 volume of water layer were titrated with 0.05 mol dm^{-3} NaOH solution. The volumes taken from the ether and water layers required 4.80 cm^3 and 16.00 cm^3 of the NaOH solution respectively.

(i) Calculate the partition coefficient, K_D for the distribution of butanedioic acid between ether and water at 25 °C.

(ii) Calculate the solubility of butanedioic acid in ether, given that the solubility of this acid in water is 8.0 g dm^{-3}.

(*b*) Consider the following reactions. Thermodynamic data supplied are **not** for the standard state.

	ΔH/kJ mol^{-1}	ΔS/J K^{-1} mol^{-1}
$C(s) + H_2O(g) \rightarrow CO(g) + H_2(g)$	130	140
$CO_2(g) + H_2(g) \rightarrow CO(g) + H_2O(g)$	40	50

(i) Calculate ΔH and ΔS for the reaction $2CO(g) \rightarrow C(s) + CO_2(g)$. State giving reasons whether the sign of ΔS agrees with the reaction taking place.

(ii) By means of a suitable calculation, predict whether the reaction given in part (i) above is spontaneous at 27 °C.

(*c*) An excess amount of C(s) and 0.15 mol of $CO_2(g)$ were placed in a closed rigid 2.0 dm^3 container and the system was allowed to reach equilibrium at a temperature of 689 °C. Once the equilibrium was achieved, the pressure in the container was found to be 8.0×10^5 Pa. (Take RT = 8000 J mol^{-1} at 689 °C)

(i) Write an expression for the equilibrium constant, K_p for the reaction $C(s) + CO_2(g) \rightleftharpoons 2CO(g)$.

(ii) Calculate K_p and K_c at 689 °C.

(iii) In another experiment, the container described above contains an excess of C(s) together with CO(g) and $CO_2(g)$ at 689 °C. The initial partial pressure of each gas is 2.0×10^5 Pa. Explain, with the aid of a calculation, the change in partial pressure of $CO_2(g)$ when the system reaches equilibrium.

5. (a) (i) $\frac{n_{butanedioic\ acid}}{n_{NaOH}} = \frac{1}{2}$ **or** for the identification of stoichiometry **(05)**

Butanedioic acid = BDA

Ether layer

$C_{BDA_ether} = \frac{1}{2} \times 0.05 \text{ mol dm}^{-3} \times 4.8 \text{ cm}^3 / 50.00 \text{ cm}^3$ **(03)**

$= 2.4 \times 10^{-3} \text{ mol dm}^{-3}$ **(04 + 01)**

Aqueous layer

$C_{BDA_aq} = \frac{1}{2} \times 0.05 \text{ mol dm}^{-3} \times 16.00 \text{ cm}^3 / 25.00 \text{ cm}^3$ **(02)**

$= 1.6 \times 10^{-2} \text{ mol dm}^{-3}$ **(04 + 01)**

$K_D = \frac{[BDA]_{ether}}{[BDA]_{aqueous}}$ **(05)**

$= 2.4 \times 10^{-3} \text{ mol dm}^{-3} / 1.6 \times 10^{-2} \text{ mol dm}^{-3} = 0.15$ **or** 3/20 **(04 + 01)**

or $K_D = \frac{[BDA]_{aqueous}}{[BDA]_{ether}}$

$= 1.6 \times 10^{-2} \text{ mol dm}^{-3} / 2.4 \times 10^{-3} \text{ mol dm}^{-3} = 6.67$ **or** 20/3

Note : Steps can be combined, award marks accordingly.

(ii) Solubility

$[BDA]_{ether} = K_D [BDA]_{Water}$ **(03)**

$= 2.\not{4} \times 10^{-3}\,mol\,dm^{-3}$ **(04 + 01)**

Consider a mixture having $1.0\,dm^3$ of ether layer and $1.0\,dm^3$ of aqueous layer.

$\frac{x}{M_{BDA}} = \frac{0.15(8.0\,g\,dm^{-3})}{M_{BDA}}$ **(05)**

$x = 1.\not{2}\,g\,dm^{-3}$ **(04 + 01)**

Note : Equation can be accepted without M_{BDA}.

5(a) : 40 marks

(b) (i) Write the two reactions as follows and add.

$CO(g) + H_2(g) \longrightarrow C(s) + H_2O(g)$ **(02)**

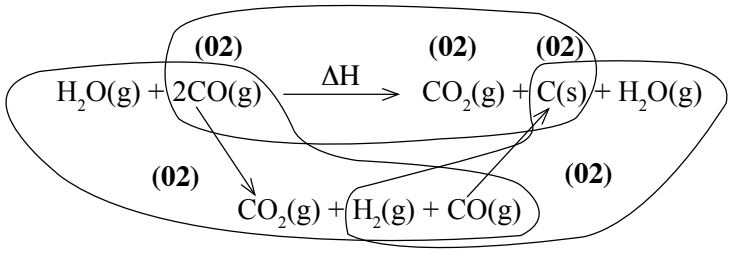
$CO(g) + H_2(g) \longrightarrow CO_2(g) + H_2(g)$ **(02)**

$2CO(g) \longrightarrow C(s) + CO_2(g)$

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

(Overall reaction must be generated by adding the two reactions for awarding marks)
(Physical states are required)

Alternate calculation using a thermodynamic cycle



$\Delta H = -130\,kJ\,mol^{-1} - 40\,kJ\,mol^{-1} = -170\,kJ\,mol^{-1}$ **(04 + 01)**

$\Delta S = -140\,J\,K^{-1}\,mol^{-1} - 50\,J\,K^{-1}\,mol^{-1} = -190\,J\,K^{-1}\,mol^{-1}$ **(04 + 01)**

(If standard states are written, do not award marks)

Sign of ΔS is negative. This agrees with the reduction of entropy, mainly due to the reduction of the number of moles of gases as the forward reaction progresses. **(05)**

(ii) Find ΔG at 27°C.

$\Delta G = \Delta H - T\Delta S$ **(02)**

(If standard states are written, do not award marks)

$\Delta G = -170\,kJ\,mol^{-1} - 300\,K^{-1}\,mol^{-1} \times (-190 \times 10^{-3}\,kJ\,K^{-1}\,mol^{-1})$ **(04 + 01)**

$\Delta G = -113\,kJ\,mol^{-1}$ **(04 + 01)**

Forward reaction is spontaneous. **(03)**

(Calculation must be shown for last 03 marks)

5(b) : 40 marks

(c) $C(s) + CO_2(g) \rightleftharpoons 2CO(g)$

(i) $K_P = \dfrac{P^2_{CO}}{P_{CO_2}}$ **(05)**

(ii)

	C(s)	+	$CO_2(g)$	$\rightleftharpoons$	$2CO(g)$
initial (mol)			0.15		
At equilibrium (mol)			$0.15 - x$		$2x$

(05)

Total number of gas moles = $0.15 - x$ **(04 + 01)**

Apply PV = nRT assuming ideal behavioue.

$0.15 - x = \dfrac{8.0 \times 10^5\,\text{Pa}\, 2.0 \times 10^{-3}\,\text{m}^3}{8.0 \times 10^5\,\text{J mol}^{-2}}$ **(04 + 01)**

$x = 0.05\,\text{mol}$ **(04 + 01)**

$n_{CO} = 0.1\,\text{mol}$ **(03)** $\quad n_{CO_2} = (0.15 - 0.05)\,\text{mol} = 0.10\,\text{mol}$ **(02)**

Therefore,

$P_{CO} = 2 \times 0.05 \times 8.0 \times 10^5\,\text{Pa} / 0.2 = 4.0 \times 10^5\,\text{Pa}$ **(04 + 01)**

$P_{CO_2} = 0.1 \times 8.0 \times 10^5\,\text{Pa} / 0.2 = 4.0 \times 10^5\,\text{Pa}$ **(04 + 01)**

$K_P = \dfrac{(4.0 \times 10^5\,\text{Pa})^2}{4.0 \times 10^5\,\text{Pa}}$ **(04 + 01)**

$= 4.0 \times 10^5\,\text{Pa}$ **(04 + 01)**

Alternate calculation

$n_{total} = 0.20\,\text{mol}, \therefore X_{CO} = X_{CO_2} = 1/2$ **(05)**

$P_{CO} = 8 \times 10^3 \times 1/2 = 4 \times 10^5\,\text{Pa}$ **(04 + 01)**

$P_{CO_2} = 8 \times 10^3 \times 1/2 = 4 \times 10^5\,\text{Pa}$ **(04 + 01)**

$K_P = (4 \times 10^5\,\text{Pa})^2 \,/\, 4 \times 10^5\,\text{Pa}$ **(04 + 01)**

$K_P = 4 \times 10^5\,\text{Pa}$ **(04 + 01)**

$K_C = K_P(RT)^{-\Delta n}$ **or** $K_P = K_C(RT)^{-\Delta n}$ **(03)**

$\Delta n = 1$ **(02)**

$K_C = 4.0 \times 10^5\,\text{Pa} \times (8 \times 10^3\,\text{J mol}^{-1})^{-1}$

$K_C = 50\,\text{mol m}^{-3}$ **or** $0.05\,\text{mol dm}^{-3}$ **(04 + 01)**

Alternate calculation

$K_C = [CO]^2 \,/\, [CO_2]$ **(05)**

$= [0.10 \,/\, (2 \times 10^{-3})]^2 \,/\, [0.10 \,/\, (2 \times 10^{-3})]$

$= 50\,\text{mol m}^{-3}\ (0.05\,\text{mol dm}^{-3})$ **(04 + 01)**

(iii) Calculate Q using the pressures.

$Q = \dfrac{(2.0 \times 10^5\,\text{Pa})^2}{2.0 \times 10^5\,\text{Pa}} = 2.0 \times 10^5\,\text{Pa}$ **(05)**

Q is smaller than K_P, Therefore P_{CO_2} decreases and P_{CO} increases until $Q = K_P$. **(05)**

Alternate calculation

C(s)	+	$CO_2(g)$	$\rightleftharpoons$	$2CO(g)$	
		$2 \times 10^5 - x$		$2 \times 10^5 + 2x$	Pressures (Pa)

$K_P = 4.0 \times 10^5 = \dfrac{(2 \times 10^5 + 2x)^2}{2.0 \times 10^5 - x}$ **(05)**

Solving the quadratic equation and predicting the P_{CO_2} decreases and P_{CO} increases. **(05)**

5(c) : 70 marks

Total for 5 : 150 marks

Question 6

6. (*a*) A 0.10 mol dm^{-3} solution of a weak acid, **HA** was prepared by diluting an appropriate amount of the pure weak acid to 25.00 cm^3 with distilled water in a volumetric flask at 25 °C. The pH of this solution was 3.0.

(i) Considering the equation, **HA**(aq) + $H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)$, calculate the dissociation constant, K_a of the weak acid.

(ii) A dilute solution of this weak acid, **HA** was titrated with a strong base, **BOH**. It was found that the pH of the titration mixture after reaching the equivalence point was 9.0. Calculate the concentration of the salt, **AB** in the titration mixture. ($K_w = 1.0 \times 10^{-14}$ mol^2 dm^{-6} at 25 °C)

(iii) The above titration mixture was diluted hundred times by adding distilled water. Calculate the pH of the diluted titration mixture.

(*b*) AgBr(s) is a pale-yellow coloured salt sparingly soluble in water.
Its solubility product, K_{sp} is 5.0×10^{-13} mol^2 dm^{-6} at 25 °C.

(i) Calculate the concentration of $Ag^+(aq)$ in a saturated solution of AgBr in equilibrium with solid AgBr at 25 °C.

(ii) Solid AgBr together with 100.0 cm^3 of the solution described in part (i) above were placed in a beaker. A volume of 100.0 cm^3 of distilled water was added to the beaker and the mixture was stirred well until the equilibrium is reached. At this stage, some solid AgBr was still left at the bottom of the beaker. What could be the concentration of $Ag^+(aq)$ in this solution? Explain your answer.

(iii) Using a suitable calculation, predict the observation expected when 10.0 cm^3 of a 1.5×10^{-4} mol dm^{-3} $AgNO_3$ solution and 5.0 cm^3 of a 6.0×10^{-4} mol dm^{-3} NaBr solution are mixed at 25 °C.

(*c*) (i) The pressure of the vapour phase in equilibrium with an ideal binary solution is *P*. The liquid phase mole fractions of the two components are X_1 and X_2, and their respective saturated vapour pressures are P_1^0 and P_2^0. Show that

$$X_1 = \frac{P - P_2^0}{P_1^0 - P_2^0}.$$

(ii) The pressure of the vapour phase in equilibrium with a binary solution containing methanol and ethanol is 4.5×10^4 Pa at 50 °C. At this temperature the saturated vapour pressures of methanol and ethanol are 5.5×10^4 Pa and 3.0×10^4 Pa respectively. Consider that the solutions behave ideally.

I. Calculate the mole fractions of methanol and ethanol in the liquid phase.

II. Calculate the mole fractions of methanol and ethanol in the vapour phase.

(iii) Based on the above calculations and given information, draw the vapour pressure - composition diagram of the methanol - ethanol mixture at 50 °C. Consider that the solutions behave ideally.

6. (a) (i) pH = 3. 0

$[H^+]$ = 1. 0 × 10^{-3} mol dm^{-3} **(04 + 01)**

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

$$K_a = \frac{[H_3O^+(aq)][A^-(aq)]}{[HA(aq)]}$$ **(02)**

(Physical states are required)

$$= \frac{(1.0 \times 10^{-3}\,mol\,dm^{-3})^2}{0.10\,mol\,dm^{-3}}$$ **(02 + 01)**

= 1. 0 × 10^{-5} mol dm^{-3} **(02 + 01)**

(ii) pH at the equivalance point is determined by the degree of hydrolysis of the salt.

Consider,

$A^-(aq) + H_2O(l) \rightleftharpoons HA(aq) + OH^-(aq)$ **(05)**

$$\frac{K_a}{K_w} = \frac{\frac{[H_3O^+(aq)][A^-(aq)]}{[HA(aq)]}}{[H_3O^+(aq)][OH^-(aq)]}$$

At the equivalance point $[HA(aq)] \approx [OH^-(aq)]$

$$\frac{K_a}{K_w} = \frac{[A^-(aq)]}{[OH^-(aq)]^2}$$

$$[OH^-(aq)] = \left[[A^-(aq)]\frac{K_w}{K_a}\right]^{1/2} \text{ ——— (1)}$$ **(05)**

At the equivalance point $[A^-(aq)] = [salt]$

Since pH = 9. 0 at the equivalance point, $[OH^-] = 10^{-5}\,mol\,dm^{-3}$ **(02)**

$$[salt] = ([OH^-(aq)])^2 \frac{K_a}{K_w}$$

$$[salt] = ([1.0 \times 10^{-5}\,mol\,dm^{-3}])^2 \frac{1.0 \times 10^{-5}\,mol\,dm^{-3}}{1.0 \times 10^{-14}\,mol^2\,dm^{-6}}$$ **(04 + 01)**

$$= 0.\ mol\,dm^{-3}$$ **(04 + 01)**

(iii) When the titration mixture at the equivalance point is100 times diluted,

(The salt concentration is decreased by100 times)

Using the equation - (1)

$$[OH^-(aq)]_{new} = \left[\frac{[A^-(aq)]}{100}\frac{K_w}{K_a}\right]^{1/2}$$ **(05)**

$$[OH^-(aq)]_{new} = \frac{1}{10}\left[\frac{[A^-(aq)]}{1}\frac{K_w}{K_a}\right]^{1/2}$$

$$[OH^-(aq)]_{new} = \frac{1}{10}\left[\frac{[0.\ mol\,dm^{-3}]}{1}\frac{1 \times 10^{-14}\,mol^2\,dm^{-6}}{1 \times 10^{-5}\,mol\,dm^{-3}}\right]^{1/2}$$ **(04 + 01)**

$[OH-(aq)] = 1.0 \times 10^{-6}\,mol\,dm^{-3}$

$[H3O+(aq)] = 1.0 \times 10^{-8}\,mol\,dm^{-3}$

Therefore, pH = 8.0 **(05)**

Alternate calculation

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

$c(1-\alpha)$ $c\alpha$ $c\alpha$

By Ostwalds law,

$$K_b = \alpha^2 c = \frac{\alpha^2 c^2}{c} = \frac{[OH^-]^2}{c}$$

$$[OH^-] = \sqrt{K_b c} = \sqrt{\frac{K_a}{K_w} c} \quad \textbf{(05)}$$

$[\text{salt}] = [A^-] = c = 0.1\,\text{mol dm}^{-3}/100$

$$[OH^-] = \sqrt{\frac{1 \times 10^{-14}\,\text{mol}^2\,\text{dm}^{-6}}{1 \times 10^{-5}\,\text{mol dm}^{-3}} \times \frac{1 \times 10^{-1}\,\text{mol dm}^{-3}}{100}} = 1 \times 10^{-6}\,\text{mol dm}^{-3} \quad \textbf{(04 + 01)}$$

pOH = 6. 0

pH = 8. 0 **(05)**

6(a) : 50 marks

(b) (i) $AgBr(s) \rightleftharpoons Ag^+(aq) + Br^-(aq)$ **(05)**

$K_{SP} = [Ag^+(aq)][Br^-(aq)]$ **(03)**

$[Ag^+(aq)] = [Br^-(aq)] = x$

$K_{SP} = x^2$ **(02)**

Therefore, $[Ag^+(aq)] = (5.0 \times 10^{-13})^{1/2}$

$= 7.\ 07 \times 10^{-7}\,\text{mol dm}^{-3}$ **or** $7.\ 1 \times 10^{-7}\,\text{mol dm}^{-3}$ **(04 + 01)**

(ii) The solution is a saturated solution of AgBr. **(05)**

Therefore, $[Ag^+(aq)]$ is as same as above, $7.\ 07 \times 10^{-7}\,\text{mol dm}^{-3}$ **(05)**

(iii) The product of concentrations of Ag^+ and Br^- must be calculated and compared with K_{SP}.

$[Ag^+(aq)] = 1.\ 5 \times 10^{-4}\,\text{mol dm}^{-3} \times 10.\ 00\,\text{cm}^3/15.\ 00\,\text{cm}^3$

$= 1.\ 0 \times 10^{-4}\,\text{mol dm}^{-3}$ **(04 + 01)**

$[Br^-(aq)] = 6.\ 0 \times 10^{-4}\,\text{mol dm}^{-3} \times 5.\ 00\,\text{cm}^3/15.\ 00\,\text{cm}^3$

$= 2.\ 0 \times 10^{-4}\,\text{mol dm}^{-3}$ **(04 + 01)**

$[Ag^+(aq)] \times [Br^-(aq)] = 2.\ 0 \times 10^{-8}\,\text{mol}^2\,\text{dm}^{-6} > K_{SP}$ **(10)**

[or any other correct approach]

Therefore, AgBr will precipitate (slightly yellow orecipitate will form) **(05)**

6(b) : 50 marks

(c) (i) Applying Raoult's law to the ideal binary mixture,

$P_i = x_i P^0_i$ **(05)**

$P = P_1 + P_2$ **(05)**

$P = x_1 P^0_1 + x_2 P^0_2$ **(05)**

$x_2 = 1 - x_1$

$P = x_1 P^0_1 + (1 - x_1) P^0_2$

$x_1 = \dfrac{(P_1 - P^0_2)}{(P^0_1 - P^0_2)}$ **(05)**

(ii) I Mole fractions in the liquid phase,

$x_{meOH} = (4.\ 5 - 3.\ 0) \times 10^4 Pa \,/\, (5.\ 5 - 3.\ 0) \times 10^4 Pa = 0.\ 6$ **(04 + 01)**

$x_{etOH} = 1 - 0.\ 6 = 0.\ 4$ **(04 + 01)**

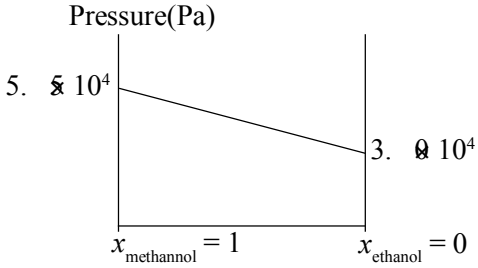
II Mole fractions in the gas phase,

$x_{methannol_gas} = 0.\ 6 \times 5.\ 5 \times 10^4 Pa \,/\, 4.\ 5 \times 10^4 Pa = 0.\ 73$ **(04 + 01)**

$x_{ethanol_gas} = 1.\ 0 - 0.\ 73 = 0.\ 27$ **(04 + 01)**

(Answers can be given as fractions)

(iii) Pressure composition diagram (ideal mixture)



mole fractions on horizontal axis **(02)**

Saturated vapour pressures corresponding to mole fractions **(04)**

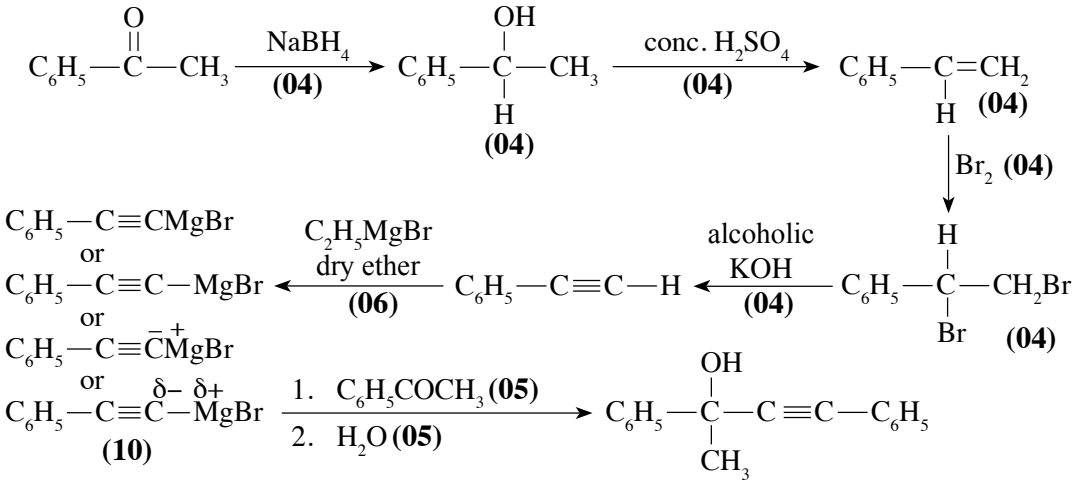
Straight line showing P total with correct slope **(04)**

Note : If more than one line is drawn, P total line must be labeled.

6(c) : 50 marks

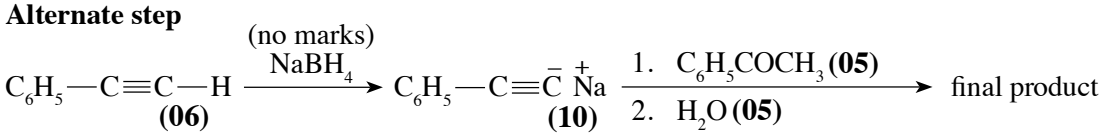
Total for 6 : 150 marks

7. (a)

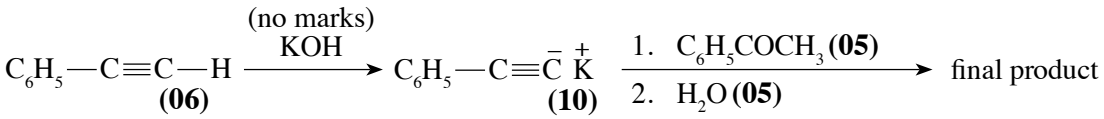


Note : Disregard reaction medium of $NaBH_4$.

Alternate step

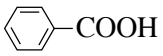
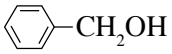
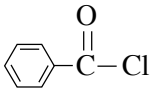
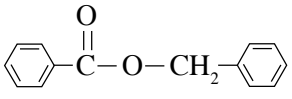
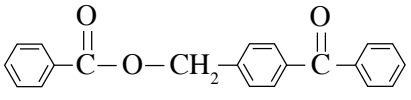


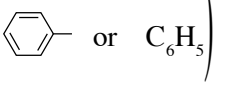
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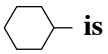
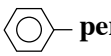


7(a) : 60 marks

(b)

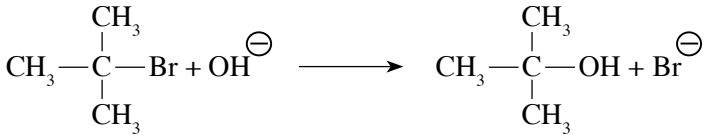
R_1	$KMnO_4 / H^+$ or $K_2Cr_2O_7 / H^+$ or CrO_3	**(06)**	**X_1**		**(07)**
R_2	$LiAlH_4$	**(06)**	**X_2**		**(07)**
R_3	H^+ or dil. HCl or dil. H_2SO_4 or H_2O	**(05)**	**X_3**		**(07)**
R_4	PCl_5 or PCl_3 or $SOCl_2$	**(06)**	**X_4**		**(07)**
R_5	conc. H_2SO_4 or $SOCl_2$	**(06)**	**X_5**		**(07)**

R_6 anhydrous $AlCl_3$ **(06)** ( or C_6H_5) **(07)**

Note : For X_1 to X_4, if  **is given instead of**  **penalize only once.**
For X_5, all aromatic rings must be shown for award of marks.

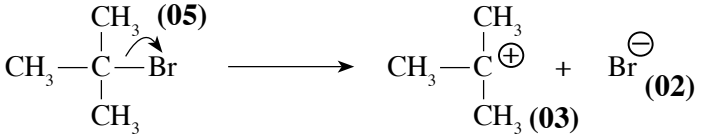
7(b) : 70 marks

(c) (i)



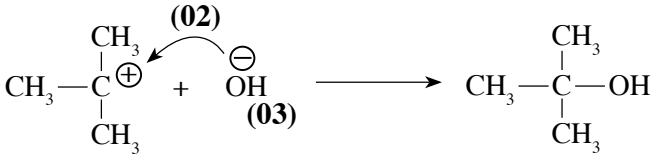
A **B**

Step I



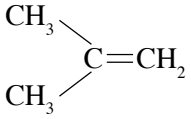
(05) **(02)** **(03)**

Step II



(02) **(03)**

(ii)



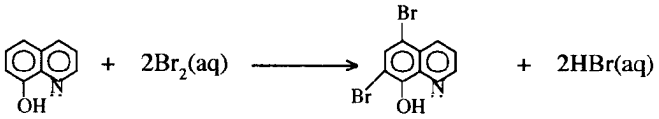
(05)

7(c) : 20 marks

Total for 7 : 150 marks

$KBrO_3$ is a primary standard for the generation of Br_2 in acidic medium.

$$BrO_3^-(aq) + 5Br^-(aq) + 6H^+(aq) \longrightarrow 3\ Br_2(aq) + 3H_2O(l)$$



The excess Br_2 is reacted with KI to give I_3^-. Then I_3^- was titrated with 0.05 mol dm^{-3} $Na_2S_2O_3$ using starch as the indicator. The volume of $Na_2S_2O_3$ required to reach the end point was 15.00 cm^3.
Calculate the concentration of Al^{3+} in solution **U** in mg dm^{-3}. (Al = 27)

8. (a) (i) A : $CrCl_3$ **or** $CrCl_3.H_2O$ **or** $[Cr(H_2O)_6]3Cl^-$

B : Na_2CrO_4

C : $Na_2Cr_2O_7$

D : $(NH_4)_2Cr_2O_7$

E : Cr_2O_3 **(Award (05) for any chromium compound)**

F : N_2

G : Ca_3N_2

H : NH_3

I : H_2

(05 × 9 = 45 marks)

(ii) Orange solution C turns yellow **(01 + 01)**

$Cr_2O_7 + 2OH^- \longrightarrow 2CrO_4^{2-} + H_2O$ **(03)**

8(a) : 50 marks

(b) (i) T Contains : Cu^{2+}, Ni^{2+}, Ba^{2+} **(10 + 10 + 10)**

(ii) Q_1 : CuS Q_2 : NiS Q_3 : $BaCO_3$ **(07 + 07 + 06)**

Note : (i) charges are required. (ii) mark independently.

8(b) : 50 marks

(c) $I_3^- + 2S_2O_3^{2-} \longrightarrow S_4O_6^{2-} + 3I^-$ **or** $I_2 + 2S_2O_3^{2-} \longrightarrow S_4O_6^{2-} + 2I^-$ **(02)**

$Br_2 + 2I^- \longrightarrow I_2 + 2Br^-$ **(02)**

Moles of $S_2O_3^{2-}$ $= \frac{0.05}{1000} \times 15.0$ **(03)**

Therefore, moles of I_2 $= \frac{1}{2} \times \frac{0.05}{1000} \times 15.0$ **(03)**

Therefore, moles of excess Br_2 $= \frac{1}{2} \times \frac{0.05}{1000} \times 15.0$ **(03)**

$= 3.75 \times 10^{-4}$ **(02)**

$BrO_3^- + 5Br^- + 6H^+ \longrightarrow 3Br_2 + 3H_2O$

Moles of BrO_3^- $= \frac{0.025}{1000} \times 25.0$ **(03)**

Therefore, moles of Br_2 produced by the above reaction

$= 3 \times \frac{0.025}{1000} \times 25.0$ **(03)**

$= 18.75 \times 10^{-4}$ **(02)**

Amount of Br_2 reacted with oxine $= (18.75 \times 10^{-4}) - (3.75 \times 10^{-4})$ **(03)**

$= 15 \times 10^{-4}$ **(02)**

Therefore, moles of oxine $= \frac{1}{2} \times 15 \times 10^{-4}$ **(03)**

$= 7.5 \times 10^{-4}$ **(02)**

Therefore, moles of Al^{3+} $= \frac{1}{3} \times 7.5 \times 10^{-4}$ **(03)**

$= 2.5 \times 10^{-4}$ **(02)**

$[Al^{3+}]$ $= \frac{2.5 \times 10^{-4}}{25.0} \times 1000 \,\text{mol dm}^{-3}$ **(03)**

$= \frac{2.5 \times 10^{-4}}{25.0} \times 1000 \times 27 \,\text{g dm}^{-3}$ **(03)**

$= \frac{2.5 \times 10^{-4}}{25.0} \times 1000 \times 27 \times 1000 \,\text{mg dm}^{-3}$ **(03)**

$= 270 \,\text{mg dm}^{-3}$ **(03)**

8(c) : 50 marks

Total for 8 : 150 marks

9. (a) (i) R_1 : Sea water **(03)**

R_2 : Oil / Fats / Coconut oil / Vegetable oil **(03)**

(ii) M_1 : Manufacture of salt **(03)**

M_2 : Manufacture of NaOH **(03)**

M_3 : Manufacture / extraction of Na (Downs cell method) **(03)**

M_4 : Manufacture of soap **(03)**

(iii) P_1 : NaCl **(03)**

P_2 : Bittern solution / Mother liquor / $MgBr_2$ **(03)**

P_3 : NaOH **(03)**

P_4 : Cl_2 **(03)**

P_5 : H_2 **(03)**

P_6 : Na **(03)**

P_7 : NOCl / Milton solution **(03)**

P_8 : Soap **(03)**

P_9 : Glycerol / Glycerine **(03)**

(iv) **Process M_1**

Sea water evaporated in three tanks **(01)**

1st tanks : $CaCO_3$ precipitates **(01)** Remaining solution transferred to 2nd tank. **(01)**

2nd tank : $CaSO_4$ precipitates **(01)** Remaining solution transferred to 3rd tank. **(01)**

3rd tank : NaCl precipitates **(01)** Remaining solution (Bittern) is removed. **(01)**

Note : Explanation could be given as a diagram.

Process M_3

Electrolysis of molten NaCl with added $CaCl_2$ **(01)**

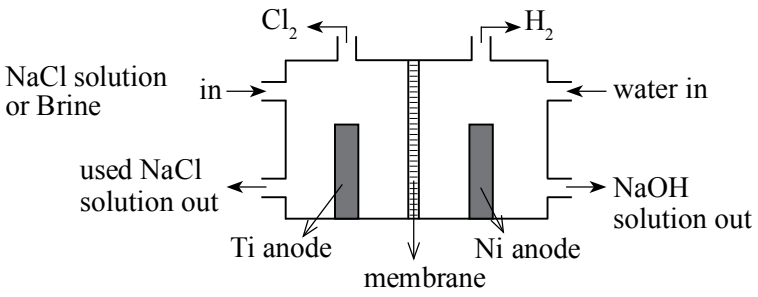
At the cathode $Na^+(l) + e \longrightarrow Na(l)$ **(02)**

At the anode $2Cl^-(l) \longrightarrow Cl_2(g) + 2e$ **(02)**

Cathode and anode are separated by a steel gauze diaphragm to prevent Na from reacting with Cl_2 gas **(02)**

Note : Physical states are required in equations.

(v)

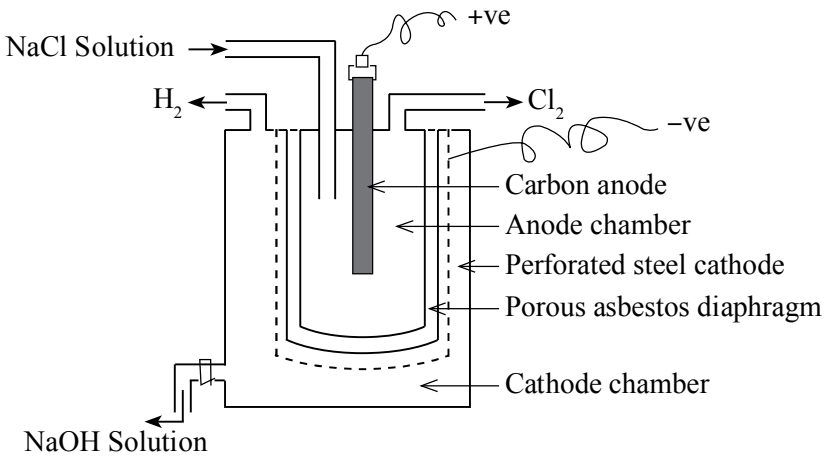


Note : Mark independently.

(01 marks × 9 + 01 for correct sketch of cell = 10 marks)

Alternate answer :

Diaphragm Cell



(01 marks × 9 + 01 for correct sketch of cell = 10 marks)

(vi) $CaCl_2$ **(03)**

(vii) P_5 : fuel / to manufacture HCl / to manufacture margarine / in weather balloons/ manufacture of NH_3 **(01)**

P_6 : Sodium vapour lamps/ synthesis of $NaNH_2$ / to dry organic solvents / as a coolant in nuclear reactors **(01)**

P_9 : to manufacture cosmetics / to manufacture TNG (explosives) **(01)**

9(a) : 75 marks

(b) (i) NO_2, SO_2, NO **(02 + 02)**

From NO :

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

$4NO_2(g) + O_2(g) + 2H_2O(l) \longrightarrow 4HNO_3(aq)$ **(02)**

$HNO_3(aq) \longrightarrow H^+(aq) + NO_3^-(aq)$ **(01)**

From NO_2 :

$4NO_2(g) + O_2(g) + 2H_2O(l) \longrightarrow 4HNO_3(aq)$ **(03)**

$HNO_3(aq) \longrightarrow H^+(aq) + NO_3^-(aq)$ **(02)**

From SO_2 :

$2SO_2(g) + O_2(g) \longrightarrow 2SO_3(g)$ **(02)**

$SO_3(g) + 2H_2O(l) \longrightarrow H_2SO_4(aq)$ **(02)**

$H_2SO_4(aq) \longrightarrow 2H^+(aq) + SO_4^{2-}(aq)$ **(01)**

or

$2SO_2(g) + O_2(g) + 2H_2O(l) \longrightarrow 2H_2SO_4(aq)$ **(03)**

$H_2SO_4(aq) \longrightarrow 2H^+(aq) + SO_4^{2-}(aq)$ **(02)**

(Generation of acid rain by any two sets of reactions given above, 05 marks × 2 = 10marks)

Note : Physical states are not required.

(ii) Points to be included :

- Damage to plants
- HNO_3/H_2SO_4 dissolves aluminosilicates on Earth to give free Al^{3+}which leaches into water and interferes with the operation of fish gills resulting in the death of fish.
- Washes out nutrients from soil
- Degrades metallic structures (e. g. vehicles, bridges, buildings, statues)
- Hardness of water increases
- Concentration of heavy metals in water increases
- Composition of Earth's surface changes (e. g. due to solubility of dolomite, limestone, marble, sand and rock /oxidation of minerals such as sulfides)

Any five (02 marks × 5 = 10 marks)

(iii) SO_2, NO, NO_2, CO_2, Volatile hydrocarbons **(any three)** **(02 + 02 + 02)**

Global warming - CO_2, Volatile hydrocarbons **(02 + 01)**

Acid rain - SO_2, NO **(02 + 01)**

Photochemical smog - NO, hydrocarbons **(02 + 01)**

(iv)

- CFCs are industrial gases that are used as coolants in refrigerators, air conditioners and spray cans.
- CFCs are released into the atmosphere during usage and repair of these equipment.
- CFCs are highly stable trace gasses in the atmosphere.
- Therefore, CFCs are persistent gasses in the atmosphere.

and

- CFCs produce in the higher atmosphere (stratosphere) in the presence of high energy UV radiation.
- The increases the rate of depletion of ozone by acting as a catalyst.
- The reduction of ozone allows harmful UV rays to reach the surface of the planet.
- Exposure to harmful UV radiation results in cancers, gene mutations and cataracts.

or

- CFC is a strong greenhouse gas.
- CFCs contribute to global warming.
- CFCs absorb IR radiation emitted from the surface of the planet.
- Global warming results in climate change.

(02 × 8 = 10 marks)

(v) CO_2 : (fossil) fuel burning **(01 + 01)**

CH_4 : wet land agriculture/ animal farms/ improper waste disposal **(01 + 01)**

NO_2 : Burning at high temperatures **(01 + 01)**

CFCs : air conditioners/ refrigerators/ spray guns **(01 + 01)**

N_2O : agriculture (use of nitrogen fertilizer) **(01 + 01)**

H_2S : Anaerobic digestion of sulfur containing substances such as coconut husks **(01 + 01)**

SO_2 : fossil fuel burning **(01 + 01)**

Volatile hydrocarbons – fossil fuel burning , natural gas extraction, transportation **(01 + 01)**

Any five (02 × 5 = 10 marks)

(vi) Limestone ($CaCO_3$) decomposes to get CaO (lime) and CO_2. **(02)**

$CaCO_3 \xrightarrow{\Delta} CaO + CO_2$ **(03)**

CaO then reacts with the SO_2 **(02)**

$CaO + SO_2 \longrightarrow CaSO_3$ **(03)**

Note : If only equation is given 05 marks

or

Slurry of lime stone is used to absorb or scrub SO_2. **(05)**

$CaCO_3 + SO_2 \longrightarrow CaSO_3 + CO_2$ **(05)**

9(b) : 75 marks

Total for 9 : 150 marks

10. (a) (i) SCN^- / NCS^- and H_2O **(05 + 05)**

(ii) AgI **(05)**

(iii) Based on the atomic composition;

coordination sphere of X : $[Fe(H_2O)_5(SCN)]$ or $[Fe(SCN)(H_2O)_5]$ **(05)**

coordination sphere of Y : $[Fe(H_2O)_4(SCN)_2]$ or $[Fe(SCN)_2(H_2O)_4]$ **(05)**

coordination sphere of Z : $[Fe(H_2O)_3(SCN)_3]$ or $[Fe(SCN)_3(H_2O)_3]$ **(05)**

Note: (NCS) could be used instead of (SCN). Could be written as either H_2O or OH_2.

Number of moles of each compound (i. e. X, Y, Z) in 100 cm^3 = (0. 1/1000) × 100

= 0. 01 **(05)**

Relative molecular mass of AgI = 235

Therefore, number of moles of AgI (or I^-) in the precipitate = 7. 05/235 = 0. 03 **(05)**

If oxidation state of Fe is +3 ;

X : Charge of complex is +2. Hence, two I **(02)**

Y : Charge of complex is +1. Hence, one I **(02)**

Z : Complex has no charge. Hence, no I **(02)**

Therefore, oxidation state of Fe has to be +3. **(04)**

or

If oxidation state of Fe is +2;

X : Charge of complex is +1. Hence, one I **(02)**

Y : Charge of complex is zero. Hence, will not have any I **(02)**

Z : Charge of complex is –1. Hence, will not have any I **(02)**

Therefore, oxidation state of Fe cannot be +2. It has to be +3. **(04)**

Structural formulae:

X : $[Fe(H_2O)_5(SCN)]I_2$ or $[Fe(SCN)(H_2O)_5]I_2$ **(05)**

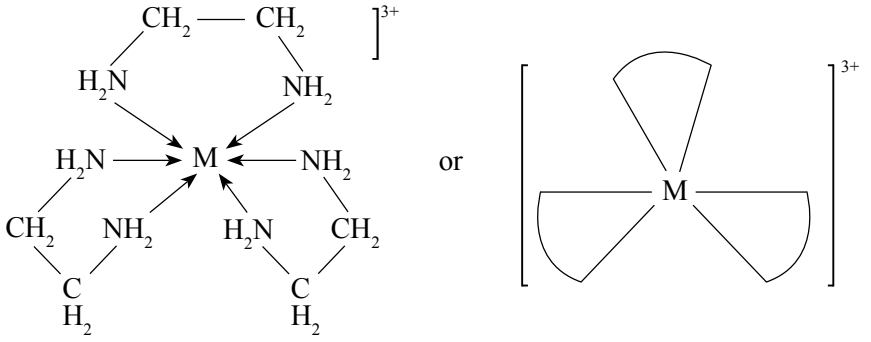
Y : $[Fe(H_2O)_4(SCN)_2]I$ or $[Fe(SCN)_2(H_2O)_4]I$ **(05)**

Z : $[Fe(H_2O)_3(SCN)_3]$ or $[Fe(SCN)_3(H_2O)_3]$ **(05)**

Note:

- **(NCS) could be used instead of (SCN). No marks for (CNS) / CSN). H_2O could be written as OH_2.**
- **If the coordination spheres of X, Y, Z are not written but the structural formulae of X, Y, Z are written, award the (05 + 05 + 05) for the correct structural formulae and the marks allocated for the respective coordination sphere (05 + 05 + 05).**

(iv) $(M(en_3)^{3+}$ **(05)**

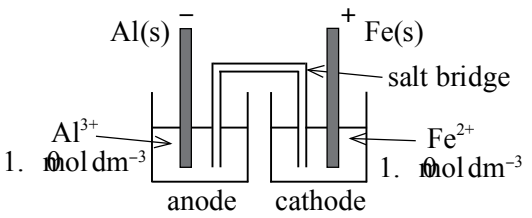


(05)

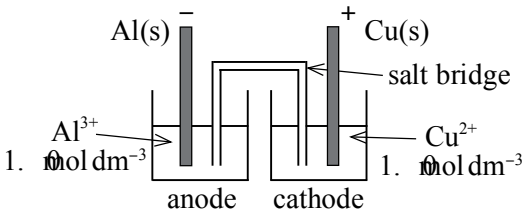
Note : Charge of the complex is required for the award of marks.

10(a) : 75 marks

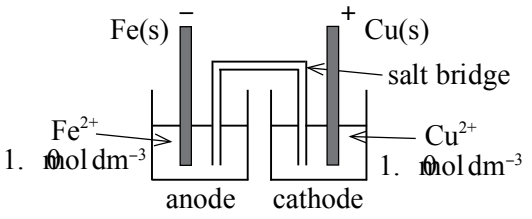
(b) (i)



A



B



C

For each electrode;

Display and identification of metal strip	**(01)**
Identification of the solution	**(01)**
Display of correct charge	**(01)**
Correct labeling as anode or cathode	**(01)**
Display of the salt bridge	**(01)**

Note : Mark each electrode individually, If a voltmeter is drawn, do not deduct marks.
If a battery or an external voltage source is connected, do not award marks.
If the electrodes are connected by a wire deduct 02 marks.

(27 marks for 3 cells)

(ii) I. Cell A : $Al(s)|Al^{3+}(aq, 1.0 mol\ dm^{-3})||Fe^{2+}(aq, 1.0 mol\ dm^{-3})|Fe(s)$ **(02)**

Cell B : $Al(s)|Al^{3+}(aq, 1.0 mol\ dm^{-3})||Cu^{2+}(aq, 1.0 mol\ dm^{-3})|Cu(s)$ **(02)**

Cell C : $Fe(s)|Fe^{2+}(aq, 1.0 mol\ dm^{-3})||Cu^{2+}(aq, 1.0 mol\ dm^{-3})|Cu(s)$ **(02)**

II. $E^0_{cell} = E^0_{cathode} - E^0_{anode}$ හෝ $E^0_{cell} = E^0_{RHS} - E^0_{LHS}$ **(03)**

Cell A

$E^0_{cell} = -0.44 V - (-1.66 V)$ **(02)**

$= 1.22 V$ **(01 + 01)**

Cell B

$E^0_{cell} = 0.34 V - (-1.66 V)$ **(02)**

$= 2.00 V$ **(01 + 01)**

Cell B

$E^0_{cell} = 0.34 V - (-0.44 V)$ **(02)**

$= 0.78 V$ **(01 + 01)**

III. Cell A : $Al(s) \rightleftharpoons Al^{3+}(aq) + 3e$ **(01)**

$Fe^{2+}(aq) + 2e \rightleftharpoons Fe(s)$ **(01)**

Cell B : $Al(s) \rightleftharpoons Al^{3+}(aq) + 3e$ **(01)**

$Cu^{2+}(aq) + 2e \rightleftharpoons Cu(s)$ **(01)**

Cell C : $Fe(s) \rightleftharpoons Fe^{2+}(aq) + 2e$ **(01)**

$Cu^{2+}(aq) + 2e \rightleftharpoons Cu(s)$ **(01)**

Note : Do not award marks if $\longrightarrow$ is used instead of $\rightleftharpoons$ Physical states are required.

(iii) $NaOH$ - not suitable, metal hydroxides can be formed. **(02)**

$NaNO_3$ - suitable, good ionic conductivity OR
(not suitable because ionic conductivities of Na^+ and NO_3^- are different) **(02)**

Acetic acid - not suitable, weakly ionized, low conductivity **(02)**

Alternate answer - 1

None of the given compound is suitable. **(03)**

$NaOH$ - metal hydroxide can be formed **(01)**

$NaNO_3$ - mobility / conductivity of two ions are different **(01)**

Acetic acid - weakly ionized / low conductivity **(01)**

Alternate answer - 2

Only $NaNO_3$ is suitable **(03)**

Due to its good ionic conductivity, does not participate in electrode reactions **(03)**

(iv) Selection of the correct pair of electrodes **(03)**

$2Al(s) + 3Cu^{2+}(aq) \longrightarrow 2Al^{3+}(aq) + 3Cu(s)$ **(02)**

(Physical states and stoichiometry must be correct.)

Initial ($mol\,dm^{-3}$)	1. 0	1. 0
After time, t ($mol\,dm^{-3}$)	$(1-3x/V)$	$(1+2x/V)$

Where V= Volume **(02)** **(02)**

$[Al^{3+}] = 1+2x/V = c$ **(03)**

$x/V = (c-1)/2$

$[Cu^{2+}] = 1-3(c-1)/2$ **(03)**

$= (5-3c)/2$

or

Selection of the correct pair of electrodes **(03)**

Assume the concentration of $[Al^{3+}]$ increased during time t = $c_1\,mol\,dm^{-3}$

Then $[Al^{3+}] = 1 + c_1 = c$ **(03)**

Concentration of $[Cu^{2+}]$ increased during time = $3c_1/2\,mol\,dm^{-3}$ **(03)**

Therefore $[Cu^{2+}] = 1-3c_1/2$ **(03)**

$= 1-3(c-1)/2$ **(03)**

$= (5-3c)/2$

10(b) : 75 marks

Total for 10 : 150 marks