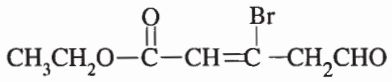
2.1.2 Paper I

1. The highest oxidation state and the outer electron configuration of the ground state of chromium respectively are
   (1) +3 and $[Ar]3d^4 4s^2$ (2) +4 and $[Ar]3d^5 4s^1$ (3) +6 and $[Ar]3d^4 4s^2$
   (4) +4 and $[Ar]3d^6 4s^0$ (5) +6 and $[Ar]3d^5 4s^1$

2. The **increasing** order of the first ionization energy of atoms N, Ne, Na, P, Ar and K is
   (1) Na < K < P < N < Ar < Ne (2) Na < K < Ar < N < P < Ne
   (3) P < N < K < Na < Ne < Ar (4) K < Na < N < P < Ne < Ar
   (5) K < Na < P < N < Ar < Ne

3. What is the IUPAC name of the following compound?



   (1) 3–bromo–5–ethoxy–5–oxo–3–pentenal (2) ethyl–3–bromo–5–oxopent–2–enoate
   (3) ethyl 3–bromo–2–en–5–oxopentanoate (4) ethyl 3–bromo–5–oxo–2–pentenoate
   (5) 3–bromo–1–ethoxy–5–oxo–2–pentenal

4. When the compound **X** having C, H, O only was treated with excess acetylchloride a compound having a relative molecular mass 126 units higher than that of **X** was obtained. The number of hydroxyl groups in **X** is
   (1) 1 (2) 2 (3) 3 (4) 4 (5) 5

5. The number of atomic orbitals possible for which the quantum numbers $n = 3$ and $m_l = -1$ is
   (1) 1 (2) 2 (3) 3 (4) 4 (5) 5

6. The electron pair geometry and the molecular shape of XeO_2F_2 respectively, are
   (1) trigonal bipyramid and see-saw. (2) trigonal bipyramid and tetrahedral.
   (3) tetrahedral and see-saw. (4) see-saw and trigonal bipyramid.
   (5) square planar and tetrahedral.

7. A mixture of Fe_2O_3 and FeO is found to contain 72.0% Fe by mass. The mass of Fe_2O_3 in 1.0 g of this mixture is (O = 16, Fe = 56)
   (1) 0.37 g (2) 0.52 g (3) 0.67 g (4) 0.74 g (5) 0.83 g

8. Samples of $F_2(g)$ and Xe(g) are mixed in a container of fixed volume. The partial pressures of $F_2(g)$ and Xe(g) before they react are 8.0×10^{-5} kPa and 1.7×10^{-5} kPa respectively. When all of the Xe(g) has reacted, forming a solid compound, the partial pressure of the remaining $F_2(g)$ was 4.6×10^{-5} kPa. The system was maintained at a constant temperature during the above process. What is the formula of the solid compound formed?
   (1) XeF_2 (2) XeF_3 (3) XeF_4 (4) XeF_6 (5) XeF_8

9. When an inorganic solid **X** was treated with dil. HCl, a colourless solution and a gas that turned a filter paper moistened with lead acetate solution black were produced. When the colourless solution was subjected to the flame test, an apple green coloured flame was observed.
   Solid **X** is
   (1) BaS (2) $CuSO_3$ (3) $BaSO_3$ (4) NiS (5) $CuCO_3$

10. Which of the following statements is **false** with regard to hypochlorous acid (HOCl) ?
    (1) HOCl is a weak acid.
    (2) The oxidation state of chlorine in HOCl is –1.
    (3) I_2 is produced when KI is added to an aqueous solution of HOCl.
    (4) In basic solution HOCl disproportionates on heating.
    (5) HOCl reacts with alkali to form salts called hyprochlorites.

11. A volume of 50.00 cm^3 of 0.01 mol dm^{-3} NaOH solution was added to 50.00 cm^3 of 0.11 mol dm^{-3} solution of the weak acid HA. The pH of the final mixture was found to be 6.2. If K_a is the dissociation constant of the acid, which of the following answers indicates its pK_a value?
    (1) 5.2 (2) 6.0 (3) 6.2 (4) 7.0 (5) 7.2

12. The IUPAC name of $[Co(CN)_2(NH_3)_4]^+$ is
(1) tetraammoniadicyanocobalt(III) ion
(2) tetraamminedicyanocobalt(III) ion
(3) dicyanotetraamminecobalt(III) ion
(4) tetraamminedicyanidecobalt(III) ion
(5) tetraaminedicyanocobalt(III) ion

13. A 50.00 cm^3 sample of a solution containing Fe^{2+} is titrated with 0.02 M $K_2Cr_2O_7$ in acidic medium. The volume of $K_2Cr_2O_7$ required to react all the Fe^{2+} is 25.00 cm^3. If this titration is carried out using 0.02 M $KMnO_4$ instead of 0.02 M $K_2Cr_2O_7$, the volume of $KMnO_4$ required is
(1) 22.00 cm^3 (2) 23.00 cm^3 (3) 25.00 cm^3 (4) 27.00 cm^3 (5) 30.00 cm^3

14. Consider the following elementary reaction.

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

The rate constant of the reaction at temperature T is k. n mol of **A** and n mol of **B** were mixed and allowed to react in a rigid container of volume V. If the universal gas constant is R, and the rate of reaction at time t is Q, the pressure (P) of the vessel at time t is given by

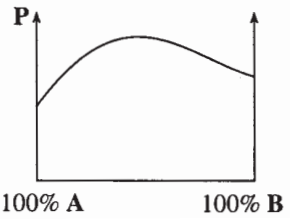
(1) $P = Q^2 \frac{RT}{V}$ (2) $P = \left[\frac{n}{V} + \left(\frac{Q}{k}\right)^{\frac{1}{2}}\right]RT$ (3) $P = \frac{Q}{k}\frac{RT}{V}$

(4) $P = \left(\frac{n}{V} + \frac{Q}{k}\right)RT$ (5) $P = \frac{2n\,RT}{V}$

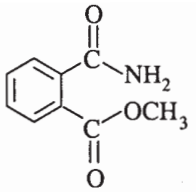
15. Volatile liquids **A** and **B** form an ideal solution when mixed. It was observed that the pressure of the vapour phase, which is in equilibrium with the liquid phase was doubled when the composition in the liquid phase was changed from $X_A = 0.2$, $X_B = 0.8$ to $X_A = 0.6$ and $X_B = 0.4$. The system was maintained at a constant temperature during the above process. The saturated vapour pressures of **A** and **B** at this temperature are P_A° and P_B° respectively. Which of the following relationships is **correct**?

(1) $\frac{P_A^\circ}{P_B^\circ} = 6$ (2) $P_A^\circ + P_B^\circ = \frac{1}{2}$ (3) $\frac{P_A^\circ}{P_B^\circ} = \frac{4}{3}$ (4) $\frac{P_A^\circ}{P_B^\circ} = \frac{3}{4}$ (5) $\frac{P_A^\circ}{P_B^\circ} = \frac{1}{6}$

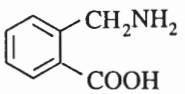
16. The variation of vapour pressure (**P**) with composition of a mixture of two miscible liquids **A** and **B** is shown in the figure.

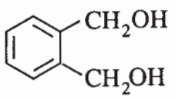


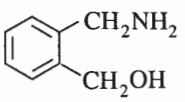
Which of the following answers is **true** about the intermolecular attractive forces?
(1) **A – A < A – B < B – B** (2) **A – A > A – B > B – B**
(3) **A – A < A – B > B – B** (4) **A – A > A – B < B – B**
(5) **A – A = A – B = B – B**

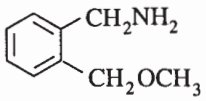
17. 

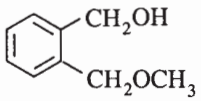
What is the **major** product obtained when the compound above is treated with $LiAlH_4$ and the reaction mixture is neutralized?

(1) 

(2) 

(3) 

(4) 

(5) 

18. Consider the following equilibria with equilibrium constants K_1, K_2 and K_3 respectively.

$$A(g) + B(g) \rightleftharpoons C(g)$$
$$C(g) + A(g) \rightleftharpoons D(g)$$
$$2A(g) + B(g) \rightleftharpoons D(g)$$

Which of the following equations shows the relationship among the three equilibrium constants?

(1) $K_3 = K_1 + K_2$ (2) $K_3 = \sqrt{K_1 K_2}$ (3) $K_3 = \frac{1}{K_1 K_2}$ (4) $K_3 = K_1 K_2$ (5) $K_3 = K_1 - K_2$

19. Which of the following arrangements shows the correct **increasing** order of pH of the following 1 M aqueous solutions?

HCl, KOH, $CaCl_2$, CH_3COOH, $CH_3COO^-Na^+$

(1) $KOH < CaCl_2 < CH_3COO^-Na^+ < CH_3COOH < HCl$
(2) $HCl < CaCl_2 < CH_3COOH < KOH < CH_3COO^-Na^+$
(3) $CH_3COOH < HCl < CaCl_2 < KOH < CH_3COO^-Na^+$
(4) $HCl < CH_3COOH < CH_3COO^-Na^+ < CaCl_2 < KOH$
(5) $HCl < CH_3COOH < CaCl_2 < CH_3COO^-Na^+ < KOH$

20. What is the total number of resonance structures that can be drawn for the HN_3 molecule? (Skeleton of the molecule, H—N—N—N)

(1) 2 (2) 3 (3) 4 (4) 5 (5) 6

21. Which of the following statements with regard to 3*d*-block transition elements is **false**?

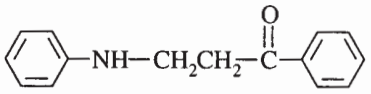
(1) Variable oxidation states result because of the comparable energies of 3*d* and 4*s* atomic orbitals.
(2) The electronegativity gradually decreases across the period from left to right.
(3) They have stronger metallic characteristics than those belonging to the *s*-block of the same period.
(4) Many ionic and covalent compounds of transition metals are coloured.
(5) Their densities are higher than the *s*-block elements of the same period.

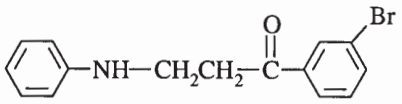
22. $N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$

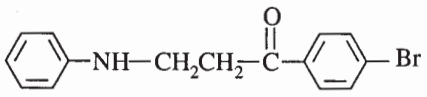
The reaction above is thermodynamically spontaneous at 298 K, but not so at high temperature. Which of the following is **true** about the reaction at 298 K?

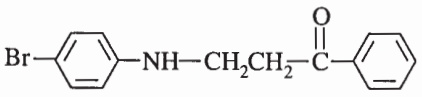
(1) ΔG, ΔH and ΔS all are positive.
(2) ΔG, ΔH and ΔS all are negative.
(3) ΔG and ΔH are negative and ΔS is positive.
(4) ΔG and ΔS are negative and ΔH is positive.
(5) ΔG and ΔH are positive and ΔS is negative.

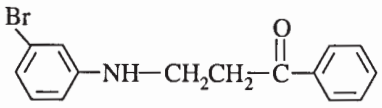
23. Predict the **major** product that will be obtained from the bromination of the following compound with $Br_2/FeBr_3$.

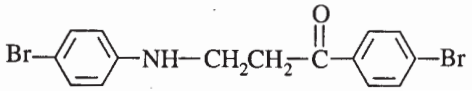


(1) 

(2) 

(3) 

(4) 

(5) 

24. Which of the following reactions is **not** likely to take place during chlorination of methane in the presence of light?

(1) $Cl-Cl \longrightarrow 2\,\dot{Cl}$

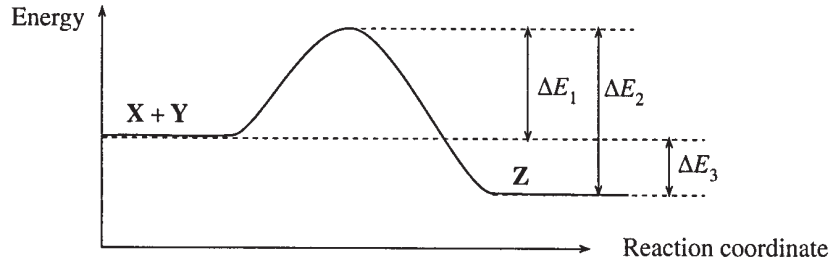
(2) $CH_4 + \dot{Cl} \longrightarrow CH_3Cl + \dot{H}$

(3) $CH_4 + \dot{Cl} \longrightarrow \dot{C}H_3 + HCl$

(4) $\dot{C}H_3 + Cl_2 \longrightarrow CH_3Cl + \dot{Cl}$

(5) $\dot{C}H_3 + \dot{Cl} \longrightarrow CH_3Cl$

25. The energy diagram for the reaction **X** + **Y** → **Z** is shown below.



The rate of this reaction is dependent on

(1) ΔE_1 only. (2) ΔE_2 only. (3) ΔE_3 only.

(4) $\Delta E_1 + \Delta E_2$. (5) $\Delta E_2 + \Delta E_3$.

26. Which of the following statements is **false** with regard to *s*-block elements?

(1) Group I elements are strong oxidizing agents.
(2) Group I elements have the lowest first ionisation energy values in a period.
(3) Group II elements are smaller than the corresponding Group I elements.
(4) In general, Groups I and II elements form ionic compounds.
(5) Group II elements are harder and have higher melting points than those of Group I.

27. Which of the following statements regarding ammonia (NH_3) is **false**?

(1) The oxidation state of N in NH_3 is −3.
(2) NH_3 gives a pink colour with Nessler's reagent.
(3) NH_3 is used as one of the raw materials in the manufacture of nitric acid.
(4) NH_3 is used to remove the acidic constituents in crude oil.
(5) NH_3 is produced on heating $NaNO_3$ with Al powder and aqueous NaOH.

28. Which of the following statements with regard to molecular oxygen (O_2) and ozone (O_3) is **false**?

(1) Molecular oxygen and ozone are allotropes.
(2) In the lower atmosphere photochemical reactions generate ozone from molecular oxygen.
(3) The O—O bond length of ozone is greater than the O—O bond length of molecular oxygen.
(4) Both molecular oxygen and ozone are greenhouse gases.
(5) Since molecular oxygen and ozone absorb UV radiation in the upper atmosphere, human life on earth is protected.

29. A 25.00 cm^3 volume of aqueous $CuSO_4$ solution is electrolysed using two platinum electrodes. The current during the electrolysis was kept at 10^{-2} A and it took 9.65 seconds to deposit all the Cu^{2+} as Cu on the cathode. What is the concentration of Cu^{2+} in the solution? (1 F = 96 500 C mol^{-1})

(1) 1×10^{-5} M (2) 2×10^{-5} M (3) 4×10^{-5} M (4) 5×10^{-5} M (5) 1×10^{-4} M

30. A solid sample contains only $CaCO_3$ and $MgCO_3$. To completely react the $CaCO_3$ and $MgCO_3$ present in the sample, 42.00 cm^3 of 0.088 M HCl were required. The anhydrous chloride salts from the reaction, obtained by evaporation of the filtrate weighed 0.19 g. The mass of $CaCO_3$ present in the solid sample is
(C = 12, O = 16, Mg = 24, Ca = 40, Cl = 35.5)

(1) 0.05 g (2) 0.07 g (3) 0.09 g (4) 0.11 g (5) 0.12 g

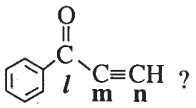
- For each of the questions **31** to **40**, one or more responses out of the four responses (*a*), (*b*), (*c*) and (*d*) given is/are correct. Select the correct response/responses. In accordance with the instructions given on your answer sheet, mark

(1) if only (*a*) and (*b*) are correct.
(2) if only (*b*) and (*c*) are correct.
(3) if only (*c*) and (*d*) are correct.
(4) if only (*d*) and (*a*) are correct.
(5) if **any other** number or combination of responses is correct.

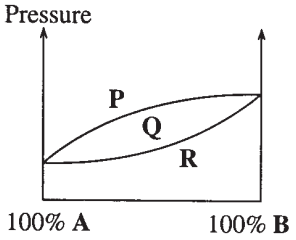
Summary of above Instructions

(1)	(2)	(3)	(4)	(5)
Only (*a*) and (*b*) are correct	Only (*b*) and (*c*) are correct	Only (*c*) and (*d*) are correct	Only (*d*) and (*a*) are correct	**Any other** number or combination of responses is correct

31. Values of E° for the Ce^{4+}/Ce^{3+} and Fe^{2+}/Fe are +1.72 V and –0.44 V respectively. According to these data which of the following statements is/are **true**?
(*a*) Ce^{4+} is a weaker oxidizing agent than Fe^{2+}.
(*b*) Ce^{4+} will reduce Fe^{2+}.
(*c*) Ce^{4+} is a better oxidizing agent than Fe^{2+}.
(*d*) Ce^{4+} will oxidize Fe.

32. Which of the following statements is/are **true** regarding the molecule  ?
(*a*) All carbon atoms are sp^2 hybridized.
(*b*) Carbon atoms labelled as ***l***, **m** and **n** and the oxygen atom lie in the same plane.
(*c*) All C—H bonds are equal in length.
(*d*) Carbon atoms labelled as ***l***, **m** and **n** lie in a straight line.

33. Shown below is the constant temperature phase diagram of **A** and **B**, which form an ideal solution.



Which of the following statements is/are **true**?
(*a*) The boiling point of compound **A** is higher than the boiling point of compound **B**.
(*b*) The vapour phase and liquid phase exist in equilibrium in the region **Q**.
(*c*) Only the vapour phase exists in the region **P**.
(*d*) Only the liquid phase exists in the region **R**.

34. Which of the following statements is/are **true** regarding polymers?
(*a*) Natural rubber has double bonds with *cis* configuration.
(*b*) Polyvinyl Chloride (PVC) is formed by addition polymerization of CHCl=CHCl.
(*c*) Polystyrene and nylon are both prepared by condensation polymerization.
(*d*) Both urea-formaldehyde and phenol-formaldehyde polymers contain $\rangle C=O$ groups in their structures.

35. The gases **A** and **B** react to form the product **P**. The material **X** in fine particle form, has been suggested for use as a catalyst for this reaction. The material **X** provides an alternative mechanism consisting of three steps. The activation energies for the three steps and for the reaction without **X** are given below.

	Activation energy / kJ mol^{-1}
Without **X**	50
With **X** step I	10
With **X** step II	5
With **X** step III	50

Which of the following statements is/are **true**?

(*a*) Use of **X** will not change the reaction rate significantly.
(*b*) Activation energy in step III can be lowered by using more **X**.
(*c*) Use of **X** increases the rate of the reaction because **X** is a material with a large surface area.
(*d*) Increasing of temperature will increase the reaction rate, regardless of whether **X** is used or not.

36. Which of the following statements is/are **true** regarding phenol?

(*a*) Phenol reacts readily with formaldehyde in acidic or basic medium.
(*b*) Phenol is less acidic than ethanol.
(*c*) Phenol reacts with aq. $NaHCO_3$ and gives CO_2.
(*d*) Phenol undergoes a substitution reaction with Br_2.

37. Which of the following statements is/are **true** regarding the compound represented by the structure given below?

$$CH_3CH_2\underset{\displaystyle Br}{\underset{|}{C}}H-CH=CH_2$$

(*a*) It can exist in two stereoisomeric forms.
(*b*) Catalytic hydrogenation of it gives a compound which does not show stereoisomerism.
(*c*) Treatment of it with alcoholic KOH gives a compound which does not show stereoisomerism.
(*d*) Treatment of it with aqueous KOH gives a compound which does not show stereoisomerism.

38. ΔH and ΔG data at temperature T are provided for the following reactions.

I. $2CH_4(g) \longrightarrow C_2H_4(g) + 2H_2(g)$ $\quad \Delta H = 201.88$ kJ mol^{-1}; $\Delta G = 169.62$ kJ mol^{-1}

II. $2CH_4(g) + O_2(g) \longrightarrow C_2H_4(g) + 2H_2O(g)$ $\quad \Delta H = -281.76$ kJ mol^{-1}; $\Delta G = -287.56$ kJ mol^{-1}

III. $2CH_4(g) + 2C(s) \longrightarrow 2C_2H_4(g)$ $\quad \Delta H = 254.14$ kJ mol^{-1}; $\Delta G = 237.74$ kJ mol^{-1}

Which of the following statements is/are **true** at temperature T?

(*a*) All three reactions I, II and III could be used to produce C_2H_4 from CH_4.
(*b*) Reaction I has a negative entropy change.
(*c*) Reaction II is the only feasible reaction for producing C_2H_4 from CH_4.
(*d*) Reaction III has a positive entropy change.

39. During cation analysis, Group I metal ions are precipitated as chlorides. Which of the following statements is/are **true** regarding the Group I analysis?

(*a*) Ag^+, Hg^{2+}, Hg_2^{2+} and Pb^{2+} form insoluble chlorides with the addition of dil. HCl.
(*b*) Only AgCl and $PbCl_2$ dissolve in aqueous NH_3 and will not reprecipitate with the addition of dil. HCl.
(*c*) Only Ag^+, Hg_2^{2+} and Pb^{2+} form insoluble chlorides with the addition of dil. HCl.
(*d*) Pb^{2+} does not precipitate in hot conc. HCl.

40. Which of the following statements is/are **false** with regard to H_2O_2?

(*a*) In the H_2O_2 molecule, the two hydroxyl groups lie in the same plane.
(*b*) H_2O_2 can act both as an oxidizing agent and a reducing agent in both acidic and basic media.
(*c*) Pure H_2O_2 is a colourless, strongly hydrogen bonded liquid.
(*d*) The oxygen atoms in H_2O_2 are *sp* hybridized.

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

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

	First Statement	Second Statement
41.	All emissions end up at $n = 1$ for the Balmer series in the hydrogen spectrum.	The Bohr model is used to explain the origin of the hydrogen spectrum.
42.	2–Butanone (MW 72) has a higher boiling point than that of pentane (MW 72).	There are no hydrogen bonds between pentane molecules.
43.	2–Methyl–1–propanol gives a turbidity with conc. $HCl/ZnCl_2$ much faster than does 2–methyl–2–propanol.	Tertiary carbocations are more stable than primary carbocations.
44.	$CaCO_3(s)$ does not decompose to $CO_2(g)$ and $CaO(s)$ at room temperature, but it could be decomposed by increasing the temperature.	Gibbs energy change of a reaction can always be made negative by increasing the temperature.
45.	Intermolecular forces between SO_2 molecules are stronger than those between CO_2 molecules.	Intermolecular forces between polar molecules are stronger than those between non-polar molecules of similar mass.
46.	$CH_3-\overset{\overset{O}{\|}}{C}-CH_2CH_3$ and $CH_2=\overset{\overset{OH}{\|}}{C}-CH_2CH_3$ are two reasonance structures of the same compound.	The number of double bonds in resonance structures of a given compound should be the same.
47.	At constant temperature, doubling the concentration of all the reactants in the elementary reaction $2\mathbf{A} + \mathbf{B} \longrightarrow 3\mathbf{D} + \mathbf{E}$ increases the rate by a factor of 8.	In an elementary reaction, the order with respect to a reactant is equal to its stoichiometric coefficient.
48.	In the extraction of iron, the reduction of haematite by CO takes place in three stages.	The temperature of the blast furnace used in the extraction of iron decreases from top to bottom.
49.	Increasing the temperature will always increase the reaction rate.	The activation energy of a reaction decreases when the temperature is increased.
50.	Ammonia and carbon monoxide are used as raw materials in the manufacture of urea.	Ammonium carbonate formed by the reaction of ammonia and carbon monoxide, decomposes to give urea.

2.1.3 Expected answers and the marking scheme for Paper I

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

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

(i) CO, CO_2, CO_3^{2-} (C—O bond distance)

CO < CO_2 < CO_3^{2-}

(ii) NO_2^+, NO_3^-, NH_3 (electronegativity of N atom)

NH_3 < NO_3^- < NO_2^+

(iii) $BeSO_4$, $MgSO_4$, $CaSO_4$ (decomposition temperature, $MSO_4 \longrightarrow MO + SO_3$, M = metal)

$BeSO_4$ < $MgSO_4$ < $CaSO_4$

(iv) Ne, Ar, Kr (boiling point)

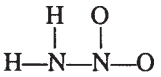
Ne < Ar < Kr

(v) S, F, Si, Cl (atomic radius)

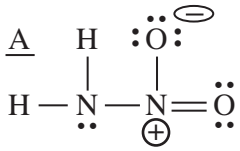
F < Cl < S < Si (05 × 5)

1(a) 25 marks

(*b*) Nitramide ($H_2N—NO_2$) is a weak acid. It decomposes to N_2O and H_2O in the presence of a base. Answer the parts (i) to (v) which are based on nitramide. Its skeleton is given below:

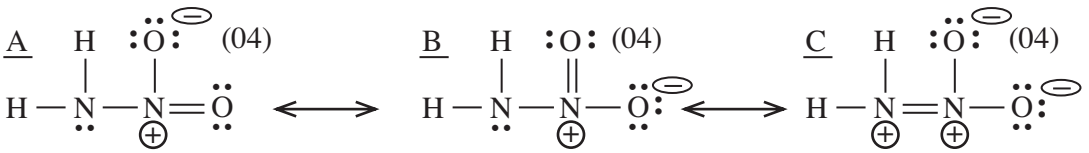


(i) Draw the **most** acceptable Lewis structure for this molecule.



(10)

(ii) Draw the resonance structures for this molecule. Giving reasons, comment on their stabilities.



A stable (01)

opposite charges on adjacent atoms (01) negative charge on more electronegative oxygen (01)

B stable (01)

opposite charges on adjacent atoms (01) negative charge on more electronegative oxygen (01)

C unstable (01)

two positive charges on adjacent atoms (02)

(21)

(iii) State the following:

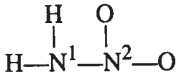
I. electron pair geometry (arrangement of electron pairs) around the atoms
II. shape around the atoms
III. hybridization of the atoms

given in the table below.

		The **N** attached to two **H** atoms	The **N** attached to two **O** atoms	
I.	electron pair geometry	tetrahedral	trigonal planar	(03 + 03)
II.	shape	pyramidal	trigonal planar	(03 + 03)
III.	hybridization	sp^3	sp^2	(03 + 03)

(iv) Is this molecule polar or non-polar? ..... polar ..... (04 marks)

(v) Identify the atomic/hybrid orbitals involved in the formation of the following bonds in the Lewis structure drawn in part (i) above. **N** atoms are labelled 1 and 2 as given below:



I. N^1 and N^2 ..... sp^3 (hybrid orbital) + sp^2 (hybrid orbital) ..... (03 + 03)

II. N^1 and H ..... sp^3 (hybrid orbital) + 1*s* (atomic orbital) ..... (03 + 03)

1 (b) 65 marks

(*c*) Xe, CH_3Cl, HF

Of the substances given above, which one/ones will have the forces given below?

(i) dipole - dipole forces ..... CH_3Cl, HF ..... (02 + 02)

(ii) hydrogen bonding forces ..... HF ..... (02)

(iii) London dispersion forces ..... Xe, CH_3Cl, HF (in any order) ..... (02 + 01 + 01)

1 (c) 10 marks

***Total* : 100 marks**

Question 2

2. (*a*) Element **A** belongs to the *s*-block. Its first ionization energy is the highest in the group. **A** reacts with water liberating a gas **B**. The resulting solution from this reaction gives a red colouration to a Bunsen burner flame and the metal oxide on evaporation. **A** reacts with $N_2(g)$ to give compound **C**. The reaction of **A** with $H_2(g)$ gives a salt-like basic compound **D**. On treatment with H_2O, **C** gives a gas **E** which turns red litmus blue.

(i) Identify **A**, **B**, **C**, **D** and **E** giving their chemical formulae.

* **A** = Li **B** = H_2 **C** = Li_3N **D** = LiH **E** = NH_3

(03 × 5 = 15)

(ii) Give balanced chemical equations for the reactions described above.

$2Li + 2H_2O \longrightarrow 2LiOH + H_2$

$2LiOH \xrightarrow{\Delta} Li_2O + H_2O$

$6Li + N_2 \longrightarrow 2Li_3N$

$2Li + H_2 \longrightarrow 2LiH$

$Li_3N + 3H_2O \longrightarrow 3LiOH + NH_3$ (03 × 5 = 15)

2 (a) 30 marks

* Note : No marks for B, C, D, E if the answer for A in 2(*a*)(i) is wrong.

(*b*) The following questions are based on the transition metals, V and Cr and their compounds.

(i) Give the ground state electronic configuration of V. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2$ or $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^3$

(5)

(ii) State the positive oxidation states of V. +2, +3, +4, +5 or +II, +III, +IV, +V or 2, 3, 4, 5 or II, III, IV, V

(02 × 4)

(iii) Give the chemical formulae of the oxides formed by V in the positive oxidation states given in (ii) above. Indicate whether each of these oxides is acidic, amphoteric or basic.

VO - basic

V_2O_3 - basic

VO_2 - amphoteric

V_2O_5 - acidic (amphoteric) (02 × 8)

(iv) Write the chemical formulae of **two** oxocations formed by V. State their colours in aqueous acidic medium.

VO_2^+ - yellow VO^+ - green (very rare)

VO^{2+} - blue (01 × 4)

(v) What is the simplest ion that chromium forms in aqueous solution? State its colour. Predict what you would expect to observe when solid Na_2CO_3 is added to an aqueous solution of this ion.

$[Cr(H_2O)_6]^{3+}$ - Violet / blue violet or $Cr^{3+}(aq)$ or Cr^{3+} - Green/blue violet (04 + 04)

Evolution of CO_2 or evolution of bubbles or green precipitate/green solution (04)

(vi) Give **one** use of the metal V.

as an ingredient in steel or in alloys or as a catalyst (V_2O_5 accepted), making aircrafts (04)

(vii) What would you **observe** when a green coloured aqueous solution of $CrCl_3$ is subjected to the following?

I. Addition of a few drops of dilute NaOH.

green precipitate (03)

II. Addition of excess dilute NaOH followed by H_2O_2, and then heated.

yellow solution (03)

(viii) When a concentrated solution of $K_2Cr_2O_7$ is treated with conc. H_2SO_4, the bright red acidic oxide **X** of chromium is precipitated. On heating **X**, the green amphoteric oxide **Y** is obtained. **Y** could also be obtained on heating $(NH_4)_2Cr_2O_7$.
Give the chemical formulae of **X** and **Y**.

X = CrO_3 **Y** = Cr_2O_3 (03 + 03)

(ix) What would you observe when dil. NaOH is added to a solution of $K_2Cr_2O_7$?

solution turns yellow or orange solution turns yellow (03)

(x) Give **one** advantage and **one** disadvantage of using $K_2Cr_2O_7$ in titrations.

Advantage: it's a primary standard or titration can be done in the presence of chloride ions. (03)

Disadvantage: difficult to observe colour change at end point or not a self - indicator (03)

2 (b) 70 marks

***Total* : 100 marks**

Question 3

3. Chlorine gas is used as an oxidizing agent to oxidize the metal ion, $M^{2+}(aq)$ to $M^{3+}(aq)$. The following data are given.

Reaction	Standard enthalpy change $\Delta H°$ at 25 °C (kJ mol^{-1})
$M(s) \longrightarrow M^{+}(aq) + e$	– 32.5
$M(s) \longrightarrow M^{2+}(aq) + 2e$	– 48.5
$M(s) \longrightarrow M^{3+}(aq) + 3e$	– 82.5
$Cl_2(g) + 2e \longrightarrow 2Cl^{-}(aq)$	– 334.0

$E°_{M^{3+}/M^{2+}} = +0.77$ V $E°_{Cl_2/Cl^-} = +1.36$ V

The above oxidation is carried out electrochemically.

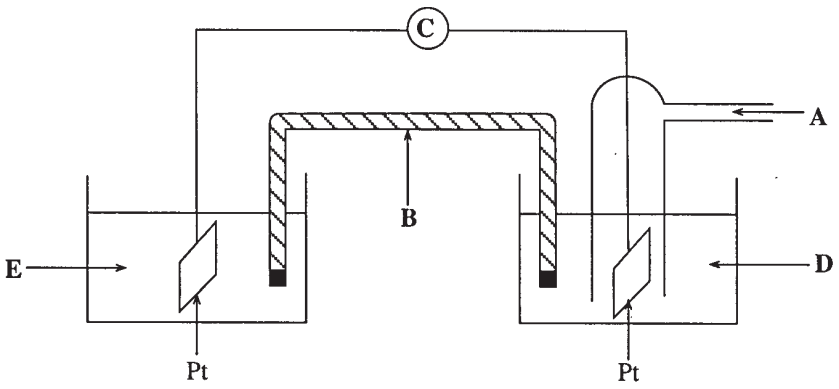
(i) Write half reactions for oxidation and reduction processes and derive the cell reaction.

Oxidation reaction : $M^{2+}(aq) \longrightarrow M^{3+}(aq) + e$ (05)

Reduction reaction : $Cl_2(g) + 2e \longrightarrow 2Cl^{-}(aq)$ (05)

Cell reaction : $2M^{2+}(aq) + Cl_2(g) \longrightarrow 2M^{3+}(aq) + 2Cl^{-}(aq)$ (05)

(ii) The following diagram shows the experimental setup needed to measure $E°_{cell}$ of the above reaction. Identify **A – E,** giving physical state, concentration / pressure where applicable.



A : Cl_2 (g, 1 atm) B : Salt bridge

C : Voltmeter (Potentiometer) D : Cl^- (aq, 1.0 mol dm^{-3})

E : Mixture of M^{2+} (aq, 1.0 mol dm^{-3}) and M^{3+} (aq, 1.0 mol dm^{-3})

(05 × 5)

(iii) Calculate E°_{cell} for the above cell.

$E^\circ_{Cell} = E^\circ_{Cl_2/Cl^-} - E^\circ_{M^{3+}/M^{2+}}$ or $E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$

or $E^\circ_{cell} = E^\circ_{RHS} - E^\circ_{LHS}$ (05)

or 1.36 V – 0.77 V

= 0.59 V (04 + 01)

(iv) Calculate the standard enthalpy change (ΔH°) at 25 °C, for the cell reaction given in part (i).

(02) **(02)**

$2\,M^{2+}(aq) + Cl_2(g) + (4e) \xrightarrow{\Delta H^\circ} 2\,M^{3+}(aq) + 2\,Cl\,(aq) + (4e)$

$2 \times (-48.5\ kj\ mol^{-1})$ **(04 + 01)**

$2 \times (-82.5\ kJ\ mol^{-1}) - 334\ kj\ mol^{-1}$ **(04 + 01)** **(04 + 01)**

$2\,M(s) + Cl_2(g)$ **(02)**

Note : If the thermodynamic cycle is not shown but the calculation in equation eq(1) is correct, award (18 + 03) marks.

$\Delta H^\circ = 2 \times (-82.5\ kJ\ mol^{-1}) - 2 \times (-48.5\ kJ\ mol^{-1}) + (-334\ kJ\ mol^{-1})$ (eq - 1)

$\Delta H^\circ = -402\ kJ\ mol^{-1}$ (03 + 01)

(v) The relationship between standard Gibb's energy change, ΔG° for the cell reaction and E°_{cell} is given by

$\Delta G^\circ = -k E^\circ_{cell}$

where, $k = 1.93 \times 10^5\ J\ mol^{-1}\ V^{-1}$

Calculate the standard Gibbs energy change (ΔG°) at 25 °C, for the above cell reaction.

$\Delta G^\circ = -k E^\circ_{cell}$

$= -1.93 \times 10^5\ (J\ mol^{-1} V^{-1}) \times 0.59\ (V)$ (04 + 01)

$= -113.87\ kJ\ mol^{-1}$ (04 + 01)

(vi) Calculate the standard entropy change (ΔS°) at 25 °C, for the above cell reaction.

$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ (No marks if standard states are not shown) (05)

$-113.87\ kJ\ mol^{-1} = -402\ (kJ\ mol^{-1}) - 298\ (K)\ \Delta S^\circ$ (04 + 01)

$\Delta S^\circ = 288\ kJ\ mol^{-1} / (-298\ K)$

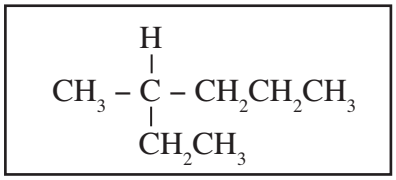
$\Delta S^\circ = 0.97\ kJ\ mol^{-1}\ K^{-1}$ (04 + 01)

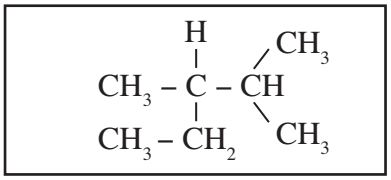
***Total* : 100 marks**

Question 4

4. (*a*) (i) Compound **A** exhibits optical isomerism and has the molecular formula C_7H_{16}.

I. Draw **two** possible structures for **A** which are not enantiomers of each other, in the boxes given below.





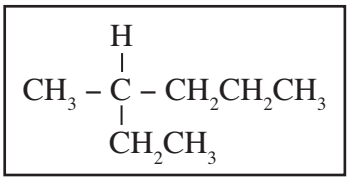
(10 + 10)

II. State the isomeric relationship between the two structures you have drawn.

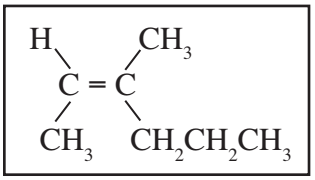
structural isomers **or** constitutional isomers **or** chain isomers ..... (03)

(ii) **B** and **C** are optically inactive compounds with the molecular formula C_7H_{14}. Both **B** and **C** exhibit geometric isomerism. **B** and **C** are **not** geometric isomers of each other. Catalytic hydrogenation of either **B** or **C** yields the same compound **A**.

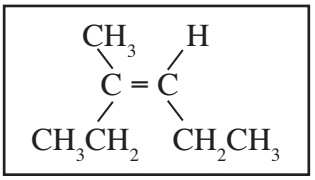
I. Draw the structures of **A**, **B** and **C** in the boxes given below (It is **not** necessary to draw the stereoisomeric forms).



A



B



C

(10 + 10 + 10)

II. Write the IUPAC names of **B** and **C**.

B : 3-methyl-2-hexene or 3-methylhex-3-ene ..... (01)

C : 3-methyl-3-hexene ..... (01)

Note : B and C can be interchanged. Accordingly, the correct IUPAC names should be written.

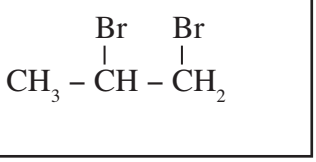
4 (a) 55 marks

(*b*) Consider the following reaction sequence:

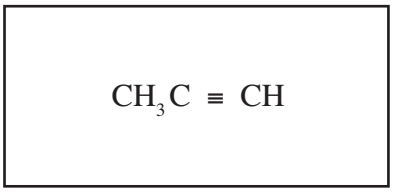


Reaction 1 **Reaction 2** **Reaction 3** **Reaction 4**

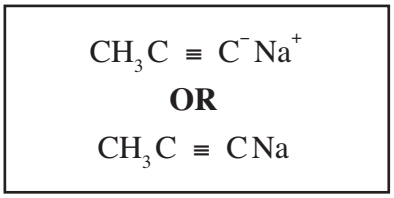
(i) Draw the structures of **P**, **Q**, **R** and **S** in the boxes given below.



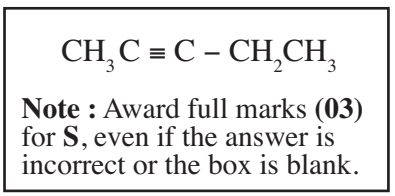
P



Q



R



Note : Award full marks **(03)** for **S**, even if the answer is incorrect or the box is blank.

S

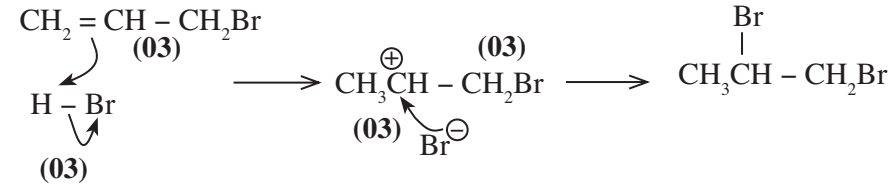
(03 × 4)

(ii) Classify each of the reactions in the above sequence as nucleophilic addition (A_N), electrophilic addition (A_E), nucleophilic substitution (S_N), electrophilic substitution (S_E), elimination (E) or acid-base (AB), by writing A_N, A_E, S_N, S_E, E, AB in the appropriate cages.

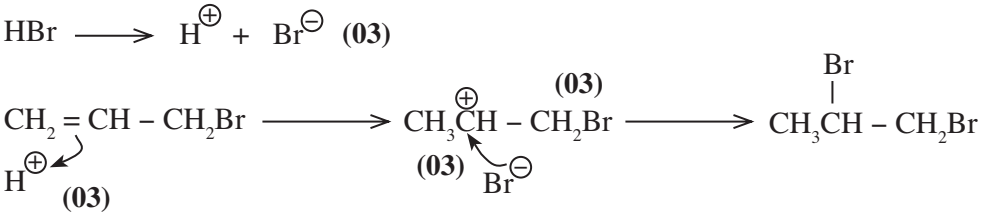
Reaction	1	2	3	4
Reaction type	A_E	E	AB	S_N

(03 × 4)

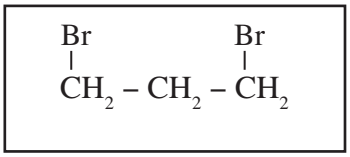
(iii) Write the mechanism for **Reaction 1.**



Alternate answer



(iv) Draw the structure of the product **T** obtained when **Reaction 1** is carried out in the presence of peroxide.



T

(03)

(v) It has been found that **T** is also formed in **Reaction 1**, as a minor product. By considering the mechanism of the reaction, explain why the major product in **Reaction 1** is **P** and not **T**.

Intermediate carbocation for P $CH_3 - \overset{\oplus}{C}H - CH_2Br$	Intermediate carbocation for T $\overset{\oplus}{C}H_2 - CH_2 - CH_2Br$	} (03)
Secondary carbocation, more stable (**P** is formed faster)	Primary carbocation, less stable	} (03)

Note : Award full marks for mentioning that it is a secondary carbocation without giving the structure, if the structure is drawn in part (iii).

4 (b) 45 marks

***Total* : 100 marks**

Question 5

PART B — ESSAY

*Answer **two** questions only.* (*Each question carries* **15 *marks.***)

---

5. (*a*) **A** and **B** are volatile and completely miscible liquids which form an ideal solution when mixed. A mixture containing 1.0 mol of liquid **A** and 1.0 mol of liquid **B** was placed in a closed container. When the system reached equilibrium, the pressure and volume of the gaseous phase, and the mole ratio of **A/B** in this phase were found to be 1.0×10^3 Pa, 0.8314 m^3 and 2/3 respectively. The system was maintained at 200 K.

Calculate the following.

(i) the total number of moles in the gas phase.

(ii) the mole fractions of **A** and **B** in the liquid phase.

(iii) the saturated vapour pressures of **A** and **B**.

(5.0 *marks*)

(*b*) In a saturated solution of $Mn(OH)_2$ at 25 °C, the concentration of Mn^{2+} is 1.0×10^{-5} mol dm^{-3}. The solubility product of $Mg(OH)_2$ at 25 °C is 1.0×10^{-10} mol^3 dm^{-9}. K_b of NH_4OH at 25 °C is 1.6×10^{-5} mol dm^{-3}.

(i) Calculate the solubility product of $Mn(OH)_2$ at 25 °C.

(ii) Calculate the concentration of hydroxide ions in a 0.01 mol dm^{-3} NH_4OH solution at 25 °C.

(iii) Determine the concentration of NH_4OH necessary to start precipitation of $Mn(OH)_2$ from a 0.001 mol dm^{-3} solution of $MnSO_4$.

(iv) If 5.35 g of NH_4Cl is dissolved in 1.00 dm^3 of 1.00 mol dm^{-3} NH_4OH solution, calculate the concentration of hydroxide ions in the solution. (H = 1.0, N = 14.0, Cl = 35.5)

(v) Calculate the number of moles of solid NH_4Cl required to prevent the precipitation of $Mg(OH)_2$ in a solution to be made by mixing 0.50 dm^3 of a 0.02 mol dm^{-3} solution of $Mg(NO_3)_2$ and 0.50 dm^3 of a 0.20 mol dm^{-3} solution of NH_4OH.

(vi) Explain the use of NH_4Cl in group analysis.

5. (*a*) **(i)**

$$PV = nRT$$

$$n = \frac{PV}{RT}$$

$$n = \frac{1.0 \times 10^3\,\text{Pa} \times 0.8314\,\text{m}^3}{8.314\,\text{J mol}^{-1}\,\text{K}^{-1} \times 200\,\text{K}} \qquad (04 + 01)$$

$$n = 0.5\,\text{mol} \qquad (04 + 01)$$

5 (a)(i) 10 marks

(ii)

Number of moles of A in gas phase = $n_{A,}$ Number of moles of B in gas phase = $n_{B,}$

mole fraction of A in gas phase = $X_{A,}$ mole fraction of B in gas phase = X_B,

mole fraction of A in liquid phase = $X'_{A,}$ mole fraction of B in liquid phase = X'_A

$$\frac{X_A}{X_B} = \frac{n_A}{n_B} = \frac{2}{3} \quad (03)$$

$$n = n_A + n_B = 0.5 \quad (03)$$

$$n_A = 0.2\,\text{mol} \quad (01 + 01)$$

$$n_B = 0.3\,\text{mol} \quad (01 + 01)$$

Amount of A left in the liquid phase $= (1.0 - 0.2)\,\text{mol} = 0.8\,\text{mol}$ (01 + 01)

Amount of B left in the liquid phase $= (1.0 - 0.3)\,\text{mol} = 0.7\,\text{mol}$ (01 + 01)

$$X'_A = \frac{0.8\,\text{mol}}{(0.8 + 0.7)\,\text{mol}} = \frac{8}{15} = 0.533 \quad (03)$$

$$X'_B = \frac{0.7\,\text{mol}}{(0.8 + 0.7)\,\text{mol}} = \frac{7}{15} = 0.467 \quad (03)$$

(If the steps are combined award marks accordingly)

5 (a)(ii) 20 marks

(iii)

Partial pressure of A = P_A, Partial pressure of B = P_B,

Saturated vapour pressure of A = $P°_{A,}$ Saturated vapour pressure of B = $P°_B$.

Applying Daltons law,

$$P_A = P \times X_A = 1.0 \times 10^3\,\text{Pa}\ \frac{0.2\,\text{mol}}{0.5\,\text{mol}} \quad (02)$$

$$P_A = 4.0 \times 10^2\,\text{Pa} \quad (01)$$

similarly

$$P_B = P \times X_B = 1.0 \times 10^3\,\text{Pa}\ \frac{0.3\,\text{mol}}{0.5\,\text{mol}} \quad (02)$$

$$P_B = 6.0 \times 10^2\,\text{Pa} \quad (01)$$

Applying Raoults law,

$$P°_B = \frac{P_A}{X'_A} = \frac{4.0 \times 10^2\,\text{Pa}}{8/15} \quad (03 + 01)$$

$$= 7.5 \times 10^2\,\text{Pa} \quad (02 + 01)$$

$$P°_B = \frac{P_B}{X'_B} = \frac{6.0 \times 10^2\,\text{Pa}}{7/15} \quad (03 + 01)$$

$$= 1.286 \times 10^3\,\text{Pa} \quad (02 + 01)$$

5 (a)(iii) 20 marks

***Total for* 5(a) 50 marks**

(*b*) (i)

$Mn(OH)_2(s) \rightleftharpoons Mn^{2+}(aq) + 2OH^-(aq)$ (physical states required) (02)

$K_{sp} = [Mn^{2+}(aq)]\,[OH^-(aq)]^2$ (physical states required) (02)

$K_{sp} = 1 \times 10^{-5}\,mol\,dm^{-3} \times (2 \times 10^{-5}\,mol\,dm^{-3})^2$ (02 + 01)

$K_{sp} = 4 \times 10^{-15}\,mol^3\,dm^{-9}$ (02 + 01)

5 (b)(i) 10 marks

(ii)

$NH_4OH(aq) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$ (physical states required) (01)

$K_b = \dfrac{[NH_4^+(aq)]\,[OH^-(aq)]}{[NH_4OH(aq)]}$ (physical states required) (01)

Since NH_4OH is a weak base, amount dissociated is very small.

$[NH_4^+(aq)] = [OH^-(aq)]$ and $[NH_4OH] = 0.01\,mol\,dm^{-3}$ (02)

$1.6 \times 10^{-5}\,mol\,dm^{-3} = \dfrac{[OH^-(aq)]^2\,(mol\,dm^{-3})^2}{0.01\,mol\,dm^{-3}}$ (02 + 01)

$[OH^-(aq)] = 4.0 \times 10^{-4}\,mol\,dm^{-3}$ (02 + 01)

5 (b)(ii) 10 marks

(iii)

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

$4 \times 10^{-15}\,(mol^3\,dm^{-9}) = 10^{-3}\,(mol\,dm^{-3}) \times [OH^-(aq)]^2$

$[OH^-(aq)]^2 = \dfrac{4 \times 10^{-15}\,(mol^3\,dm^{-9})}{10^{-3}\,(mol\,dm^{-3})} = 4 \times 10^{-2}\,(mol\,dm^{-3})^2$ (04 + 01)

$[OH^-(aq)] = 2 \times 10^{-6}\,mol\,dm^{-3}$ (04 + 01)

The $[OH^-(aq)]$ necessary to just precipitate $Mn(OH)_2 = 2 \times 10^{-6}\,mol\,dm^{-3}$. Assuming the concentration of NH_4OH necessary to provide $[OH^-(aq)] = 2 \times 10^{-6}\,mol\,dm^{-3}$ is x.

$NH_4OH(aq) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

$x - 2 \times 10^{-6}\,mol\,dm^{-3}$ $\quad 2 \times 10^{-6}\,mol\,dm^{-3}$ $\quad 2 \times 10^{-6}\,mol\,dm^{-3}$

$1.6 \times 10^{-5}\,mol\,dm^{-3} = \dfrac{[2 \times 10^{-6}]^2\,(mol\,dm^{-3})^2}{x - 2 \text{ x } 10^{-6}\,mol\,dm^{-3}}$ (04 + 01)

$x = 2.25 \times 10^{-6}\,mol\,dm^{-3}$ (04 + 01)

or

$1.6 \times 10^{-5}\,mol\,dm^{-3} = \dfrac{[2 \times 10^{-6}]^2\,(mol\,dm^{-3})^2}{x}$ (04 + 01)

$x = 2.2 \times 10^{-7}\,mol\,dm^{-3}$ (04 + 01)

5 (b)(iii) 20 marks

(iv)

Molar mass of NH_4Cl $= 14.0 + 1.0 \times 4 + 35.5 = 53.5\,g\,mol^{-1}$

Therefore the amount of $NH_4Cl = 5.35\,g / 53.5\,g\,mol^{-1} = 0.1\,mol$ (01 + 01)

Since NH_4Cl is completely dissociated in aqueous medium

$[NH_4^+(aq)] = 0.1\,mol\,dm^{-3}$ (01 + 01)

Let's take the concentration of NH_4OH as c $mol\,dm^{-3}$ and the degree of dissociation as $\propto$.

$NH_4OH\,(aq) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

at equlibrium

$c\,(1 - \propto)\,mol\,dm^{-3}$ $\quad c \propto mol\,dm^{-3}$ $\quad c \propto mol\,dm^{-3}$

$[NH^+_4(aq)] = (0.1 + c \propto)\,mol\,dm^{-3} = 0.1\,mol\,dm^{-3}$ (03 + 01)

$[NH_4OH\,(aq)] = (0.1 - c \propto)\,mol\,dm^{-3} = 1.0\,mol\,dm^{-3}$ (03 + 01)

Note : If written as statements award (04) + (04) marks.

$$1.6 \times 10^{-5}\,mol\,dm^{-3} = \frac{0.1\,mol\,dm^{-3} \times [OH^-(aq)]}{1.0\,mol\,dm^{-3}}$$ (03 + 01)

$[OH^-(aq)] = 1.6 \times 10^{-4}\,mol\,dm^{-3}$ (03 + 01)

5 (b)(iv) 20 marks

Alternate Answer

Mol. Wt. of $H_4Cl = 14.0 + 1.0 \times 4 + 35.5 = 53.5\,g\,mol^{-1}$

Therefore the amount of $NH_4Cl = 5.35\,g / 53.5\,g\,mol^{-1} = 0.1\,mol$ (01 + 01)

Since NH_4Cl is completely dissociated in aqueous medium.

$[NH_4^+(aq)] = 0.1\,mol\,dm^{-3}$ (01 + 01)

$[NH^+_4(aq)] = (0.1 + c\propto)\,mol\,dm^{-3} = 0.1\,mol\,dm^{-3}$ (03 + 01)

$[NH_4OH\,(aq)] = (0.1 - c\propto)\,mol\,dm^{-3} = 1.0\,mol\,dm^{-3}$ (03 + 01)

Note : If written as statements award (04) + (04) marks.

$$pOH = pK_b + \log\left(\frac{[salt]}{[base]}\right)$$ (03 + 01)

$$pOH = -\log(1.6 \times 10^{-5}) + \log\left(\frac{[0.1\,mol\,dm^{-3}]}{[1.0\,mol\,dm^{-3}]}\right)$$ (03 + 01)

$pOH = 3.796$

$[OH^-] = 1.6 \times 10^{-4}\,mol\,dm^{-3}$ (03 + 01)

5 (b)(iv) 20 marks

(v)

The $[Mg(NO_3)_2(aq)]$ in the final solution

$$= \frac{0.2\,mol\,dm^{-3} \times 0.50\,dm^3}{1.0\,dm^3} = 0.01\,mol\,dm^{-3} \qquad (04 + 01)$$

To avoid the precipitation of $(OH)_2(s)$ in the final mixture, the following criteria should be satisfied.

$Mg(NO_3)_2$ is completely dissociated to Mg^{2+} and NO_3^- ions.

Therefore $[Mg^{2+}(aq)]$ in the final solution = $0.01\,mol\,dm^{-3}$

In order to prevent precipitation of $Mg(OH)_2$.

$K_{sp} \geq [Mg^{2+}(aq)]\,[OH^-(aq)]^2$

$1 \times 10^{-10}\,(mol^3\,dm^{-9}) \geq 10^{-2}\,(mol\,dm^{-3}) \times [OH^-(aq)]^2$

$$[OH^-(aq)]^2 \leq \frac{1 \times 10^{-10}\,(mol^3\,dm^{-9})}{10^{-2}\,(mol\,dm^{-3})} = 1 \times 10^{-8}\,(mol\,dm^{-3})^2 \qquad (04 + 01)$$

$$[OH^-(aq)] \leq 1 \times 10^{-4}\,mol\,dm^{-3} \qquad (04 + 01)$$

The $[NH_4OH(aq)]$ in the final solution

$$= \frac{0.2\,mol\,dm^{-3} \times 0.50\,dm^3}{1.0\,dm^3} = 0.01\,mol\,dm^{-3} \qquad (04 + 01)$$

Let the required concentration of NH_4Cl to keep $[OH^-(aq)]$ at $1 \times 10^{-4}\,mol\,dm^{-3}$ be x.

Since amount dissociated is very small, $[NH^+_4(aq)] = [NHCl(aq)] = x$.

$$1.6 \times 10^{-5}\,mol\,dm^{-3} = \frac{x\,(mol\,dm^{-3}) \times 1 \times 10^{-4}\,(mol\,dm^{-3})}{0.1\,mol\,dm^{-3}} \qquad (04 + 01)$$

$$x = 1.6 \times 10^{-2}\,mol\,dm^{-3} \qquad (04 + 01)$$

The amount of NH_4Cl neccessary to prevent precipitation of $Mg(OH)_2$,

$= 1.6 \times 10^{-2}\,mol\,dm^{-3} \times 1.0\,dm^3 = 1.6 \times 10^{-2}\,mol$ (04 + 01)

5 (b)(v) 35 marks

(vi)

In group separation to avoid the precipitation of $Mg(OH)_2$ in group III (or other cations that may precipitate as hydroxides), NH_4Cl is added before adding NH_4OH. (05)

5 (b)(vi) 05 marks

***Total for* 5(b) 100 marks**

***Total for* 5 : 150**

Question 6

6. (*a*) Consider the reaction,

$$mM + nN \longrightarrow cC$$

where m, n and c are stoichiometric coefficients of **M**, **N** and **C** respectively.

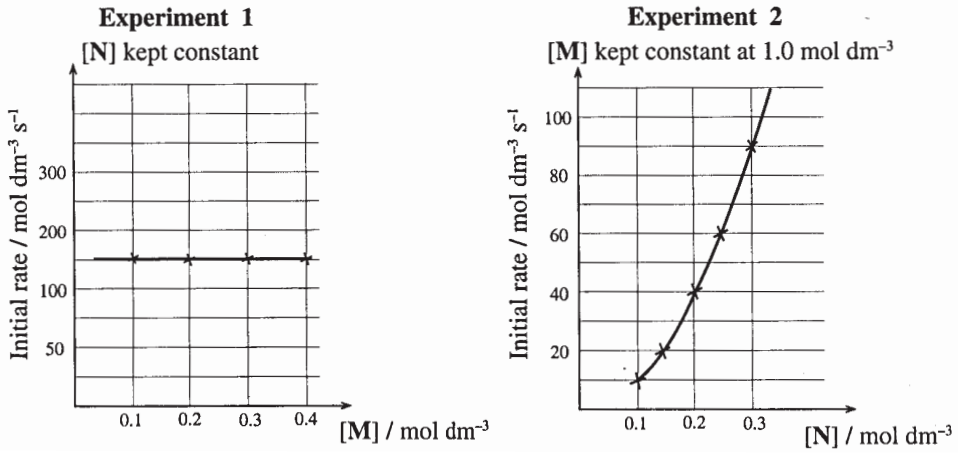
(i) Considering the above reaction to be an elementary reaction, write an expression for the rate of reaction. (The rate constant of the reaction = k.)

(ii) Two experiments were conducted to find the order of the reaction.

Experiment 1 : Initial rate was measured varying the concentration of **M** while keeping the concentration of **N** constant.

Experiment 2 : Initial rate was measured varying the concentration of **N** while keeping the concentration of **M** constant at 1.0 mol dm^{-3}.

Both experiments were conducted at the same temperature. The results of the experiments are shown in the graphs below.



I. Find the order of the reaction with respect to **M**.

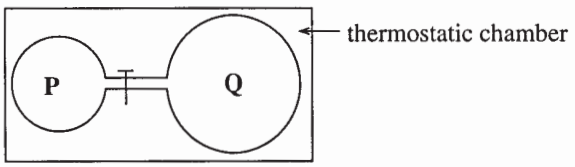
II. Find the order of the reaction with respect to **N**.

III. What is the overall order of the reaction?

IV. Find the rate constant, k of the reaction.

(6.0 *marks*)

(*b*) Two rigid bulbs **P** (volume = V) and **Q** (volume = 2V) connected by a tap are placed in a thermostatic chamber as shown below.



Initially the tap is closed. **P** contains 1.0 mol of gas **AB** and **Q** is empty. When the temperature of the system was increased to 400 K, **AB**(g) dissociated into **A**(g) and **B**(g) according to the equilibrium reaction given below.

$$AB(g) \rightleftharpoons A(g) + B(g)$$

The equilibrium constant for the above equilibrium is K_c. When the system has reached equilibrium (first equilibrium) the amount of **A**(g) was found to be x mol. The tap was opened and the system was allowed to reach equilibrium again (second equilibrium). The amount of **A**(g) formed was found to be y mol.

(i) Show that $K_cV\ (1 - x) = x^2$ and $3K_cV\ (1 - y) = y^2$.

(ii) If $y = 0.5$ mol, calculate the value of x.

(iii) Explain your answer in (ii) above using the Le Chatelier's principle.

(iv) The temperature of the system was increased to 600 K. When the system reached equilibrium (third equilibrium) the pressure of the system was 1.7 times that at the second equilibrium. The amount of **A**(g) at the third equilibrium was z mol. Calculate the value of z.

(v) Show that the decomposition of **AB**(g) is endothermic.

(vi) State any assumption/s made in your calculations.

6. **(*a*)** **(i)** Rate = $k [M]^m [N]^n$ (10)

(ii) I. According to the first graph, the rate of the reaction is independent of [M]. Therefore, the order to the reaction with respect to M must be zero (m = 0).

(10)

Therefore, Rate = $k [N]^n$ (05)

II. From second graph, when N = 0.1 mol dm^{-3} ; Rate = 10 mol dm^{-3} s^{-1},
When N = 0.2 mol dm^{-3} ; Rate = 40 mol dm^{-3} s^{-1}.

When the concentration is doubled, rate increased four times, therefore the order with respect N is 2. (20)

Or

Using data for any two points,

10 mol dm^{-3} s^{-1} = $k(0.1 \text{ mol dm}^{-3})^n$ ———— (1) (04 + 01)

40 mol dm^{-3} s^{-1} = $k(0.2 \text{ mol dm}^{-3})^n$ ———— (2) (04 + 01)

$$\frac{(2)}{(1)} \quad \frac{40 \text{ mol dm}^{-3} \text{ s}^{-1}}{10 \text{ mol dm}^{-3} \text{ s}^{-1}} = \frac{(0.2 \text{ mol dm}^{-3})}{(0.1 \text{ mol dm}^{-3})^n} \quad (04 + 01)$$

$4 = 2^n$

$n = 2$ (05)

Note : For obtaining n = 2 only by argument, e.g. curved shape of the graph means order = 2, award **only 10 marks.**

III. Overall order = n + m = 2 + 0 = 2 (05)

IV. From equation (1),

$$k = \frac{10 \text{ mol dm}^{-3} \text{ s}^{-1}}{(0.1 \text{ mol dm}^{-3})^2} \quad (04 + 01)$$

= 1000 mol^{-1} dm^3 s^{-1} (04 + 01)

6 (a)(ii) 50 marks

***Total for* 6(a) 60 marks**

(*b*) (i)

	$AB(g) \rightleftharpoons$	$A(g)$	+	$B(g)$	
At $t = 0$	$1.0\,mol$	0		0	
at equlibrium	$(1-x)\,mol$	$x\,mol$		$x\,mol$	(05)
or					
concentration at equlibrium	$\frac{1-x}{V}$	$\frac{x}{V}$		$\frac{x}{V}$	

$$K_C = \frac{\left(x/V\right)\left(x/V\right)}{\left((1-x)/V\right)} = \frac{x^2}{(1-x)V} \qquad (05)$$

$$K_C V(1-x) = x^2$$

After opening the tap the volume is increased to $3V$. The amount dissociated is y mol.

	$AB(g) \rightleftharpoons$	$A(g)$	+	$B(g)$	
at equlibrium	$(1-y)\,mol$	$y\,mol$		$y\,mol$	(05)
or					
concentration at equlibrium (mol dm^{-3})	$\frac{1-y}{3V}$	$\frac{y}{3V}$		$\frac{y}{3V}$	

$$K_C = \frac{\left(y/3V\right)\left(y/3V\right)}{\left((1-y)/3V\right)} = \frac{y^2}{(1-y)3V} \qquad (05)$$

$$3K_C V(1-y) = y^2$$

6 (b)(i) 20 marks

(ii) Equilibrium constant K_C in both occasions is the same because there is no change in temperature. (05)

$$K_C = \frac{x^2}{(1-x)\,V} = \frac{y^2}{(1-y)\,3V} \qquad (05)$$

If $y = 0.5\,mol$

$$\frac{x^2}{(1-x)\,V} = \frac{(0.5\,mol)^2}{(1.0\,mol - 0.5\,mol)\,3V} \qquad (05)$$

$$\frac{x^2}{(1-x)\,V} = \frac{(0.5\,mol)^2}{3(0.5\,mol)} = \frac{0.5\,mol}{3}$$

$$3x^2 - 0.5\,mol\,(1-x) = 0$$

$$(3x - 1\,mol)\,(2x + 1\,mol) = 0$$

$$x = \frac{1}{3}\,mol \quad \text{or} \quad x = -\frac{1}{2} \quad \text{(can not be accepted)}$$

$$x = 0.33\,mol \qquad (05)$$

6 (b)(ii) 20 marks

(iii) When volume is V, the amount dissociated = 0.33 mol. When the volume is increased to $3V$ the amount dissociated = 0.50 mol. Increasing of volume decreases the pressure of the system, 50 more AB(g) is dissociated to counter this change.

(10)

6 (b)(iii) 10 marks

(iv) Applying $PV = nRT$ to second equilibrium,

$y = 0.5$

$n = 1 + y = 1.5\,\text{mol}$ (04 + 01)

Volume $= 3V$ and $T = 400\,\text{K}$

$$P_2 = 1.5\ \frac{R \times 400\,\text{K}}{3\text{V}}$$ (05)

When the temperature is increased to 600 K

Pressure = $P_3 = 1.7\ P_2$

Applying $PV = nRT$ for third equilibrium

$n = (1 + z)\,\text{mol}$ (04 + 01)

$V = 3V$ and $T = 600\ \text{K}$

$$P_2 = 1.7\left(1.5\ \frac{R \times 400\,\text{K}}{3V}\right) = \frac{(1+z)\ R \times 600\ \text{K}}{3V}$$ (05)

$$1+z = \frac{1.5 \times 400\,\text{K} \times 1.7}{600\,\text{K}} = 1.7$$

$z = 0.7\,\text{mol}$ (04 + 01)

6 (b)(iv) 25 marks

(v) Increasing of temperature from 400 K to 600 K (at constant volume) has increased the amount dissociated. Therefore, supply of heat has driven the reaction forward. Therefore, the forward reaction must be endothermic.

(10)

6 (b)(v) 10 marks

(v) All the gasses behave as ideal gasses. (05)

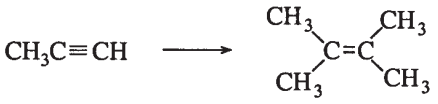
6 (b)(vi) 05 marks

***Total for* 6(b) 90 marks**

***Total for* 6 : 150**

Question 7

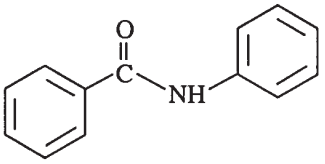
7. (*a*) Using **only** the chemicals given in the list, show how you would carry out the following conversion.



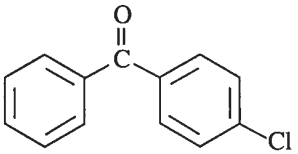
List of chemicals
$NaBH_4$, $HgSO_4$, dil. H_2SO_4,
conc. H_2SO_4, PCl_5, Mg, ether

(4.0 *marks*)

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



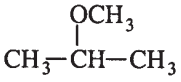
A



B

(6.0 *marks*)

(*c*) It is possible to synthesize the following compound **X** using two different pathways. Each pathway can be written as a nucleophilic substitution reaction.



X

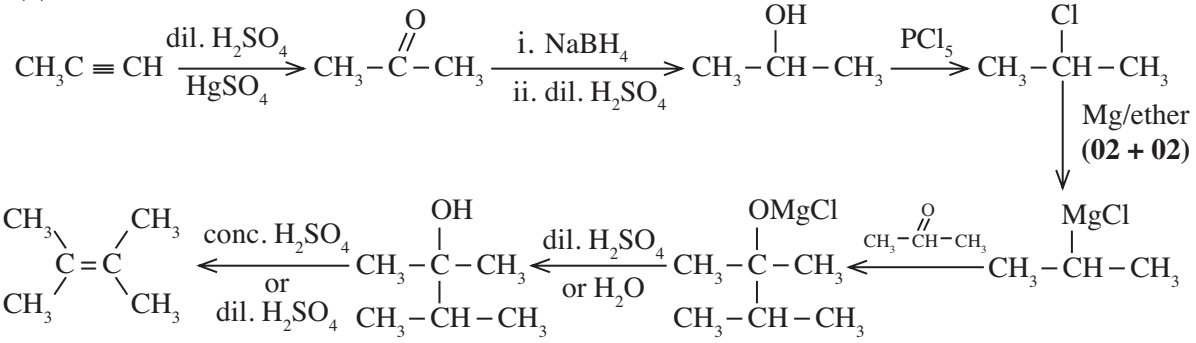
(i) Write the reactants for each pathway.

(ii) One of the above pathways will result in the formation of another compound **Y** in additon to **X**. Identify the reactants involved in this pathway and write the structure of **Y**.

(iii) State what **type of reaction** is involved in the formation of **Y**.

(iv) Assume that the reactants identified in (ii) above, form **X**, by a two step reaction. Show how **X** is formed by writing these two steps. Use curved arrows to indicate movement of electrons.

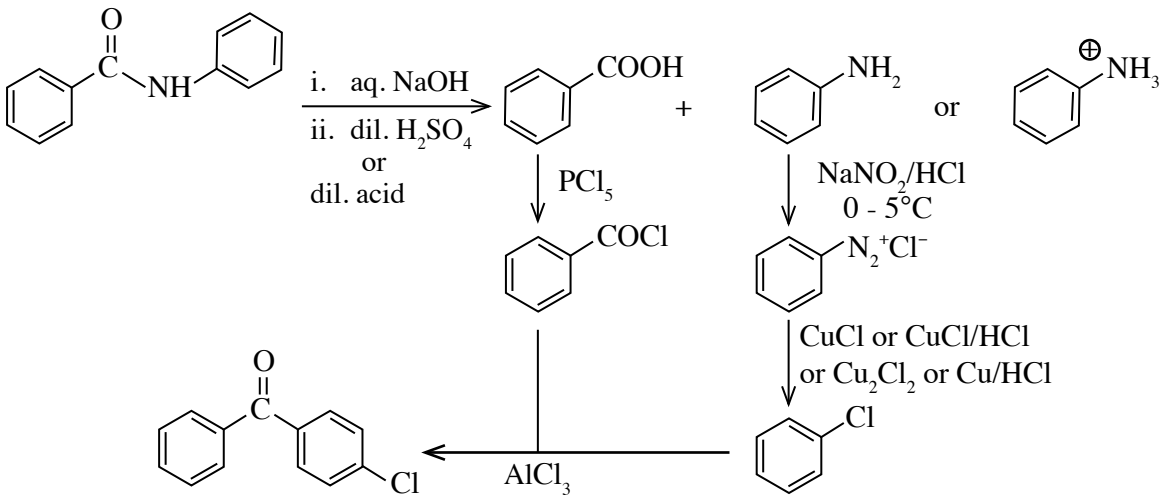
7. (*a*)



(03 × 12 + 04)

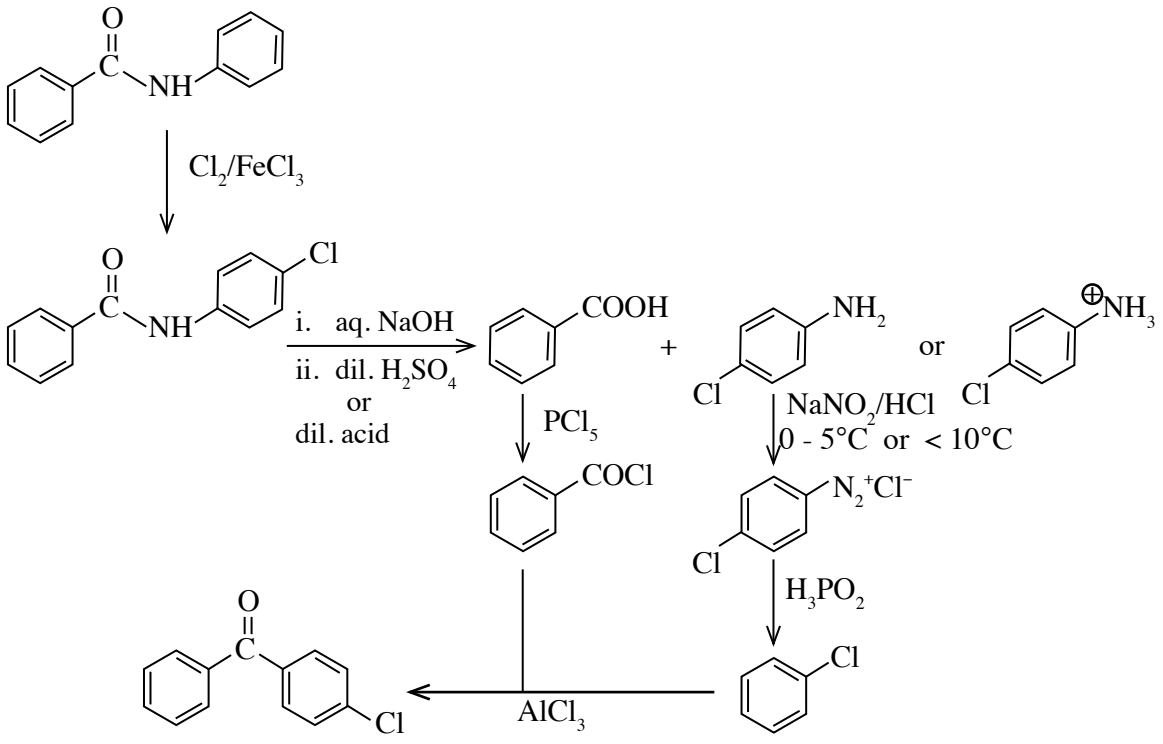
***Total for* 7(a) 40 marks**

(***b***)



(06 × 10)

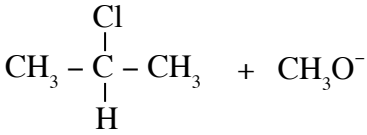
Marks may be awarded for the following alternate scheme as well.



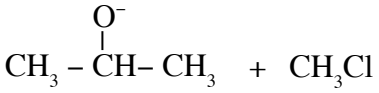
(05 × 12)

***Total for* 7(*b*)**	**60 marks**

(*c*) (i)



(06 + 06)

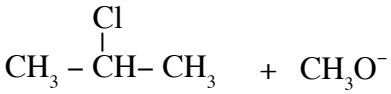


(06 + 06)

Note : CH_3OH with Na is acceptable for CH_3O^-. In place of Cl there can be Br or I.

7 (c)(i) 24 marks

(ii)



(02 + 02)

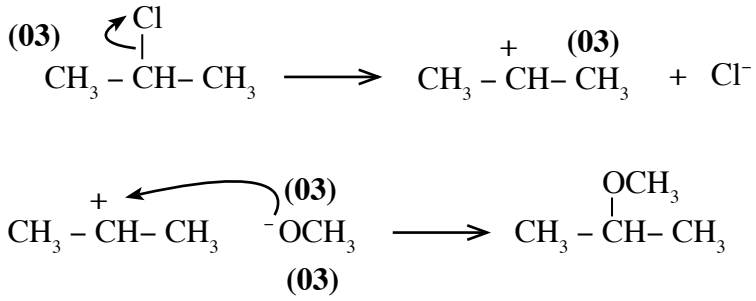
Y = $CH_3CH{=}CH_2$ (04)

7 (c)(ii) 08 marks

(iii) Elimination (06)

7 (c)(iii) 06 marks

(iv)



7 (c)(iv) 12 marks

***Total for* 7(*c*) 50 marks**

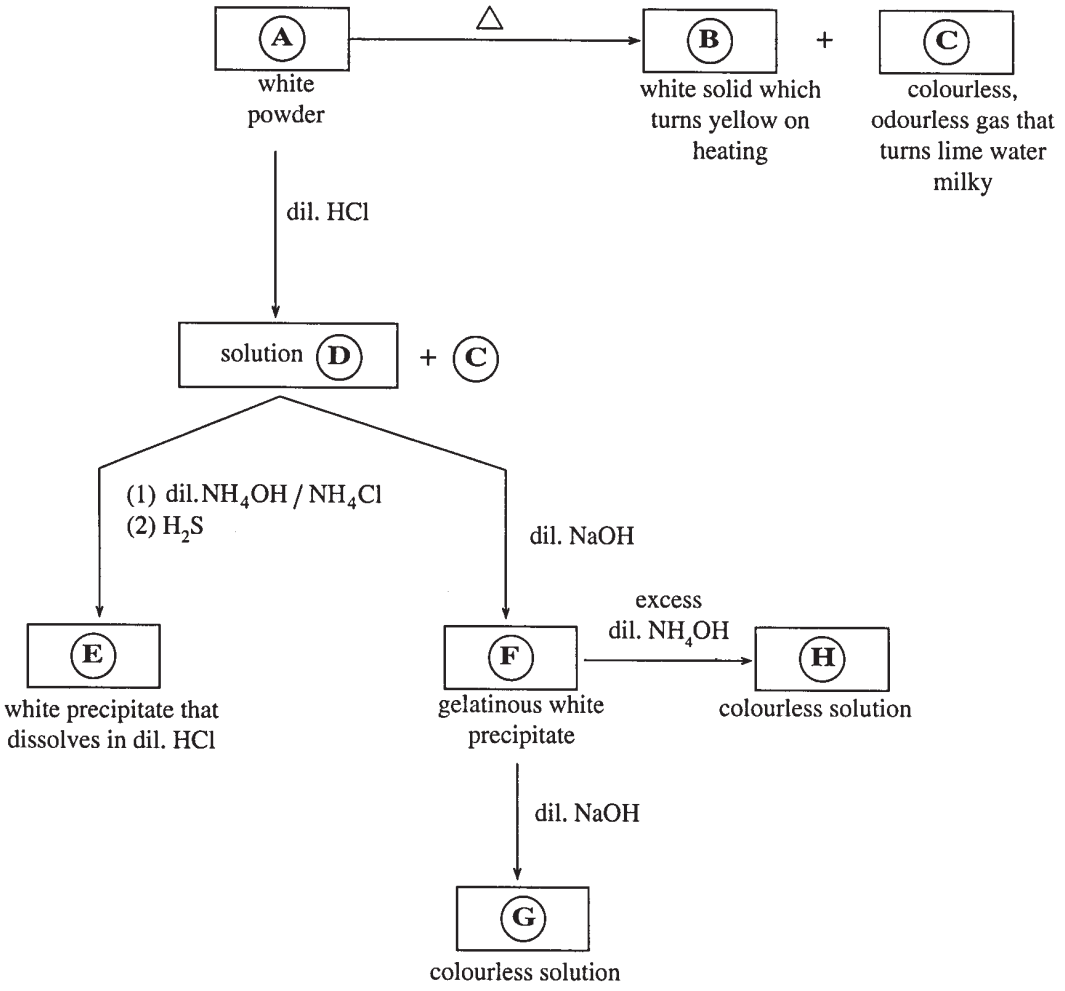
***Total for* 7 : 150**

Question 8

PART C — ESSAY

*Answer **two** questions only. (Each question carries **15** **marks**.)*

8. (*a*) Reactions of compounds of an element in the 3*d* block of the Periodic Table are given below. Identify the species **A**, **B**, **C**, **D**, **E**, **F**, **G** and **H**.



(5.0 *marks*)

(*b*) Tests (1) and (2) were carried out with an aqueous solution **Z** produced by passing the colourless gas **P** into water. The tests and observations are given below.

Test	Observation
(1) Added an acidified solution of $K_2Cr_2O_7$ to the solution.	A clear green solution was obtained.
(2) Added H_2O_2 to the solution and warmed. Then added a solution of $BaCl_2$.	A white precipitate insoluble in dil. HCl was formed.

(i) Identify gas **P**. (Reasons are **not** required.)

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

(iii) When gas **Q** was passed through solution **Z**, a pale yellow (could be seen as white) turbidity resulted.

I. Identify gas **Q**. (Reasons are **not** required.)

II. Give the balanced chemical equation for this reaction.

(5.0 *marks*)

(*c*) A sample given for analysis was found to contain NaOH, Na_2CO_3 and an inert water soluble substance. The following procedure was used to determine the percentage of Na_2CO_3 in the sample.

Note: The inert substance **does not** participate in the reactions in the procedure given below.

Procedure:

A weight of 42.40 g of the sample was transferred quantitatively to a 500 cm^3 volumetric flask and made upto the mark with distilled water. The flask was shaken thoroughly (**solution X**).

(1) A 25.00 cm^3 portion of **solution X** was titrated with dil. HCl solution using methyl orange as the indicator, until the colour changed from orange to red. The burette reading at the end point was 32.00 cm^3.

(2) A 25.00 cm^3 portion of **solution X** was warmed to 70 °C and 1% $BaCl_2$ solution was added in slight excess. The $BaCO_3$ precipitate formed was filtered, and the filtrate was titrated with dil. HCl solution using phenolphthalein as the indicator until the colour changed from pink to colourless. The burette reading at the end point was 24.00 cm^3.

(3) To a 25.00 cm^3 volume of the dil. HCl solution, 5% KIO_3 and 5% KI solutions were added in excess. The liberated I_2 was titrated with a 0.50 mol dm^{-3} $Na_2S_2O_3$ solution using starch as the indicator. The burette reading at the end point was 12.50 cm^3.

(i) Determine the concentration of the HCl solution.

8. (*a*) **(i)** A = $ZnCO_3$ B = ZnO C = CO_2

D = $ZnCl_2$ or Zn^{2+} or $[ZnCl_4]^{2-}$ or $[Zn(H_2O)_6]^{2+}$

E = ZnS F = $Zn(OH)_2$

G = Na_2ZnO_2 or $(Na_2Zn(OH)_4$ or $Zn(OH)_4^{2-}$ or ZnO_2^{2-}

H = $[Zn(NH_3)_4]^{2+}$ or $[Zn(NH_3)_6]^{2+}$ (06 × 08)

If **all** answers are correct (02)

Total for **8(*a*)** **50 marks**

(*b*) **(i)** SO_2 (10)

8 (b)(i) 10 marks

(ii)

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

$Cr_2O_7^{2-} + 14H^+ + 6e \longrightarrow 2Cr^{3+} + 7H_2O$ (03)

$Cr_2O_7^{2-} + 2H^+ + 3SO_2 \longrightarrow 2Cr^{3+} + 3SO_4^{2-} + H_2O$ (04)

$H_2O_2 + 2H^+ + 2e \longrightarrow 2\,H_2O$ (03)

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

$SO_2 + H_2O_2 \longrightarrow SO_4^{2-} + 2H^+$ or $SO_2 + H_2O_2 \longrightarrow H_2SO_4$ (04)

$H_2SO_4 + BaCl_2 \longrightarrow BaSO_4\downarrow + 2HCl$ or $SO_4^{2-} + BaCl_2 \longrightarrow BaSO_4\downarrow + 2Cl^-$ (04)

Alternate answer (I)

$3(H_2SO_3 + 2H_2O \longrightarrow SO_4^{2-} + 4H^+ + 2e)$ (03)

$Cr_2O_7^{2-} + 14H^+ + 6e \longrightarrow 2Cr^{3+} + 7H_2O$ (03)

$Cr_2O_7^{2-} + 2H^+ + 3H_2SO_3 \longrightarrow 2Cr^{3+} + 3SO_4^{2-} + 4H_2O$ (04)

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

$H_2SO_3 + H_2O \longrightarrow SO_4^{2-} + 4H^+ + 2e$ (03)

$H_2SO_3 + H_2O_2 \longrightarrow SO_4^{2-} + 2H^+ + H_2O$ (04)

$H_2SO_4 + BaCl_2 \longrightarrow BaSO_4\downarrow + 2HCl$ or $SO_4^{2-} + BaCl_2 \longrightarrow BaSO_4\downarrow + 2Cl^-$ (04)

Alternate answer (II)

$3(SO_3^{2-} + H_2O \longrightarrow SO_4^{2-} + 2H^+ + 2e)$ (03)

$Cr_2O_7^{2-} + 14H^+ + 6e \longrightarrow 2Cr^{3+} + 7H_2O$ (03)

$Cr_2O_7^{2-} + 8H^+ + 3SO_3^{2-} \longrightarrow 2Cr^{3+} + 3SO_4^{2-} + 4H_2O$ (04)

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

$SO_3^{2-} + H_2O \longrightarrow SO_4^{2-} + 2H^+ + 2e$ (03)

$SO_3^{2-} + H_2O_2 \longrightarrow SO_4^{2-} + H_2O$ (04)

$H_2SO_4 + BaCl_2 \longrightarrow BaSO_4\downarrow + 2HCl$ or $SO_4^{2-} + BaCl_2 \longrightarrow BaSO_4\downarrow + 2Cl^-$ (04)

Note :

If equations are not balanced - No marks

If the half reactions are not given but the correct complete reaction is given, award full marks, i.e. (03 + 03 + 04)

8 (b)(ii) 24 marks

(iii) I. $Q = H_2S$ (10)

II. $2H_2S + SO_2 \longrightarrow 3S\downarrow + 2H_2O$

or

$2H^+ + 2H_2S + SO_3^{2-} \longrightarrow 3S + 3H_2O$

$3H_2S + H_2SO_4 \longrightarrow 4S + 4H_2O$ (06)

8 (b)(iii) 16 marks

***Total for* 8(*b*) 50 marks**

(*c*) (i) $IO_3^- + 5I^- + 6H^+ \longrightarrow 3I_2 + 3H_2O$ --------- (1) (04)

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

Amount of moles of $S_2O_3^{2-}$ = $\frac{0.50}{1000} \times 12.50$ (02)

Amount of moles of I_2 = $\frac{0.50}{1000} \times 12.50 \times \frac{1}{2}$ (02)

Amount of moles of H^+ = $\frac{0.50}{1000} \times 12.50 \times \frac{1}{2} \times 2$ (02)

$[H^+]$ = $\frac{0.50}{1000} \times 12.50 \times \frac{1}{2} \times 2 \times \frac{1000}{25.0}$ (02)

= **0.25 mol dm^{-3}** (02)

Note : The relationship $H^+ \equiv S_2O_3^{2-}$ can also be used in the above calculation.

8 (c)(i) 16 marks

(ii)

$NaOH + HCl \longrightarrow NaCl + H_2O$ (01)

$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2$ (01)

Amount of moles of HCl required to react with NaOH and Na_2CO_3 = $\frac{0.25}{1000} \times 32.0$ (03)

Amount of moles of HCl required to react with NaOH = $\frac{0.25}{1000} \times 24.0$ (03)

Therefore, amount of moles of HCl required to react with Na_2CO_3

= $\frac{0.25}{1000} \times 32.0 - \frac{0.25}{1000} \times 24.0$ (03)

= 0.008 – 0.006

= 0.002 (03)

Therefore, amount of moles of Na_2CO_3 in 25.0 cm^3 = $\frac{0.002}{2}$ (03)

Amount of moles of Na_2CO_3 in 500.0 cm^3 = $\frac{0.002 \times 20}{2}$

= 0.02 (03)

Molecular mass of Na_2CO_3 = 106 g mol^{-1}

Mass of Na_2CO_3 = $0.02 \times 106 = 2.12$ g (03)

% Na_2CO_3 in sample = $\frac{2.12}{42.4} \times 100$ % (03)

= **5.0 %** (03)

8 (c)(ii) 29 marks

(iii) Assumption/s - All the carbonate in the solution is precipitated as $BaCO_3$ on the addition of excess $BaCl_2$.

(03)

8 (c)(iii) 05 marks

***Total for* 8(*c*) 50 marks**

***Total for* 8 : 150**

Question 9

9. (*a*) (i) I. With the aid of balanced chemical equations list the steps involved, along with the reaction conditions, in the manufacture of H_2SO_4 using the Contact Process.

II. Briefly describe the physicochemical principles related to this process.

III. Give **two** uses of H_2SO_4.

(ii) Using balanced chemical equations, indicate how the following conversions could be carried out industrially:

I. limestone $\longrightarrow C_2H_2$

II. $N_2 \longrightarrow NaNO_2$

Note: Where applicable give the reaction conditions and indicate how the reagents/reactants are obtained industrially.

(iii) The following questions are based on the manufacture of Na_2CO_3 using the Solvay Process.

I. State the starting materials used in this process.

II. Indicate how the materials stated in I are obtained.

III. Give the **final** by-product of this process.

IV. Give **two** reasons as to why low temperatures are used in this process.

V. Give **two** uses of Na_2CO_3.

VI. Propose a method to convert the final by-product stated in III to gypsum, using sea water as a natural resource. **(7.5 *marks*)**

(*b*) As an alternative to chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) were introduced to reduce the ozone layer depletion. However, both these groups of compounds not only deplete the ozone layer but also contribute to other environmental problems.

(i) Draw the chemical structures of all the CFCs and HCFCs with a single C atom. Label each of them as a CFC or HCFC.

(ii) "Under normal atmospheric conditions, HCFCs are more reactive than CFCs." Comment on this statement.

(iii) Name another environmental problem that is associated with CFCs and HCFCs. Comment on their relative contribution towards this environmental problem.

(iv) Identify **three** properties of CFCs that make them suitable for use as refrigerants.

(v) Explain how CFCs contribute to the depletion of the ozone layer.

(vi) Briefly describing the consequence of the depletion of the ozone layer, identify **three** problems associated with it. **(7.5 *marks*)**

9. (*a*) **(i) I.**

$$S(s) + O_2(g) \xrightarrow{\Delta \ \textbf{(01)}} SO_2(g) \qquad (02)$$

$$2\,SO_2(g) + O_2(g) \underset{\text{1 – 2 atm } \textbf{(01)}}{\overset{\text{450 °c } \textbf{(01)}}{\rightleftharpoons}} 2SO_3(g) \qquad (02)$$

V_2O_5 **(01)**

$$SO_3(g) + H_2SO_4(l) \longrightarrow H_2S_2O_7(l) \qquad (02)$$

$$H_2SO_4(l) + H_2O(l) \longrightarrow 2H_2SO_4(aq) \qquad (02)$$

Other methods of producing SO_2 are also acceptable :

eg : $2PbS(s) + 3O_2(g) \xrightarrow{\Delta} 2PbO(s) + 2SO_2(g)$

$2ZnS(s) + 3O_2(g) \xrightarrow{\Delta} 2ZnO(s) + 2SO_2(g)$

$2H_2S(g) + 3O_2(g) \xrightarrow{\Delta} 2H_2O(g) + 2SO_2(g)$

(H_2S in crude oil burned in air)

$$2CuFeS_2(s) + 4O_2(g) \xrightarrow{\Delta} Cu_2S(s) + 2FeO(s) + 3SO_2(g)$$
(copper pyrites)

$$4CuFeS_2(s) + 11O_2(g) \xrightarrow{\Delta} 2Cu_2O(s) + 4FeO(s) + 8SO_2(g)$$
$$4FeS_2(s) + 11O_2(g) \xrightarrow{\Delta} 2Fe_2O_3(s) + 8SO_2(g)$$

Note : Physical states are not required.

9 (a)(i)(I) 12 marks

II.

The reaction between SO_2 and O_2 is reversible **(01)** and exothermic **(01)** and the number of molecules decreases in the forward reaction **(01).** According to the Le Chatelier's principle **(01) the forward reaction will be favoured by low temperature (01) and high pressure (01).**

The small advantage gained in this reaction by using high pressure is more than offset by the greater cost of equipment that would be needed **(01).** Hence, 1 - 2 atm pressure is used.

At tow temperatures, the rate of reaction is low **(01).** Hence, a temperature of 450°C is used to get an acceptable rate. A catalyst, (V_2O_5), is used **(01)** to speed up the rate of the reaction **(01)** and achieve the equilibrium condition faster **(01)**.

9 (a)(i)(II) 11 marks

III.

Manufacture of fertilizers	Manufacture of chemicals
Production of dyes	Production of drugs
Production of explosives	In automobile batteries/battery acid
Production of detergents	Extracting metals from metal ores
Oxidizing agent	Dehydrating agent
Manufacture of synthetic fibers	Manufacture of plastics
Manufacture of paints & pigments	Used in petroleum refining
Drying agent (gases)	

(any two) (01 × 2)

9 (a)(i)(III) 02 marks

Total for **9(*a*)(i)**	**25 marks**

(ii) I. $CaCO_3(s) \xrightarrow{\Delta\ (01)} CaO(s) + CO_2(g)$ (02)

$CaO(s) + 3C(s) \xrightarrow{\Delta\ (01)} CaC_2(s) + CO(g)$ (02)

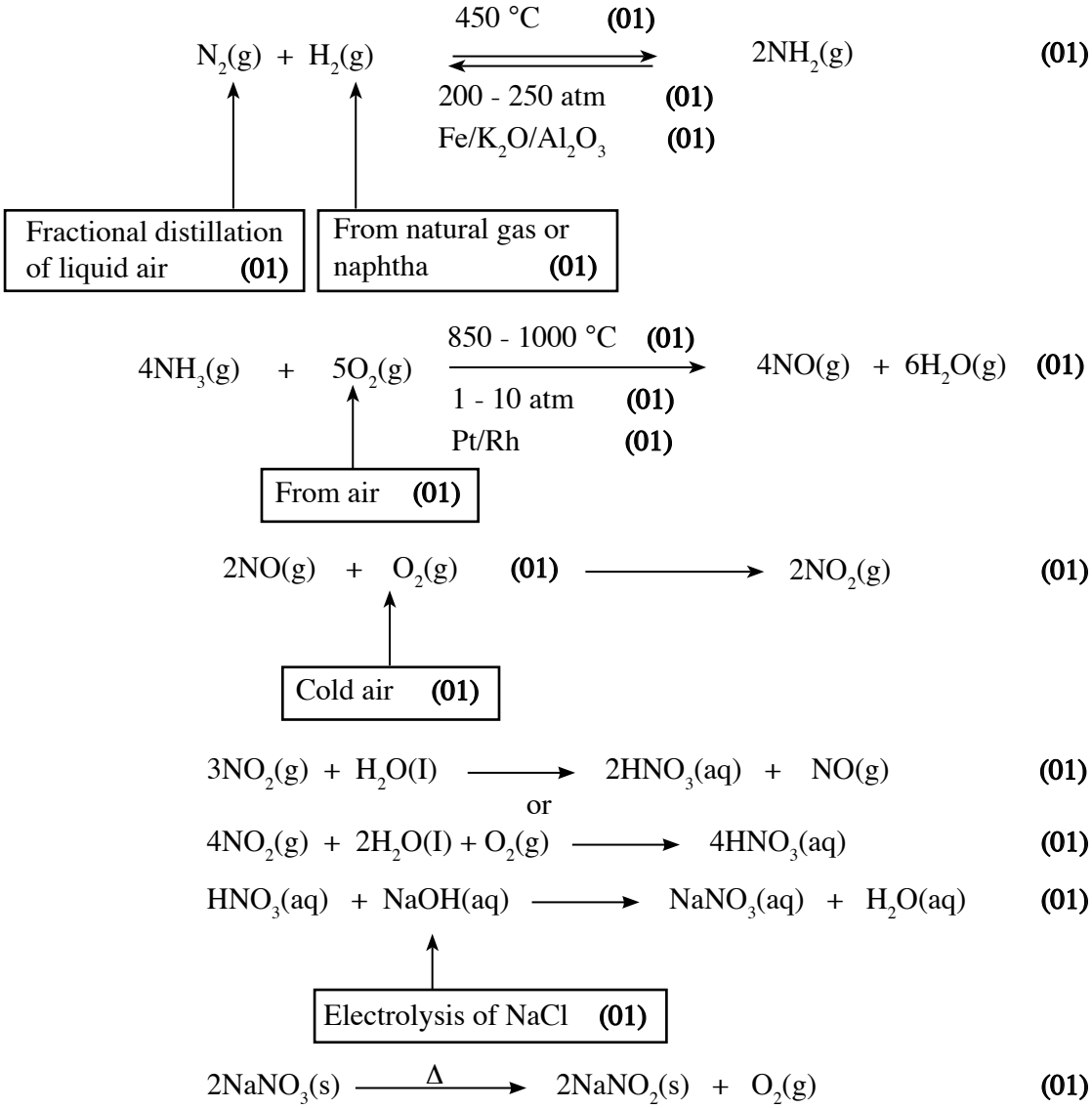
or

$2CaO(s) + 5C(s) \xrightarrow{\Delta} 2CaC_2(s) + CO_2(g)$

$CaC_2(s) + 2H_2O(l) \longrightarrow Ca(OH)_2(aq) + C_2H_2(g)$ (02)

9 (a)(ii)(I) 08 marks

II.



Note : Physical states are not required. **9 (a)(ii)(II) 17 marks**

***Total for* 9(*a*)(ii) 25 marks**

(iii) I. Brine (concentrated NaCl solution), NH_3 and CO_2 (02 + 02 + 02)

II. Brine - from sea water (02)
NH_3 - from the Haber process (02)
CO_2 - from limestone (02)

III. $CaCl_2$ (02 marks)

IV. to precipitate $NaHCO_3$ (02)
to dissolve gases in brine (02)

V. manufacture of glass, detergents, soap, sodium silicate and paper, to soften hard water, as washing soda in detergents, extinguishing fires

(any two) (02 + 02)

VI. $CaCl_2$ is added to remaining mother liquor after precipitating NaCl from sea water. (01)

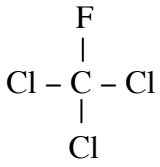
Good source of SO_4^{2-} (01)

$CaCl_2(s) + SO_4^{2-} \longrightarrow CaSO_4 . 2H_2O$ (gypsum) (01)

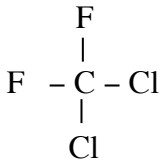
9 (a)(iii) 25 marks

Total for **9(*a*)**	**75 marks**

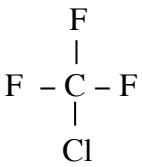
(*b*) (i)



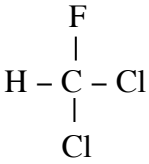
CFC



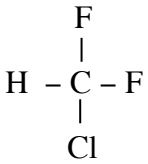
CFC



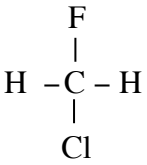
CFC



HCFC



HCFC



HCFC

(03 × 6)

(2 for structure only, 3 for structure and identification)

9 (b)(i) 18 marks

(ii) Statement is correct. **(03)** Compared to C – F and C – Cl bonds C – H bonds are weaker **(03)** and subjected to reaction with environmental chemicals **(03)**.

9 (b)(ii) 09 marks

(iii) Global warming. **(03)** Both the CFCs and HCFCs are greenhouse gases **(03)** that contribute to the elevation of atmospheric temperatures **(03)**. Since HCFCs are more reactive their atmospheric lifetime is shorter **(03)** and hence the contribution to the global warming is less than that of CFCs **(03)**.

9 (b)(iii) 15 marks

(iv)

chemically inert	-	no damage to the food
physiologically inert	-	no health problems even if consumed
nonflammable	-	safety
easily compressible and expandable	-	effective coolant
less viscous	-	easily mobile
low boiling points	-	gaseous at room temperature
high specific heat		

(any three) (03 × 3)

9 (b)(iv) 09 marks

(v) At the higher elevations, CFCs are exposed to UV radiation. UV radiation cleaves C – Cl (or C – F) bonds **(03)** and generates chlorine (or fluorine) free radicals **(03)**. These radicals catalyze the destruction of ozone molecules **(03)** and deplete the levels of ozone in the upper atmosphere **(03)**.

$$CFCl_3 \xrightarrow[(03)]{UV\ (or\ h\upsilon)} {}^{\bullet}CFCl_2 + {}^{\bullet}Cl \quad \text{(any CFC can be used)}$$
(03)

$${}^{\bullet}Cl + O_3 \longrightarrow {}^{\bullet}OCl + O_2 \qquad (01)$$

$$O_2 \xrightarrow{h\upsilon} 2O \qquad (01)$$

$${}^{\bullet}OCl + O \longrightarrow {}^{\bullet}Cl + O_2 \qquad (01)$$

9 (b)(v) 12 marks

(vi) Depletion of ozone layer allows the penetration of high energy UV to the ground **(03)**. Penetrated UV can cause to following problems.

Elevates the atmospheric temperature

Produces ozone at the grouns level

Cataract in eyes

Skin carcinoma

Adversely affects vegetation **(any three, 03 marks each)**

9 (b)(vi) 12 marks

***Total for* 9(*b*) 75 marks**

***Total for* 9 : 150**

Facility of part (*b*) was less than that of (*a*). Answering questions related to the understanding of global environment had become difficult for students. Not paying adequate attention to last lessons and not covering the entire syllabus would have caused this situation. Hence, it is stressed that in order to answer the chemistry paper successfully, full coverage of the syllabus is essential and the students should be prepared to answer the questions set on all the topics.

Question 10

10. (*a*) Predict the products and give balanced chemical equations for the following reactions. State the action of the species underlined, in the reaction.

(i) $\underline{H_2O_2}(aq) + PbS(s) \longrightarrow$

(ii) $MnO_4^-(aq) + \underline{H_2O_2}(aq) + H^+(aq) \longrightarrow$

(iii) $Cr_2O_7^{2-}(aq) + \underline{H_2S}(aq) + H^+(aq) \longrightarrow$

(iv) $Cu(s) + \underline{H_2S}(g) \xrightarrow{\Delta}$

(v) $C(s) + \underline{\text{conc. } HNO_3} \xrightarrow{\Delta}$

(2.5 *marks*)

(*b*) A solution **T** has been prepared by dissolving 0.300 g of FeC_2O_4 in dilute H_2SO_4. The solution was heated to 65 °C. Calculate the volume of 0.025 mol dm^{-3} $KMnO_4$ solution required to react completely with FeC_2O_4 under these conditions.

(C = 12, O = 16, Fe = 56)

Note : Consider FeC_2O_4 to exist as Fe^{2+} and $C_2O_4^{2-}$ in solution **T**.

(5.0 *marks*)

(*c*) Liquefied-petroleum gas (LP gas) is commonly used as a fuel for cooking purposes in Sri Lanka. It is a mixture of liquefied propane and butane, under high pressure. The following data are provided.

Substance	Standard enthalpy of formation ΔH_f° at 25 °C (kJ mol^{-1})
$H_2O(l)$	– 286
$CO_2(g)$	– 394
$C_3H_8(g)$	– 104
$C_4H_{10}(g)$	– 126

(i) Calculate the standard enthalpies of combustion of propane and butane gases at 25 °C.

(ii) Calculate the amount of heat needed to increase the temperature of 400 g of water from 25 °C to 85 °C. (Heat capacity of water is 4.2 J g^{-1} $°C^{-1}$).

(iii) Assuming complete combustion would take place, calculate the mass of CO_2 emitted in each case when the above process (ii) is carried out using:

I. propane as the fuel.

II. butane as the fuel.

(iv) Based on your calculations in (iii) above, identify which fuel is more environmentally friendly and explain why it is so.

(7.5 *marks*)

10.(*a*) (i) $\underline{4H_2O_2} + PbS \longrightarrow PbSO_4 + 4H_2O$ (04)

Oxidizing agent **or** undergoes reduction (01)

(ii) $2MnO_4^- + \underline{5H_2O_2} + 6H^+ \longrightarrow 2Mn^{2+} + 8H_2O + 5O_2$ (04)

Reducing agent **or** undergoes oxidation (01)

(iii) $Cr_2O_7^{2-} + \underline{3H_2S} + 8H^+ \longrightarrow 2Cr^{3+} + 3S + 7H_2O$ (04)

Reducing agent **or** undergoes oxidation (01)

(iv) $Cu(s) + \underline{H_2S} \xrightarrow{\Delta} CuS + H_2$ (04)

Oxidizing agent **or** undergoes reduction **or** acts as an acid (01)

(v) $C + \underline{4HNO_3} \xrightarrow{\Delta} CO_2 + 4NO_2 + 2H_2O$ (04)

Oxidizing agent **or** undergoes reduction (01)

***Total for* 10(*a*) 25 marks**

(*b*)

Method 1

Half reactions taking place :

$5(Fe^{2+} \longrightarrow Fe^{3+} + e)$ (02)

$5(C_2O_4^{2-} \longrightarrow 2CO_2 + 2e)$ (02)

$3\,(MnO_4^- + 8H^+ + 5e \longrightarrow Mn^{2+} + 4H_2O)$ (02)

$3\,MnO_4^- + 5C_2O_4^{2-} + 5Fe^{2+} + 24H^+ \longrightarrow 5Fe^{3+} + 10CO_2 + 12H_2O + 3Mn^{2+}$ (08)

Molar mass of $FeC_2O_4 = 144\,g$

Amount of moles of $FeC_2O_4 = \dfrac{0.300\,g}{144\,g}$ (03)

Amount of moles of Fe^{2+} = Amount of moles of $C_2O_4^{2-} = \dfrac{0.300\,g}{144\,g} = 2.08 \times 10^{-3}$ (03)

Let the volume of $KMnO_4$ be V cm^3

Amount of moles of $MnO_4^- = \dfrac{0.025}{1000} \times V$ (03)

Therefore, amount of moles of Fe^{2+} = Amount of moles of $C_2O_4^{2-} = \dfrac{0.025}{1000} \times V \times \dfrac{5}{3}$

(03 + 03 + 09)

$= \dfrac{0.025}{1000} \times V \times \dfrac{5}{3} = 2.08 \times 10^{-3}$ (07)

V = **50.0 cm^3** (04 + 01 = 05 marks)

Method 2

$5\ (Fe^{2+} \longrightarrow Fe^{3+} + e)$ (02)

$MnO_4^- + 8H^+ + 5e \longrightarrow Mn^{2+} + 4H_2O$ (02)

$5Fe^{2+} + MnO_4^- + 8H^+ \longrightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$ ---------- (1) (04)

$5(C_2O_4^{2-} \longrightarrow 2CO_2 + 2e)$ (02)

$2\ (MnO_4^- + 8H^+ + 5e \longrightarrow Mn^{2+} + 4H_2O)$ (02)

$2\ MnO_4^- + 5C_2O_4^{2-} + 16H^+ \longrightarrow 10CO_2 + 2Mn^{2+} + 8H_2O$ ---------- (2) (04)

Amount of moles of Fe^{2+} = Amount of moles of $C_2O_4^{2-} = \frac{0.300\ g}{144\ g} = 2.08 \times 10^{-3}$ (03 + 03)

Let the volume of MnO_4^- for reaction (1) be $V_1\ cm^3$

Amount of moles of $MnO_4^- = \frac{0.025}{1000} \times V_1$ (03)

Therefore, amount of moles of $Fe^{2+} = \frac{0.025}{1000} \times V_1 \times 5$ (03)

$= \frac{0.025}{1000} \times V_1 \times 5 = 2.08 \times 10^{-3}$ (03)

$V_1 = 16.67\ cm^3 \approx 16.7\ cm^3$ (03)

Let the volume of MnO_4^- for reaction (2) be $V_2\ cm^3$

Amount of moles of $MnO_4^- = \frac{0.025}{1000} \times V_2$ (03)

Amount of moles of $C_2O_4^{2-} = \frac{0.025}{1000} \times V_2 \times \frac{5}{2}$ (03)

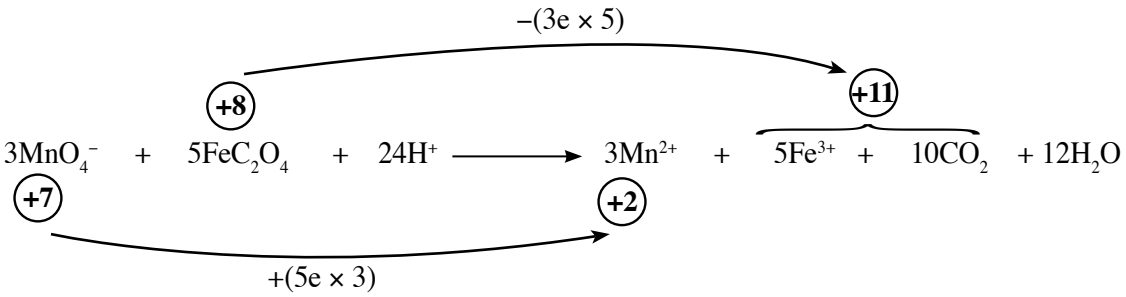
$= \frac{0.025}{1000} \times V_2 \times \frac{5}{2} = 2.08 \times 10^{-3}$ (03)

$V_2 = 33.28\ cm^3 \approx 33.3\ cm^3$ (03)

Total volume = $16.67\ cm^3 + 33.28\ cm^3$ (01)

= **$50.0\ cm^3$** (04 + 01)

Method 3



(02 + 02 + 02 + 08)

Amount of moles of FeC_2O_4 = $\frac{0.300\,g}{144\,g}$ = 2.08×10^{-3} (03)

Let the volume of MnO_4^- for the reaction be V cm^3

Amount of moles of MnO_4^- = $\frac{0.025}{1000} \times V$ (03)

5 moles of FeC_2O_4 ≡ 3 moles of $KMnO_4$ (09)

$\frac{0.300\ g}{144\ g} \times 3 = \frac{0.025 \times V \times 5}{1000}$ (16)

V = **50.0 cm^3** (04 + 01)

Total for **10(*b*)**	**50 marks**

(*c*) (i)

Burning of propane

$H_2(g) + 1/2O_2(g) \longrightarrow H_2O(l)$ $\Delta H_1 = -286\,kJ\,mol^{-1}$ ---- (1) (01)

$C(graphite) + O_2(g) \longrightarrow CO_2(g)$ $\Delta H_2 = -394\,kJ\,mol^{-1}$ ---- (2) (01)

$3C\ (graphite) + 4H_2(g) \longrightarrow C_3H_8(g)$ $\Delta H_3 = -104\,kJ\,mol^{-1}$ ---- (3) (02)

$C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(l)$ ΔH_4 ---- (4) (02)

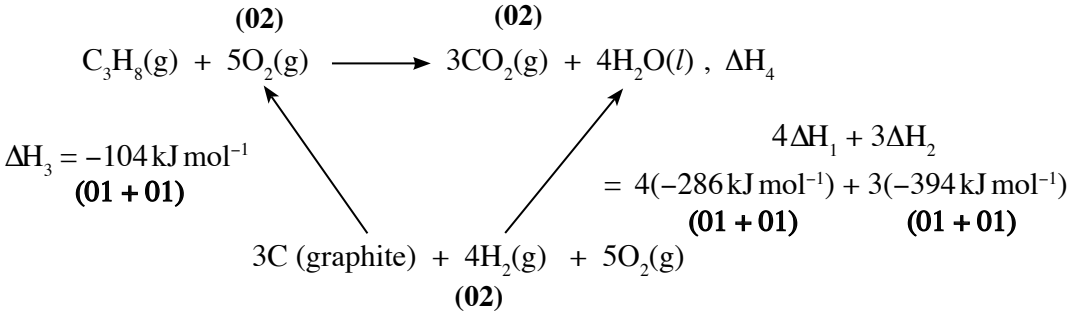
$\Delta H_4 = 4\Delta H_1 + 3\Delta H_2 - \Delta H_3$

$\Delta H_4 = 4(-286\,kJ\,mol^{-1}) + 3\,(-394\,kJ\,mol^{-1}) - (-104\,kJ\,mol^{-1})$

(01 + 01) **(01 + 01)** **(01 + 01)**

$= -2222\,kJ\,mol^{-1}$ (02 + 01)

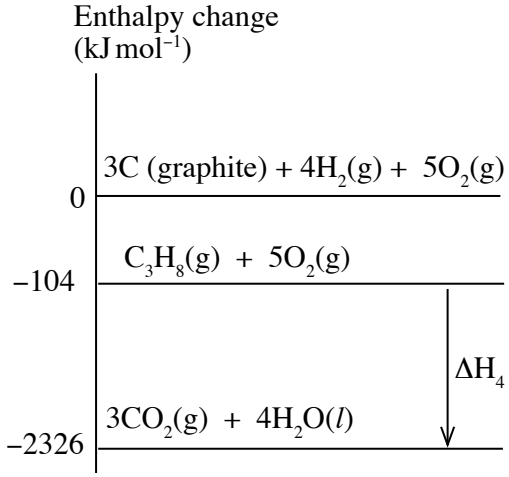
OR



$\Delta H_4 = 4\Delta H_1 + 3\Delta H_2 - \Delta H_3$

$= -2222\,kJ\,mol^{-1}$ (02 + 01)

OR



(02)

(02)

(02)

$\Delta H_4 = 4(-286\,kJ\,mol^{-1}) + 3(-394\,kJ\,mol^{-1}) - (-104\,kJ\,mol^{-1})$

(01 + 01) (01 + 01) (01 + 01)

(or correct enthalpy changes on the diagram)

$= -2222\,kJ\,mol^{-1}$ (02 + 01)

<u>Burning of butane</u>

$H_2(g) + 1/2O_2(g) \longrightarrow H_2O(l)$ $\Delta H_1 = -286\,kJ\,mol^{-1}$ ---- (1) (01)

$C(graphite) + O_2(g) \longrightarrow CO_2(g)$ $\Delta H_2 = -394\,kJ\,mol^{-1}$ ---- (2) (01)

$4C\,(graphite) + 5H_2(g) \longrightarrow C_4H_{10}(g)$ $\Delta H_3 = -126\,kJ\,mol^{-1}$ ---- (3) (02)

$C_4H_{10}(g) + 13/2O_2(g) \longrightarrow 4CO_2(g) + 5H_2O(l)$ ΔH_4 ---- (4) (02)

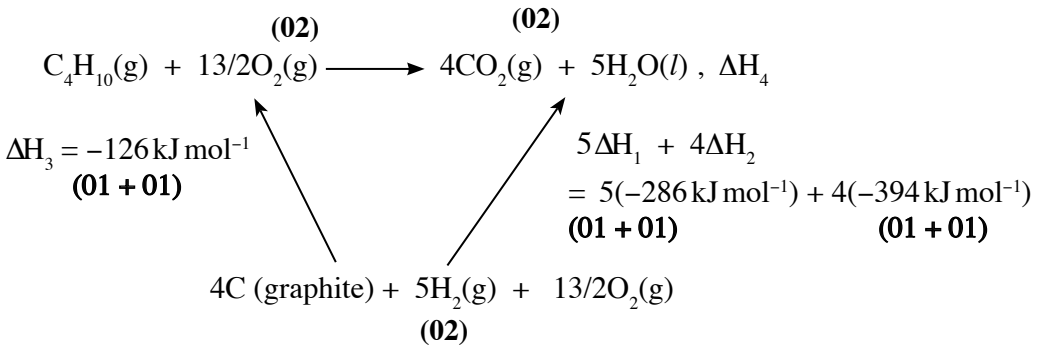
$\Delta H_4 = 5\Delta H_1 + 4\Delta H_2 - \Delta H_3$

$\Delta H_4 = 5(-286\,kJ\,mol^{-1}) + 4(-394\,kJ\,mol^{-1}) - (-126\,kJ\,mol^{-1})$

(01 + 01) (01 + 01) (01 + 01)

$= -2880\,kJ\,mol^{-1}$ (02 + 01)

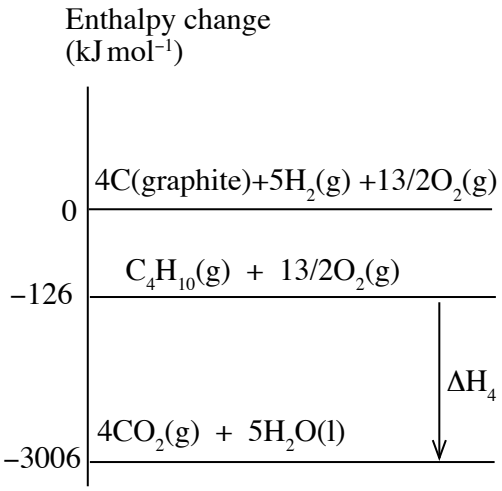
OR



$\Delta H_4 = 5\Delta H_1 + 4\Delta H_2 - \Delta H_3$

$= -2880\,kJ\,mol^{-1}$ (02 + 01)

OR



(02)

(02)

(02)

$\Delta H_4 = 5\,(-286\,kJ\,mol^{-1}) + 3\,(-394\,kJ\,mol^{-1}) - (-126\,kJ\,mol^{-1})$

(01 + 01) (01 + 01) (01 + 01)

(or correct enthalpy changes on the diagram)

$= -2880\ kJ\ mol^{-1}$ (02 + 01)

10 (c)(i) 30 marks

(ii) Heat needed to increase the temperature of 400 g of water from 25 °C to 85 °C.

$q = 400\,g \times 4.2\,J\,g^{-1}\,°C^{-1}\,(85 - 25)\,°C$ (04 + 01)

$= 100.8\,kJ$ (04 + 01)

10 (c)(ii) 10 marks

(iii) Amount of propane needed to produce the amount of heat in (ii).

$= 1/2222\,kJ\,mol^{-1} \times 100.8\,kJ = 4.54 \times 10^{-2}\,mol$ (04 + 01)

Amount of CO_2 emitted

$= 4.54 \times 10^{-2}\,mol \times 3$

$= 1.36 \times 10^{-1}\,mol$ (04 + 01)

Mass of CO_2 emitted

= 1.36×10^{-1} mol $\times$ 44 g mol^{-1}

= 5.98 g (04 + 01)

Amount of butane needed to produce the amount of heat in (ii).

= 1/2880 kJ mol^{-1} $\times$ 100.8 kJ

= 3.50×10^{-2} mol (04 + 01)

Amount of CO_2 emitted

= 3.50×10^{-2} mol $\times$ 4

= 1.40×10^{-1} mol (04 + 01)

Mass of CO_2 emitted

= 1.40×10^{-1} mol $\times$ 44 g mol^{-1}

= 6.16 g (04 + 01)

10 (c)(iii) 30 marks

(iv) Propane is a more environmental friendly fuel because it emits less CO_2 compared to butane when the same amount of heat is produced.

(05)

10 (c)(iv) 05 marks

Total for **10(*c*) 75 marks**

Total for **10 : 150**