

AL/2024/02/E-I

සියලු ම හිමිකම් ඇවිරිණි / முழுப் பதிப்புரிமையுடையது / All Rights Reserved

ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව
 இலங்கைப் பரீட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம்
 Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka
 ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව
 இலங்கைப் பரීட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம் இலங்கைப் பரīட்சைத் திணைக்களம் இலங்கைப் பரīட்சைத் திணைக்களம்
 Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka

අධ්‍යයන පොදු සහතික පත්‍ර (උසස් පෙළ) විභාගය, 2024
 கல்விப் பொதுத் தராதரப் பத்திர (உயர் தர)ப் பரீட்சை, 2024
 General Certificate of Education (Adv. Level) Examination, 2024

රසායන විද්‍යාව I
 இரசாயனவியல் I
 Chemistry I

02 E I

පැය දෙකයි
 இரண்டு மணித்தியாலம்
 Two hours

Instructions:

- * This paper consists of 09 pages.
- * Periodic Table printed on page 10 can be detached if necessary.
- * Answer all the questions.
- * Use of calculators is not allowed.
- * Write your Index Number in the space provided in the answer sheet.
- * Follow the instructions given on the back of the answer sheet carefully.
- * In each of the questions 1 to 50, pick one of the alternatives from (1), (2), (3), (4), (5) which is correct or most appropriate and mark your response on the answer sheet with a cross (X) in accordance with the instructions given on the back of the answer sheet.

Universal gas constant $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$
 Avogadro constant $N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$

Planck's constant $h = 6.626 \times 10^{-34} \text{ J s}$
 Velocity of light $c = 3 \times 10^8 \text{ m s}^{-1}$

- Which of the following chemical species is expected to have the **highest** boiling point?
 (1) He (2) Ne (3) CH_4 (4) N_2 (5) CO
- The orbital diagram in which both Aufbau principle and Hund's rule are violated is

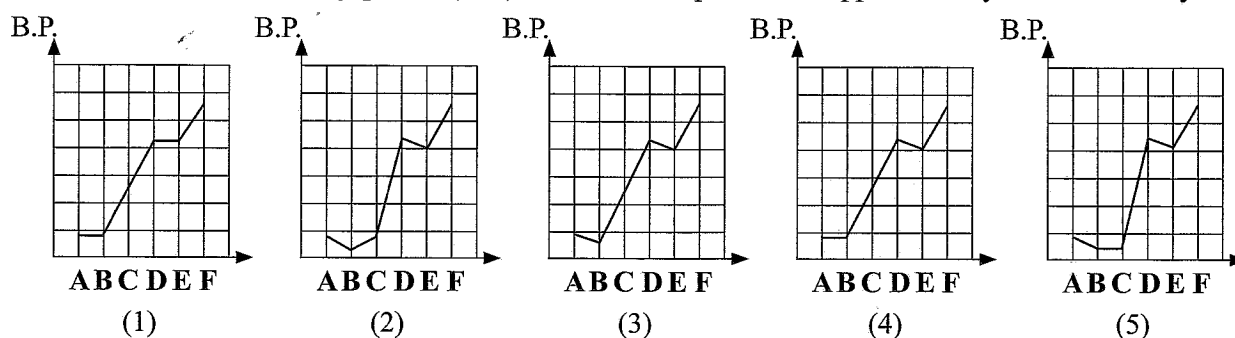
	2s	2p
(1)	$\uparrow\downarrow$	$\uparrow\downarrow \uparrow \circ$
(2)	\uparrow	$\uparrow\downarrow \uparrow \circ$
(3)	$\uparrow\downarrow$	$\uparrow \uparrow \uparrow$
(4)	$\uparrow\downarrow$	$\uparrow\downarrow \uparrow \uparrow$
(5)	\uparrow	$\uparrow\downarrow \uparrow \uparrow$
- In an atom, how many orbitals can have the quantum numbers $n = 3$, $m_l = -1$ and $n = 4$, $m_l = -1$?
 (1) 2 (2) 3 (3) 4 (4) 5 (5) 6
- The de Broglie wavelengths of two particles X and Y are 1 nm and 3 nm respectively. If the mass of X is three times the mass of Y, the ratio of kinetic energies of X and Y (X:Y) would be
 (1) 1:4 (2) 1:3 (3) 3:4 (4) 3:1 (5) 4:1
- What is the IUPAC name of the following compound?

(1) 2-amino-5-chloro-3-pentanol	$ \begin{array}{c} \text{NH}_2 \\ \\ \text{CH}_3\text{CHCHCH}_2\text{CH}_2\text{Cl} \\ \\ \text{OH} \end{array} $
(2) 4-amino-1-chloro-3-pentanol	
(3) 5-chloro-3-hydroxy-2-pentanamine	
(4) 1-chloro-3-hydroxy-4-pentanamine	
(5) 2-amino-5-chloro-3-hydroxypentane	
- At temperature 25°C , the pH of a saturated solution of metal hydroxide $\text{M}(\text{OH})_2$ is
 (K_{sp} of $\text{M}(\text{OH})_2$ at $25^\circ\text{C} = 4 \times 10^{-12} \text{ mol}^3 \text{ dm}^{-9}$)
 (1) 2 (2) 4 (3) 7 (4) 10 (5) 12

7. The shapes of IO_3^+ , NFC_2 , F_3ClO_2 and F_4BrO^- are respectively
- (1) trigonal planar, trigonal pyramidal, square pyramidal and trigonal bipyramidal.
 - (2) trigonal pyramidal, trigonal planar, square pyramidal and trigonal bipyramidal.
 - (3) trigonal pyramidal, T-shape, trigonal bipyramidal and square pyramidal.
 - (4) T-shape, trigonal planar, trigonal bipyramidal and square pyramidal.
 - (5) trigonal planar, trigonal pyramidal, trigonal bipyramidal and square pyramidal.
8. Select the **incorrect** statement.
- (1) Among the chemical species NCl_3 , SO_3 and PCl_5 the only polar species is NCl_3 .
 - (2) Among the elements Mg, Al, Si and P, the lowest first ionization energy is shown by Al.
 - (3) Among the elements B, C and O, the lowest negative value for electron gain energy is shown by C.
 - (4) Among the chemical species NO_3^- , SO_3 , SO_3^{2-} and ClF_3 , only NO_3^- and SO_3 have the same shape.
 - (5) Among the ions Li^+ , Na^+ , Be^{2+} and Mg^{2+} , the largest difference in size is between Na^+ and Be^{2+} .
9. Consider the following compounds, A, B, C, D, E and F.

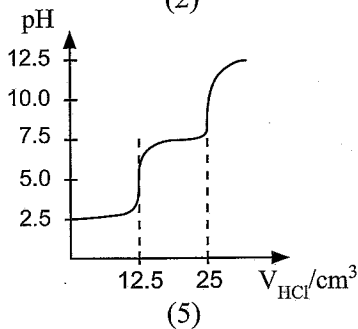
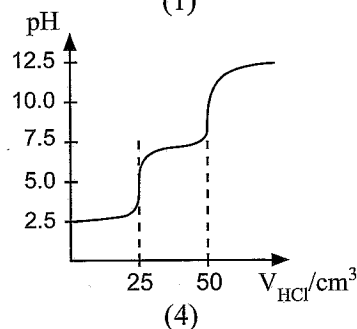
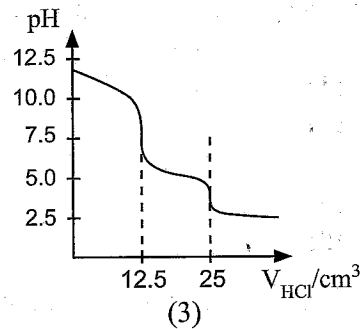
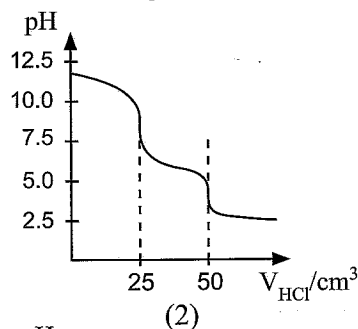
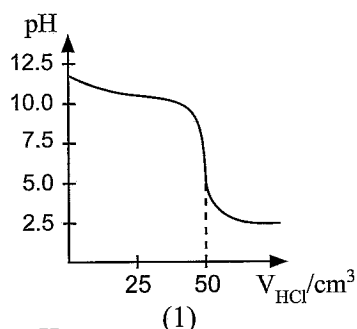
	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$	$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3\text{CHCH}_2\text{CH}_3 \end{array}$	$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3\text{CHCHO} \end{array}$
	A	B	C
Relative Molecular Mass	72	72	72
	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$	$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3\text{CHCH}_2\text{OH} \end{array}$	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$
	D	E	F
Relative Molecular Mass	74	74	88

The variation of boiling points (B.P.) of these compounds is approximately shown best by

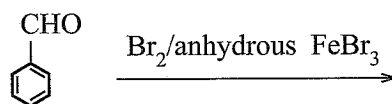


10. At a given temperature, a catalyst increases the rate of a reaction by
- (1) increasing the number of high energy collisions of reactant molecules.
 - (2) increasing kinetic energy of reactant molecules.
 - (3) increasing number of collisions among reactant molecules.
 - (4) increasing the activation energy of the reaction.
 - (5) providing a new pathway for the reaction.
11. $\text{FeCl}_3(\text{s})$ reacts with $\text{NH}_3(\text{g})$ and $\text{H}_2\text{O}(\text{l})$ to produce $\text{Fe}(\text{OH})_3$ and NH_4Cl .
When 97.5 g of $\text{FeCl}_3(\text{s})$, 34 g of $\text{NH}_3(\text{g})$ and 27 g of $\text{H}_2\text{O}(\text{l})$ are made to react, the maximum quantity of $\text{Fe}(\text{OH})_3$ that can be obtained is
(H = 1, N = 14, O = 16, Cl = 35.5, Fe = 56)
- (1) 21.3 g
 - (2) 23.8 g
 - (3) 53.5 g
 - (4) 63.9 g
 - (5) 71.3 g
12. Bond energies of H—H, Cl—Cl and H—Cl are 436, 242 and 431 kJ mol^{-1} respectively. Enthalpy change (kJ mol^{-1}) of the reaction $\frac{1}{2}\text{H}_2(\text{g}) + \frac{1}{2}\text{Cl}_2(\text{g}) \longrightarrow \text{HCl}(\text{g})$ is
- (1) -184
 - (2) -92
 - (3) 92
 - (4) 184
 - (5) 247

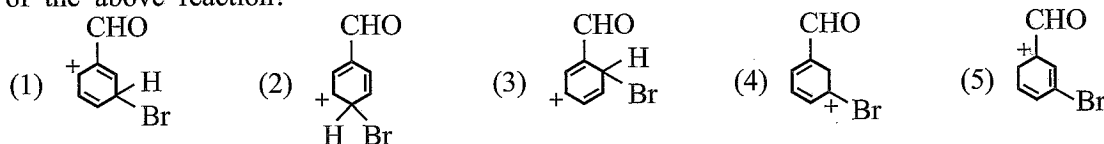
13. Which of the following figures correctly represents the titration curve when $0.100 \text{ mol dm}^{-3} \text{ HCl(aq)}$ is added to 25.00 cm^3 of $0.05 \text{ mol dm}^{-3} \text{ CO}_3^{2-}(\text{aq})$ solution?



14. Consider the following reaction.



Which of the following is a resonance structure of the intermediate which gives the major product of the above reaction?

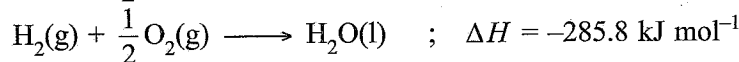
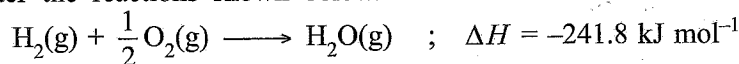


15. Consider the reaction of $\text{KMnO}_4(\text{aq})$ with $\text{H}_2\text{O}_2(\text{l})$ in the presence of dilute $\text{H}_2\text{SO}_4(\text{aq})$. The correct co-efficients of the reactants when the chemical equation of the reaction is balanced with the smallest whole number co-efficients are

	$\text{MnO}_4^- (\text{aq})$	$\text{H}_2\text{O}_2 (\text{l})$	$\text{H}^+ (\text{aq})$
(1)	2	3	10
(2)	2	4	6
(3)	2	5	6
(4)	2	5	8
(5)	2	5	16

16. A first-order gas phase reaction $\text{A(g)} \longrightarrow \text{B(g)} + \text{C(g)}$ occurs in a closed container at a given temperature. The half-life ($t_{1/2}$) of the reaction is 20 s when the initial pressure is 100 kPa. The half-life of the reaction when the initial pressure is 200 kPa at the same temperature is
- (1) 10 s (2) 20 s (3) 40 s (4) 400 s (5) 800 s

17. Consider the reactions shown below.



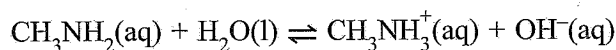
Enthalpy change of vaporization (kJ mol^{-1}) of water is

- (1) -88 (2) -44 (3) 0 (4) 44 (5) 88

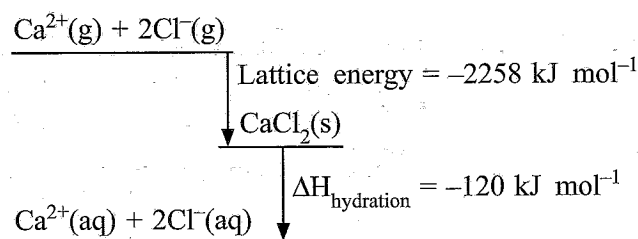
18. When solutions of reactants **A** and **B** are mixed in a beaker, a spontaneous reaction takes place with the lowering of the temperature of the mixture. Which of the following is correct for the reaction between **A** and **B**?

	ΔH	ΔS
(1)	-	+
(2)	-	-
(3)	-	0
(4)	+	-
(5)	+	+

19. Select the correct statement with regard to the given reaction.

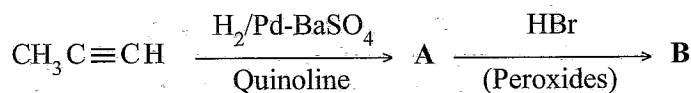


- (1) $\text{CH}_3\text{NH}_2(\text{aq})$ behaves as a Lewis-acid in the forward reaction while $\text{CH}_3\text{NH}_3^+(\text{aq})$ behaves as a Lewis-base in the reverse reaction.
 - (2) $\text{H}_2\text{O}(\text{l})$ behaves as a Lewis-base in the forward reaction while $\text{OH}^-(\text{aq})$ behaves as a Lewis-base in the reverse reaction.
 - (3) $\text{CH}_3\text{NH}_2(\text{aq})$ behaves as a Lewis-base in the forward reaction while $\text{OH}^-(\text{aq})$ behaves as a Lewis-acid in the reverse reaction.
 - (4) $\text{H}_2\text{O}(\text{l})$ behaves as a Lewis-acid in the forward reaction while $\text{CH}_3\text{NH}_3^+(\text{aq})$ behaves as a Lewis-base in the reverse reaction.
 - (5) $\text{CH}_3\text{NH}_2(\text{aq})$ behaves as a Lewis-base in the forward reaction while $\text{OH}^-(\text{aq})$ behaves as a Lewis-base in the reverse reaction.
20. Consider the enthalpy diagram shown below.



The enthalpy change of hydration of $\text{Ca}^{2+}(\text{g})$ is $-1650 \text{ kJ mol}^{-1}$. The hydration enthalpy change of $\text{Cl}^-(\text{g})$ (kJ mol^{-1}) is

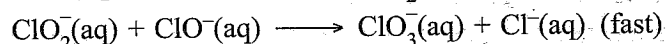
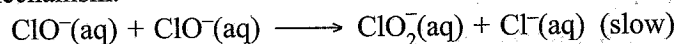
- (1) -728 (2) -364 (3) 364 (4) 728 (5) 2378
21. Consider the following reaction scheme.



A and **B** respectively could be:

- (1) $\text{CH}_3\text{CH}_2\text{CH}_3$ and $\text{CH}_3\text{CH}(\text{Br})\text{CH}_3$ (2) $\text{CH}_3\text{CH}=\text{CH}_2$ and $\text{CH}_3\text{CH}(\text{Br})\text{CH}_3$
- (3) $\text{CH}_3\text{CH}_2\text{CH}_3$ and $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$ (4) $\text{CH}_3\text{CH}=\text{CH}_2$ and $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$
- (5) $\text{CH}_3\text{CH}=\text{CH}_2$ and $\text{CH}_3\text{CH}(\text{Br})\text{CH}_2\text{Br}$

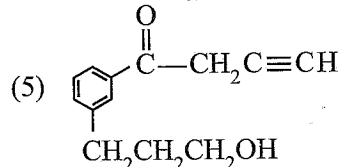
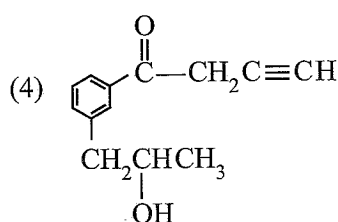
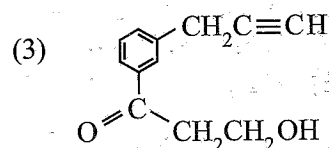
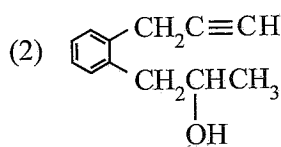
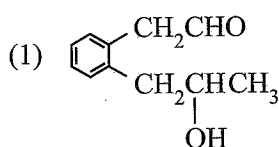
22. At a given temperature, the reaction $3\text{ClO}^-(\text{aq}) \longrightarrow \text{ClO}_3^-(\text{aq}) + 2\text{Cl}^-(\text{aq})$ occurs through the following mechanism.



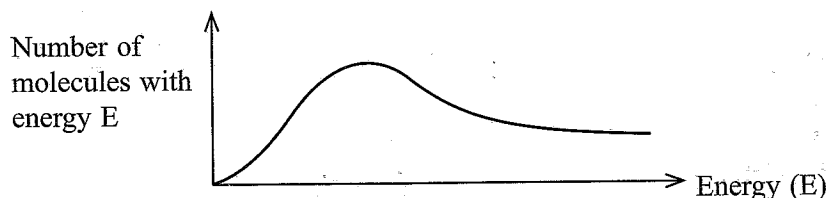
The rate law of this reaction is, (k = rate constant)

- (1) $\text{rate} = k[\text{ClO}^-(\text{aq})]$ (2) $\text{rate} = k[\text{ClO}^-(\text{aq})]^3$
 (3) $\text{rate} = k[\text{ClO}^-(\text{aq})]^2$ (4) $\text{rate} = k[\text{ClO}_2^-(\text{aq})][\text{ClO}^-(\text{aq})]$
 (5) $\text{rate} = k[\text{Cl}^-(\text{aq})][\text{ClO}^-(\text{aq})]$

23. Compound A forms a coloured precipitate with 2,4-dinitrophenylhydrazine (2,4-DNP). Compound A also forms a precipitate with ammoniacal AgNO_3 . Compound A reacts with acidified $\text{K}_2\text{Cr}_2\text{O}_7$ to give product B and a green colour solution. Compound B does not dissolve in aqueous Na_2CO_3 . Compound A could be:



24. At a given temperature the distribution of kinetic energies of molecules of a gas within a sealed container is shown in the following graph.

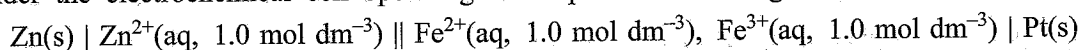


Some of the gas is removed and the container resealed; then the gas is cooled. Which of the following correctly describes the change in the graph?

Area under the curve **Position of the maximum point**

- (1) decrease shift to the left
 (2) increase shift to the left
 (3) no change shift to the left
 (4) decrease shift to the right
 (5) no change no change

25. Consider the electrochemical cell operating at temperature 298 K given below.

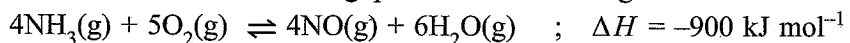


Which of the following gives the correct overall cell reaction and E_{cell}° ?

$$E_{\text{Zn}^{2+}(\text{aq})/\text{Zn(s)}}^\circ = -0.76 \text{ V} \quad E_{\text{Fe}^{3+}(\text{aq})/\text{Fe}^{2+}(\text{aq})}^\circ = +0.77 \text{ V}$$

- | Cell reaction | $E_{\text{cell}}^\circ / (\text{V})$ |
|--|--------------------------------------|
| (1) $\text{Zn(s)} + 2\text{Fe}^{3+}(\text{aq}) \longrightarrow 2\text{Fe}^{2+}(\text{aq}) + \text{Zn}^{2+}(\text{aq})$ | 1.53 |
| (2) $\text{Zn(s)} + 2\text{Fe}^{3+}(\text{aq}) \longrightarrow 2\text{Fe}^{2+}(\text{aq}) + \text{Zn}^{2+}(\text{aq})$ | -1.53 |
| (3) $\text{Zn(s)} + 2\text{Fe}^{3+}(\text{aq}) \longrightarrow 2\text{Fe}^{2+}(\text{aq}) + \text{Zn}^{2+}(\text{aq})$ | 0.01 |
| (4) $\text{Zn}^{2+}(\text{aq}) + 2\text{Fe}^{2+}(\text{aq}) \longrightarrow 2\text{Fe}^{3+}(\text{aq}) + \text{Zn(s)}$ | -1.53 |
| (5) $\text{Zn}^{2+}(\text{aq}) + 2\text{Fe}^{2+}(\text{aq}) \longrightarrow 2\text{Fe}^{3+}(\text{aq}) + \text{Zn(s)}$ | -0.01 |

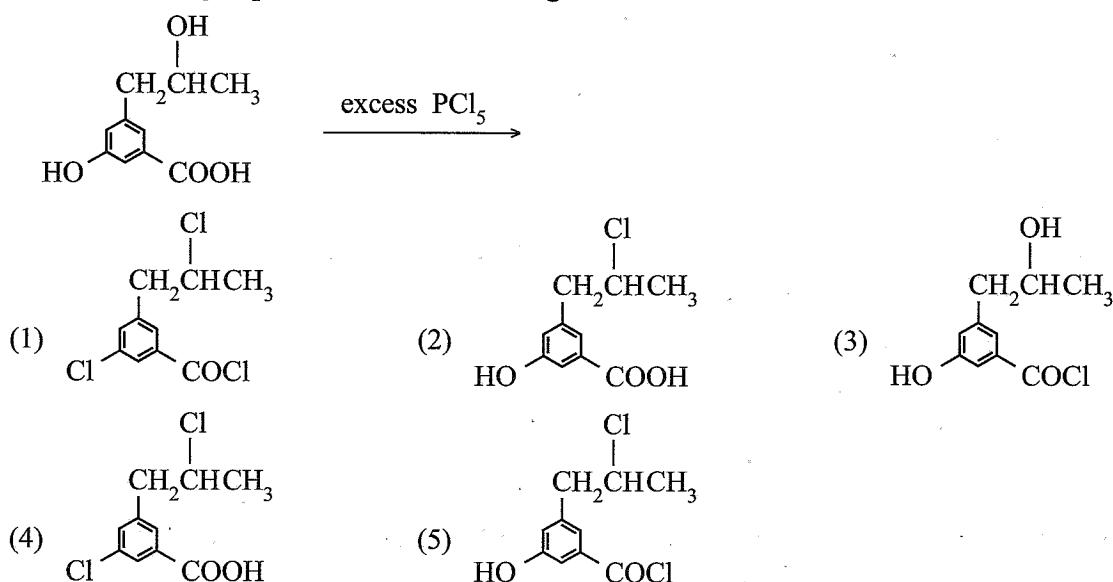
26. Consider the reaction below taking place in a closed-rigid container at a given temperature.



Which of the following statements is true for this reaction?

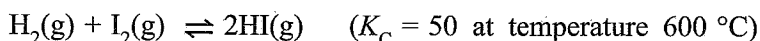
- (1) High pressure and high temperature give the highest equilibrium amount of NO(g).
 - (2) Low pressure and high temperature give the highest equilibrium amount of NO(g).
 - (3) High pressure and low temperature give the highest equilibrium amount of NO(g).
 - (4) Low pressure and low temperature give the highest equilibrium amount of NO(g).
 - (5) Changes in pressure and temperature have no effect on the equilibrium amount of NO(g).
27. The following information is displayed on the label of a bottle which contains concentrated NH_3 solution.
- NH_3 content – 30.0% (by mass)
density – 0.850 g cm^{-3}
- When 400.0 cm^3 of this NH_3 solution was reacted completely with H_2SO_4 , the amount of ammonium sulfate that can be formed is
(H = 1, N = 14, O = 16, S = 32)
- (1) 132 g (2) 396 g (3) 528 g (4) 792 g (5) 1584 g

28. What is the major product of the following reaction?



29. A wood ash sample X contains CaCO_3 , K_2CO_3 , and an inert material. In X the molar ratio of CaCO_3 : K_2CO_3 is 2:1. A 1.0 g sample of dry powdered X was reacted with excess HCl. The concentration and volume of HCl used was 0.30 mol dm^{-3} and 25.0 cm^3 respectively. After the reaction was completed, the remaining HCl was quantitatively collected and titrated with 0.10 mol dm^{-3} NaOH. The burette reading at the end-point was 15.0 cm^3 . The percentage of CaCO_3 in the wood ash sample X is
- (1) 10% (2) 16% (3) 20% (4) 24% (5) 40%

30. Consider the equilibrium reaction given below.



Equal molar amounts of $\text{H}_2(\text{g})$, $\text{I}_2(\text{g})$ and $\text{HI}(\text{g})$ were inserted into a 2.0 dm^3 previously evacuated closed-rigid container at room temperature and the temperature was increased to 600 $^\circ\text{C}$.

Which of the following will occur as the system reaches equilibrium?

- (1) More $\text{H}_2(\text{g})$ and $\text{I}_2(\text{g})$ will be produced because $Q_c > K_c$ (Q_c = reaction quotient)
- (2) Less $\text{H}_2(\text{g})$ and $\text{I}_2(\text{g})$ will be produced because $Q_c > K_c$
- (3) More $\text{H}_2(\text{g})$ and $\text{I}_2(\text{g})$ will be produced because $Q_c < K_c$
- (4) Less $\text{HI}(\text{g})$ will be produced because $Q_c < K_c$
- (5) More $\text{HI}(\text{g})$ will be produced because $Q_c < K_c$

- 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

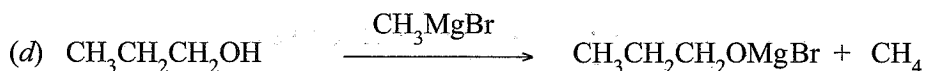
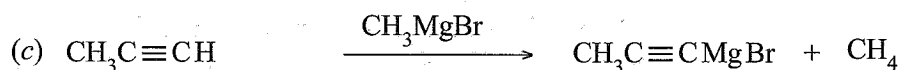
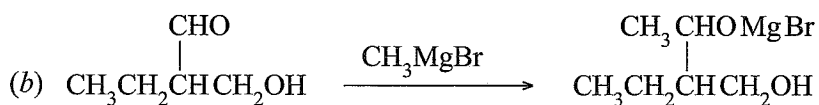
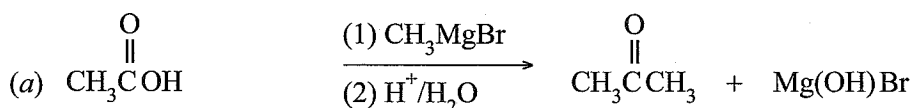
31. Which of the following statements is/are correct regarding the experiment for determination of the order of the reaction between $\text{Fe}^{3+}(\text{aq})$ and $\text{I}^{-}(\text{aq})$ (iodine-clock experiment)?

- (a) The time taken to react a constant amount of $\text{S}_2\text{O}_3^{2-}(\text{aq})$ is measured.
- (b) The concentration of $\text{S}_2\text{O}_3^{2-}(\text{aq})$ must be much higher than the concentration of $\text{I}^{-}(\text{aq})$.
- (c) $\text{S}_2\text{O}_3^{2-}(\text{aq})$ cannot be used in the experiment determining the rate constant of the reaction between $\text{Fe}^{3+}(\text{aq})$ and $\text{I}^{-}(\text{aq})$.
- (d) The concentration of $\text{S}_2\text{O}_3^{2-}(\text{aq})$ must be much smaller than the concentration of $\text{I}^{-}(\text{aq})$.

32. Which of the following statements is/are true regarding the reaction of 2-bromo-2-methylpropane with aqueous NaOH?

- (a) It is an electrophilic substitution reaction.
- (b) A carbocation is formed as an intermediate during the reaction.
- (c) The major product formed is $(\text{CH}_3)_3\text{COH}$.
- (d) $(\text{CH}_3)_2\text{C}=\text{CH}_2$ can be formed as a byproduct.

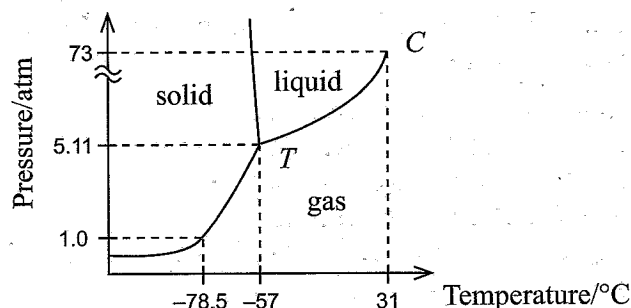
33. Which of the following reactions is/are correct?



34. Which of the following statements is/are true with regard to *s* and *p* block elements and their compounds?

- (a) Be reacts with hydrogen gas to produce an ionic metal hydride.
- (b) Mg has the highest electronegativity among *s*-block elements.
- (c) NH_3 , SO_2 and H_2S can act as oxidizing agents as well as reducing agents.
- (d) Na and Ba react with excess oxygen gas when heated to give Na_2O_2 and BaO_2 respectively.

35. The phase-diagram of carbon dioxide (CO_2) is shown below.



It is observed that liquid CO_2 does not form when a sample of solid CO_2 (dry-ice) is placed in a beaker at 25°C and 1 atm pressure. According to the above diagram which of the following statement/s explain/s this observation?

- The temperature at the triple-point is less than the critical temperature.
 - The temperature at the critical point is higher than 25°C .
 - The pressure of the triple-point is higher than 1 atm.
 - At 1 atm pressure solid CO_2 is in equilibrium only with the gas phase.
36. Which of the following statements is/are true?
- Following a systematic method of waste disposal contributes to minimize global warming.
 - Minimizing deforestation contributes to increase global warming.
 - NO gas emitted from transportation contributes to increase global warming.
 - Coolant gases used in refrigerators and air-conditioners contribute to increase global warming.
37. Which of the following statements is/are true with regard to the function of the ozone layer in the stratosphere?
- NO_2 is required for the formation of ozone.
 - Atomic oxygen produced in the troposphere produces ozone after reaching the stratosphere.
 - Ozone level in the stratosphere fluctuates throughout the year.
 - Infrared radiation is essential for the formation of ozone.
38. Consider the following cells.
- A : $\text{Zn(s)} \mid \text{Zn}^{2+}(\text{aq}, 1.0 \text{ mol dm}^{-3}) \parallel \text{Cu}^{2+}(\text{aq}, 1.00 \text{ mol dm}^{-3}) \mid \text{Cu(s)}$
- B : $\text{Zn(s)} \mid \text{Zn}^{2+}(\text{aq}, 1.0 \text{ mol dm}^{-3}) \parallel \text{Cu}^{2+}(\text{aq}, 1.00 \text{ mol dm}^{-3}) \mid \text{Cu(s)}$
- Ion migration occurs at both A and B.
 - Mixing of electrolytes is prevented in both A and B.
 - Ion migration occurs only in B.
 - Mixing of electrolytes is prevented only in B.
39. Which of the following statements is/are correct regarding 3d-block elements and their compounds?
- The correct IUPAC name of $[\text{Cr}(\text{NH}_3)_6]\text{Br}_3$ is hexaamminechromium(III) tribromide.
 - Based on the electronic configurations of the 3d-block metals, Zn is expected to have the lowest melting point.
 - Cu shows the lowest stable oxidation state among 3d-block elements.
 - CrO_3 dissolves in aqueous NaOH and gives $\text{Cr}_2\text{O}_7^{2-}$ ion.
40. Which of the following statements is/are true regarding some industrial processes?
- The entropy change for the reaction of $\text{N}_2(\text{g})$ with $\text{H}_2(\text{g})$ to produce $\text{NH}_3(\text{g})$ in the Haber-Bosch process is positive ($\Delta S > 0$).
 - The reaction of $\text{N}_2(\text{g})$ with $\text{H}_2(\text{g})$ to produce $\text{NH}_3(\text{g})$ in the Haber-Bosch process is an exothermic reaction.
 - The industrial process for the production of high purity TiO_2 from rutile by chlorination followed by oxidation, results in the release of CO_2 to the environment.
 - The reaction of $\text{SO}_2(\text{g})$ with $\text{O}_2(\text{g})$ to give $\text{SO}_3(\text{g})$ in the contact process for producing sulphuric acid is an endothermic reaction.

- 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.	Metallic bonding in Group 1 elements (Li–Cs) is weaker than metallic bonding in Group 2 elements (Be–Ba).	Metallic bonding involves only one valence electron in Group 1 elements whereas two electrons are involved in Group 2 elements.
42.	$\begin{array}{c} \text{CH}_3 \quad \quad \text{Br} \\ \diagdown \quad \diagup \\ \text{C} = \text{C} \\ \diagup \quad \diagdown \\ \text{Cl} \quad \quad \text{CH}_2\text{CH}_3 \end{array} \quad \text{and} \quad \begin{array}{c} \text{CH}_3 \quad \quad \text{CH}_2\text{CH}_3 \\ \diagdown \quad \diagup \\ \text{C} = \text{C} \\ \diagup \quad \diagdown \\ \text{Cl} \quad \quad \text{Br} \end{array}$ <p>are diastereoisomers of each other.</p>	Stereoisomers which are not mirror images of each other are diastereoisomers.
43.	When a few drops of dilute mineral acid are added to a 100 cm ³ solution of CH ₃ NH ₂ (aq)/CH ₃ NH ₃ Cl(aq), the pH of the solution does not change significantly.	A solution containing CH ₃ NH ₂ (aq) and CH ₃ NH ₃ Cl(aq) acts as a buffer solution.
44.	Aqueous solutions of Ni ²⁺ , Cu ²⁺ and Zn ²⁺ when individually treated with excess NH ₄ OH(aq) do not give permanent precipitates.	All three ions Ni ²⁺ (aq), Cu ²⁺ (aq) and Zn ²⁺ (aq) give ammine complexes when individually treated with excess NH ₄ OH(aq).
45.	Benzene reacts with electrophilic reagents to give substitution products and not addition products.	The carbocation intermediate formed by the reaction between benzene and the electrophile is stabilized by the delocalization of its positive charge.
46.	In an electrochemical cell constructed by Ag ⁺ (aq)/Ag(s) and Cu ²⁺ (aq)/Cu(s) electrodes, electrons flow from Cu to Ag. $E^\circ_{\text{Cu}^{2+}(\text{aq})/\text{Cu}(\text{s})} = 0.34 \text{ V}$, $E^\circ_{\text{Ag}^+(\text{aq})/\text{Ag}(\text{s})} = 0.80 \text{ V}$	In the electrochemical cell Cu(s) Cu ²⁺ (aq, 1 M) Ag ⁺ (aq, 1 M) Ag(s), the Cu ²⁺ (aq) Cu(s) electrode is the cathode. $E^\circ_{\text{Cu}^{2+}(\text{aq})/\text{Cu}(\text{s})} = 0.34 \text{ V}$, $E^\circ_{\text{Ag}^+(\text{aq})/\text{Ag}(\text{s})} = 0.80 \text{ V}$
47.	N ₂ (g) cannot behave as an oxidizing agent.	When heated N ₂ (g) reacts with Li to give an ionic product which reacts with water liberating NH ₃ (g).
48.	Addition of dilute HNO ₃ (aq) to a saturated solution of PbC ₂ O ₄ increases the solubility of PbC ₂ O ₄ (s).	In the equilibrium PbC ₂ O ₄ (s) \rightleftharpoons Pb ²⁺ (aq) + C ₂ O ₄ ²⁻ (aq), C ₂ O ₄ ²⁻ (aq), can be considered as the conjugate-base of H ₂ C ₂ O ₄ (aq) acid.
49.	The amount of CO(g) produced by the reaction of coke and O ₂ (g) in a blast furnace increases with increasing temperature.	The reaction between coke and O ₂ (g) which produces CO(g) has a positive entropy change.
50.	Thermoset polymers cannot be softened by heating.	Thermoset polymers have a molecular structure arranged as a three dimensional network.

The Periodic Table

1	1																	2
	H																	He
2	3	4											5	6	7	8	9	10
	Li	Be											B	C	N	O	F	Ne
3	11	12											13	14	15	16	17	18
	Na	Mg											Al	Si	P	S	Cl	Ar
4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	55	56	La-	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
	Cs	Ba	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	87	88	Ac-	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
	Fr	Ra	Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව
இலங்கைப் பரீட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம்
Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka
ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව
இலங்கைப் பரීட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம் இலங்கைப் பரīட்சைத் திணைக்களம் இலங்கைப் பரīட்சைத் திணைக்களம் இலங்கைப் பரīட்சைத் திணைக்களம்
Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka

අධ්‍යයන පොදු සහතික පත්‍ර (උසස් පෙළ) විභාගය, 2024
கல்விப் பொதுத் தராதரப் பத்திர (உயர் தர)ப் பரீட்சை, 2024
General Certificate of Education (Adv. Level) Examination, 2024

රසායන විද්‍යාව II
இரசாயனவியல் II
Chemistry II

02 E II

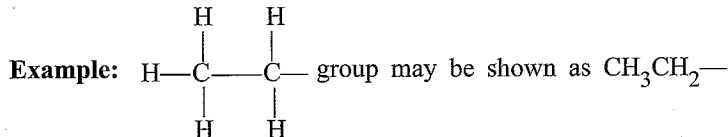
පැය තුනයි
மூன்று மணித்தியாலம்
Three hours

අමතර කියවීමේ කාලය - මිනිත්තු 10 යි
மேலதிக வாசிப்பு நேரம் - 10 நிமிடங்கள்
Additional Reading Time - 10 minutes

Use **additional reading time** to go through the question paper, select the questions and decide on the questions that you give priority in answering.

Index No. :

- * A Periodic Table is provided on page 16.
- * Use of calculators is not allowed.
- * Universal gas constant, $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$
- * Avogadro constant, $N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$
- * In answering this paper, you may represent alkyl groups in a condensed manner.



PART A — Structured Essay (pages 2 - 8)

- * Answer **all** the questions on the question paper itself.
- * Write your answer in the space provided for each question. Please note that the space provided is sufficient for the answer and that extensive answers are not expected.

PART B and PART C — Essay (pages 9 - 15)

- * Answer **four** questions selecting **two** questions from each part. Use the papers supplied for this purpose.
- * At the end of the time allotted for this paper, tie the answers to the three Parts A, B and C together so that Part A is on top and hand them over to the Supervisor.
- * You are permitted to remove **only** Parts B and C of the question paper from the Examination Hall.

For Examiner's Use Only

Part	Question No.	Marks
A	1	
	2	
	3	
	4	
B	5	
	6	
	7	
C	8	
	9	
	10	
Total		

Total	
In Numbers	
In Letters	

Code Numbers

Marking Examiner 1	
Marking Examiner 2	
Checked by :	
Supervised by :	

PART A — STRUCTURED ESSAY

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

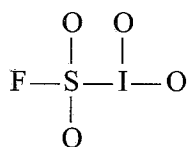
Do not
write
in this
column.

1. (a) State whether the following statements are **true** or **false** on the dotted lines. Reasons **not** required.

- (i) Particles in both cathode rays and β rays have the same charge to mass ratio (e/m).
- (ii) In a copper (Cu) atom there are 6 electrons having magnetic quantum number, $m_l = -1$
- (iii) The F_2ClO^+ ion has a trigonal planar shape.
- (iv) Sulphur (S) has the **lowest** first ionization energy among the elements F, S and Cl.
- (v) Rules related to polarizing power of cations and polarizability of anions, predict that the melting point of LiCl is **higher** than that of KF.
- (vi) In nitrous acid (HNO_2) the two N—O bonds are equal in length.
- (vii) The number of Lewis dot-dash structures (resonance structures) that can be drawn for the ion CN_2^{2-} is 3.
- (viii) The boiling point of hexane is **higher** than that of 2,2-dimethylbutane.

(32 marks)

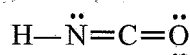
(b) (i) Draw the **most** acceptable Lewis dot-dash structure for the molecule ISO_4F . Its skeleton is given below.



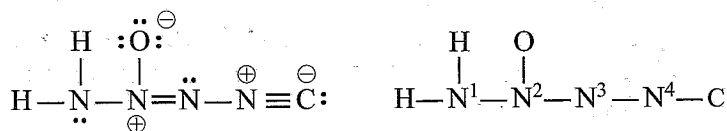
(ii) Give oxidation numbers of the S and I atoms in the structure drawn in (i) above.

S, I

(iii) An acceptable (stable) Lewis dot-dash structure for the HNC molecule is given below. Draw **two** more Lewis dot-dash structures (resonance structures) for this molecule and indicate their stabilities relative to the structure given by writing **stable** or **less stable** or **unstable** under these structures.



- (iv) Complete the table based on the Lewis dot-dash structure and its labelled skeleton given below.



	N ¹	N ²	N ³	N ⁴
I. the number of VSEPR pairs around the atom				
II. electron pair geometry around the atom				
III. shape around the atom				
IV. hybridization of the atom				

- Parts (v) to (viii) are based on the Lewis dot-dash structure given in part (iv) above. Labelling of atoms is as in part (iv).

- (v) Identify atomic/hybrid orbitals involved in the formation of σ bonds between the two atoms given below.

- I. H—N¹ H N¹
- II. N¹—N² N¹ N²
- III. N²—O N² O
- IV. N²—N³ N² N³
- V. N³—N⁴ N³ N⁴
- VI. N⁴—C N⁴ C

- (vi) Identify the atomic orbitals involved in the formation of π bonds between the two atoms given below.

- I. N²—N³ N² N³
- II. N⁴—C N⁴ C
- N⁴ C

- (vii) State approximate bond angles around the N¹, N², N³ and N⁴ atoms.

N¹, N², N³, N⁴

- (viii) Arrange the atoms N¹, N², N³ and N⁴ in **increasing** order of their electronegativities.

..... < < <

(56 marks)

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

- (i) B, O, F, S, Na, Mg (electronegativity)

..... < < < <

- (ii) K⁺, Mg²⁺, Ca²⁺, Al³⁺, Cl⁻, S²⁻ (ionic radius)

..... < < < <

(12 marks)

Do not
write
in this
column.

Do not
write
in this
column.

2. (a) (i) I. **X** is an orange coloured ionic compound. It is composed of three elements in the ratio 7:2:2 (not in the order of writing the chemical formula). Of these, two are metals that belong to the same row of the Periodic Table. One of these two metals belongs to the *s*-block and the other to the *d*-block. The *d*-block metal is widely used for electroplating.

Identify **X**.

- II. **Y** is a mineral acid. It is composed of three elements in the ratio 1:2:4 (not in the order of writing the chemical formula). One of the elements in **Y** is also found in **X**. **Y** is used in the manufacture of phosphate fertilizer.

Identify **Y**.

- III. **Z** is a tri-atomic gas with a pungent smell. It has a V-shape. It is used in the manufacture of **Y**.

Identify **Z**.

- (ii) Write the oxidation numbers and the electronic configurations of the two metals in **X**.

metal	oxidation number	electronic configuration
metal	oxidation number	electronic configuration

- (iii) I. Name the process by which **Y** is manufactured using **Z**.

.....

- II. When the gas formed on reaction of **Z** with $O_2(g)$ is dissolved in a concentrated solution of **Y**, the compound **P** is formed. When compound **P** reacts with water, **Y** is obtained again. Write the name and the chemical formula of compound **P**.

name chemical formula

- (iv) Write the balanced chemical equation for the reaction taking place when **X**, **Y** and **Z** are reacted together.

.....

(50 marks)

- (b) A student is provided with eight bottles labelled **A**, **B**, **C**, **D**, **E**, **F**, **G** and **H** with aqueous solutions of $BaCl_2$, NaI , $Pb(NO_3)_2$, $dil. HCl$, $Al_2(SO_4)_3$, $AgNO_3$, $conc. NH_4OH$ and $dil. NH_4OH$ (not in order). Some useful observations for their identification on mixing two solutions at a time are given below.

	Solutions Mixed	Observation
I.	A + C	a yellow precipitate soluble in hot water
II.	B + C	a yellow precipitate insoluble in H
III.	A + E	a white precipitate soluble in hot water
IV.	B + E	a white precipitate soluble in D
V.	E + F	a white precipitate insoluble in G
VI.	A + F	a white precipitate insoluble in G
VII.	D + G	a colourless solution
VIII.	H + G	a colourless solution

Do not
write
in this
column.

(i) Identify A to H.

A	E
B	F
C	G
D	H

(ii) Give balanced chemical equations for the formation of precipitates, in each of the reactions I to VI. Use the symbol \downarrow to indicate precipitates.

I.

II.

III.

IV.

V.

VI.

(50 marks)

100

3. (a) At temperature 25 °C, dissociation constants of $\text{H}_2\text{CO}_3(\text{aq})$ acid are,

$$K_1 = 4.5 \times 10^{-7} \text{ mol dm}^{-3} \text{ and } K_2 = 4.7 \times 10^{-11} \text{ mol dm}^{-3}$$

(i) Write the equilibrium reactions for the first and second dissociations of $\text{H}_2\text{CO}_3(\text{aq})$.(ii) Considering the first dissociation, calculate the concentrations of $\text{H}_3\text{O}^+(\text{aq})$ and $\text{HCO}_3^-(\text{aq})$ in $0.05 \text{ mol dm}^{-3} \text{ H}_2\text{CO}_3(\text{aq})$ solution at 25 °C.

Do not
write
in this
column.

- (iii) Considering the second dissociation, show that $[\text{CO}_3^{2-}(\text{aq})]$ of the solution is approximately equal to K_2 . State any assumption/s made.

(60 marks)

- (b) You are provided with an aqueous solution containing $0.01 \text{ mol dm}^{-3} \text{ Al}^{3+}(\text{aq})$ ions and $0.01 \text{ mol dm}^{-3} \text{ Ag}^{+}(\text{aq})$ ions at temperature 25°C . To 1.0 dm^3 of this solution, a concentrated solution of $\text{PO}_4^{3-}(\text{aq})$ ions was added dropwise with continuous stirring.

At temperature 25°C ,

$$K_{\text{sp}}(\text{AlPO}_4) = 1.3 \times 10^{-20} \text{ mol}^2 \text{ dm}^{-6} \text{ and } K_{\text{sp}}(\text{Ag}_3\text{PO}_4) = 8.1 \times 10^{-12} \text{ mol}^4 \text{ dm}^{-12}.$$

- (i) Neglecting any volume change that may occur when the $\text{PO}_4^{3-}(\text{aq})$ solution is added, state which metal ion (Al^{3+} or Ag^{+}) will precipitate first from the mixture. Give reasons for your answer based on a suitable calculation.

- (ii) Calculate the concentration of the ion which precipitated first when the second ion starts to precipitate.

Do not
write
in this
column.

(40 marks)

100

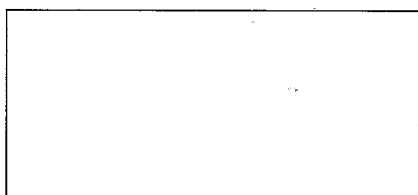
4. (a) ● The organic compound **A** having the molecular formula $C_5H_{10}O_3$ reacts with excess PCl_5 to give compound **B**, having a relative molecular mass of 155. Compound **A** liberates CO_2 with aqueous Na_2CO_3 . (C = 12.0, H = 1.0, O = 16.0, Cl = 35.5)

- (i) Write the functional groups present in compound **A**.

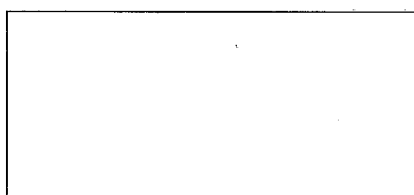
(10 marks)

- Compound **A** does not exhibit optical isomerism. Compound **A** reacts with pyridinium chlorochromate to give compound **C**. Compound **C** gives a silver mirror with ammoniacal $AgNO_3$. Compound **B** reacts with water to form compound **D**. Compound **D** reacts with alcoholic KOH to give the product **E** which contains a double bond.

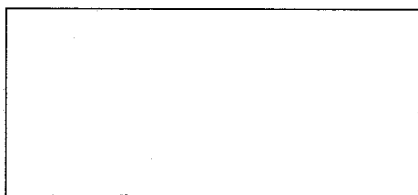
- (ii) Draw the structures of **A**, **B**, **C**, **D** and **E** in the relevant boxes.



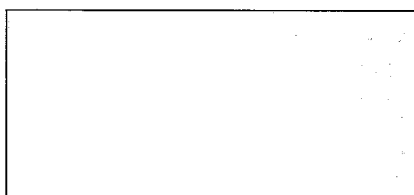
A



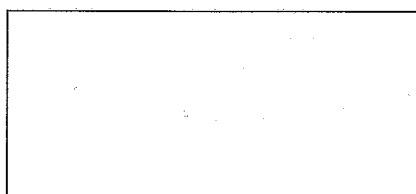
B



C



D



E

(35 marks)

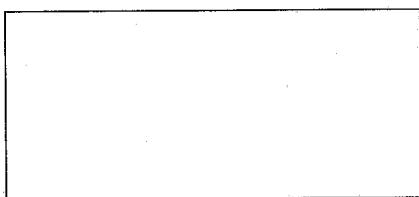
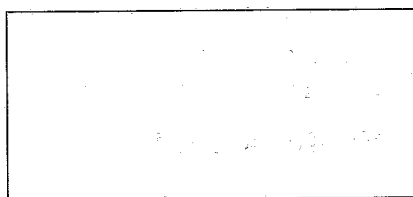
Do not
write
in this
column.

- Compound **F** is a structural isomer of **A**. Compound **F** reacts with excess PCl_5 to give compound **G** having a relative molecular mass of 155. Compound **F** does not liberate CO_2 with aqueous Na_2CO_3 . Compound **F** exhibits optical isomerism. Compound **F** does not give a turbidity when treated with conc. HCl /anhydrous ZnCl_2 . Compound **F** forms a coloured precipitate with 2,4-dinitrophenylhydrazine (2,4-DNP) and gives a silver mirror with ammoniacal AgNO_3 .

(iii) Write the functional groups present in **F**.

(09 marks)

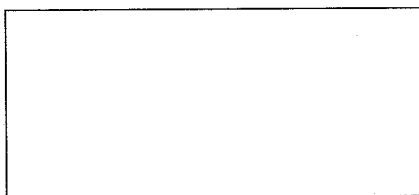
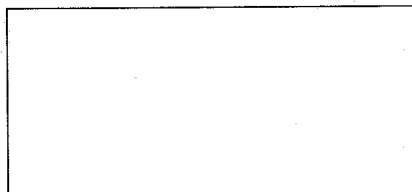
(iv) Draw the structures of **F** and **G** in the relevant boxes.

**F****G**

(14 marks)

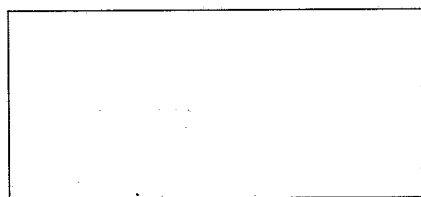
(b) (i) Draw the structure of the product **H** formed in the relevant box when acetone is reacted with dilute aqueous NaOH .

(ii) Draw the structure of the product **I** formed in the relevant box when **H** is heated with hydrochloric acid.

**H****I**

(12 marks)

(c) (i) Draw the structure of the product **J** formed in the relevant box from the reaction between acetone and HCN .

**J**

(ii) Write the mechanism of the above reaction.

(20 marks)

100

සියලු ම හිමිකම් ඇවිරිණි / முழுப் பதிப்புரிமையுடையது / All Rights Reserved]

ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව
 இலங்கைப் பரீட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம்
 Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka
 ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව
 இலங்கைப் பரීட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம் இலங்கைப் பரීட்சைத் திணைக்களம்
 Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka

අධ්‍යයන පොදු සහතික පත්‍ර (උසස් පෙළ) විභාගය, 2024

கல்விப் பொதுத் தராதரப் பத்திர (உயர் தர)ப் பரீட்சை, 2024

General Certificate of Education (Adv. Level) Examination, 2024

රසායන විද්‍යාව II
 இரசாயனவியல் II
 Chemistry II

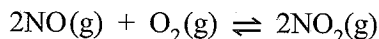
02 E II

* Universal gas constant $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$ * Avogadro constant $N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$

PART B — ESSAY

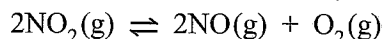
Answer *two* questions only. (Each question carries 150 marks.)

5. (a) A mixture of NO(g) and $\text{O}_2\text{(g)}$ in 2:1 molar ratio respectively, was introduced to a rigid closed container of volume 10 dm^3 and allowed to react at temperature T . After a certain time, the system reached the equilibrium as given below, at temperature T .



At equilibrium, the following observations were noted.

- The pressure of the gaseous mixture was $32 \times 8.314 \times 10^3 \text{ Pa}$.
 - The total number of moles of the three gases was 0.64.
 - The mass of O_2 was 6.4 g.
- (i) Calculate the concentration of each gaseous species in mol dm^{-3} at equilibrium. (O = 16)
- (ii) Calculate the equilibrium constant, K_c at temperature T .
- (iii) Calculate the value of temperature T (in K) under these conditions. State any assumption/s made.
- (iv) Calculate the equilibrium constant K_p for the reaction,

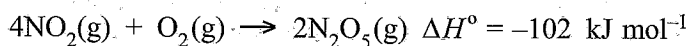
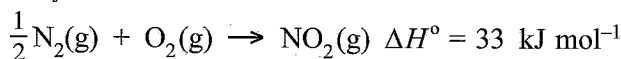


at the temperature determined in (iii) above.

(70 marks)

- (b) Consider the information given below at temperature 298 K.

$$\Delta H_f^\circ(\text{NO(g)}) = 90 \text{ kJ mol}^{-1}$$



- (i) Calculate ΔH° at temperature 298 K for the reaction,
- $$2\text{NO(g)} + \text{O}_2\text{(g)} \rightarrow 2\text{NO}_2\text{(g)}$$
- (ii) Calculate $\Delta H_f^\circ(\text{N}_2\text{O}_5\text{(g)})$ at temperature 298 K.
- (iii) Using the results obtained in (ii) above, predict the following.

I. the sign of $\Delta S_f^\circ(\text{N}_2\text{O}_5\text{(g)})$ II. spontaneity of the reaction for the formation of $\text{N}_2\text{O}_5\text{(g)}$ from $\text{N}_2\text{(g)}$ and $\text{O}_2\text{(g)}$

(80 marks)

6. (a) According to the kinetic molecular theory of gases, for an ideal gas at temperature T , $PV = \frac{1}{3}mN\overline{C^2}$. Here P is the pressure of the gas, V is the volume of the gas, m is the mass of a gas molecule, N is the number of molecules of gas and $\overline{C^2}$ is the mean square speed of the gas.

(i) Show that $\overline{C^2} = \frac{3RT}{M}$ for an ideal gas. M is the molar mass of the gas.

(ii) A and B are two ideal gases with molar masses M_A and M_B respectively. Show that the mean square speed of gas B ($\overline{C_B^2}$) at temperature $T = 300 \frac{M_B}{M_A}$, is equal to the mean square speed of gas A ($\overline{C_A^2}$) at $T = 300$. (Temperatures are given in kelvin)

(iii) Derive an expression for the ratio between the molar kinetic energies of the two gases A and B at any given temperature T .

(40 marks)

(b) (i) Define the term 'an elementary reaction'.

(ii) Define the term 'molecularity' of a reaction.

(iii) For an elementary reaction what is the relationship between 'reaction order' and 'molecularity'?

(iv) The following table gives the variation of the concentration of the reactant in a reaction with time.

Time (minutes)	0	10	20	30	40
Reactant concentration (mol dm ⁻³)	1.6	0.8	0.4	0.2	0.1

I. Determine the order of the reaction.

II. State the half-life of the reaction.

(v) Consider the information given below for two first order reactions ① and ② at a given temperature.

	Reaction	Reaction rate/ mol dm ⁻³ s ⁻¹	Rate constant/s ⁻¹	Half-life/s
①:	A → P ₁	r_A	k_A	$(t_{1/2})_A$
②:	B → P ₂	r_B	k_B	$(t_{1/2})_B$
	(P ₁ , P ₂ = Products)			

A first order reaction with rate constant, k has a half-life, $t_{1/2} = \frac{0.693}{k}$.

If $r_B = 3r_A$ when $[B] = 2[A]$, show that $2(t_{1/2})_A = 3(t_{1/2})_B$.

(75 marks)

- (c) At temperature 25 °C, 50.0 cm³ of 0.30 g dm⁻³ iodine aqueous solution was shaken well with 10.0 cm³ of CCl₄. When the system reached equilibrium the concentration of iodine in the water layer was found to be 0.02 g dm⁻³.

(i) Calculate the concentration of iodine in the CCl₄ layer at equilibrium.

(ii) At temperature 25 °C, calculate the partition co-efficient of I₂ between CCl₄ and water.

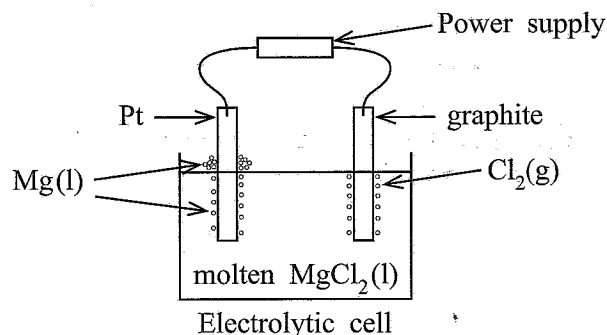
(iii) If the above experiment was done at 25 °C with 20.0 cm³ of CCl₄ instead 10.0 cm³, calculate the concentration of iodine in the water layer at equilibrium.

(35 marks)

- 7.(a) Mg metal can be extracted by the electrolysis of molten $\text{MgCl}_2(\text{l})$ using inert electrodes (examples :Pt, graphite). A simple setup for this is shown in the diagram.

$$E^\circ_{\text{Mg}^{2+}(\text{l})/\text{Mg}(\text{s})} = -2.37 \text{ V}$$

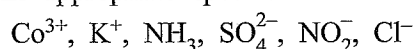
$$E^\circ_{\text{H}_2\text{O}(\text{l})/\text{H}_2(\text{g})} = -0.63 \text{ V}$$



- (i) Identify the anode and the cathode. Write the half reaction taking place at each electrode.
- (ii) Write the overall cell reaction.
- (iii) State the direction of electron flow through the external circuit as the cell operates.
- (iv) Explain the following:
 - I. Molten $\text{MgCl}_2(\text{l})$ is used instead of $\text{MgCl}_2(\text{s})$ in this extraction process.
 - II. A solution of $\text{MgCl}_2(\text{aq})$ cannot be used in this extraction process.
- (v) If a 5.37 A current is passed through this cell for one hour and the $\text{Cl}_2(\text{g})$ formed is collected at temperature 300 K and pressure 1 atm ($\sim 1.0 \times 10^5 \text{ Pa}$), calculate the volume of $\text{Cl}_2(\text{g})$ produced in dm^3 . (1 F = 96 500 C)

(75 marks)

- (b) (i) P, Q, R, S and T are coordination compounds of $\text{Co}(\text{III})$. They have an octahedral geometry. Give the structural formulae or draw the structures of these coordination compounds, selecting the appropriate species from the list given below.



Note : In the above coordination compounds NO_2^- behaves as a monodentate ligand when attached to the metal ion.

P – Only neutral ligands are coordinated to the metal ion. On reaction of an aqueous solution of **P** with dil. HCl , reddish-brown fumes are evolved. **P** gives four ions in aqueous solution.

Q – Two types of ligands are coordinated to the metal ion. They are neutral ligands and mono-atomic anionic ligands. A white precipitate insoluble in dilute acid is formed on addition of $\text{BaCl}_2(\text{aq})$ to an aqueous solution of **Q**. **Q** gives two ions in aqueous solution.

R – Two types of ligands are coordinated to the metal ion. They are neutral ligands and multi-atomic anionic ligands. **R** shows geometric isomerism. On reaction of an aqueous solution of **R** with $\text{AgNO}_3(\text{aq})$, a white precipitate is formed. This precipitate is soluble in dil. NH_4OH . **R** gives two ions in aqueous solution.

S – It is a non-ionic compound. An equal number of neutral ligands and multi-atomic anionic ligands are coordinated to the metal ion.

T – Only mono-atomic anionic ligands are coordinated to the metal ion. **T** gives four ions in aqueous solution.

- (ii) I. Write the IUPAC name of **T**.
II. Draw the structures of the geometric isomers of **R**.
- (iii) **X** is a coordination compound of $\text{Co}(\text{III})$ with an octahedral geometry. The ligands H_2O and CO_3^{2-} are coordinated to the metal ion. On treatment of an aqueous solution of **X** with $\text{AgNO}_3(\text{aq})$ a pale yellow precipitate, soluble in conc. NH_4OH is formed. **X** gives two ions in aqueous solution. Give the structural formula or draw the structure of **X**.
Note : CO_3^{2-} coordinates to the metal ion through two oxygen atoms.

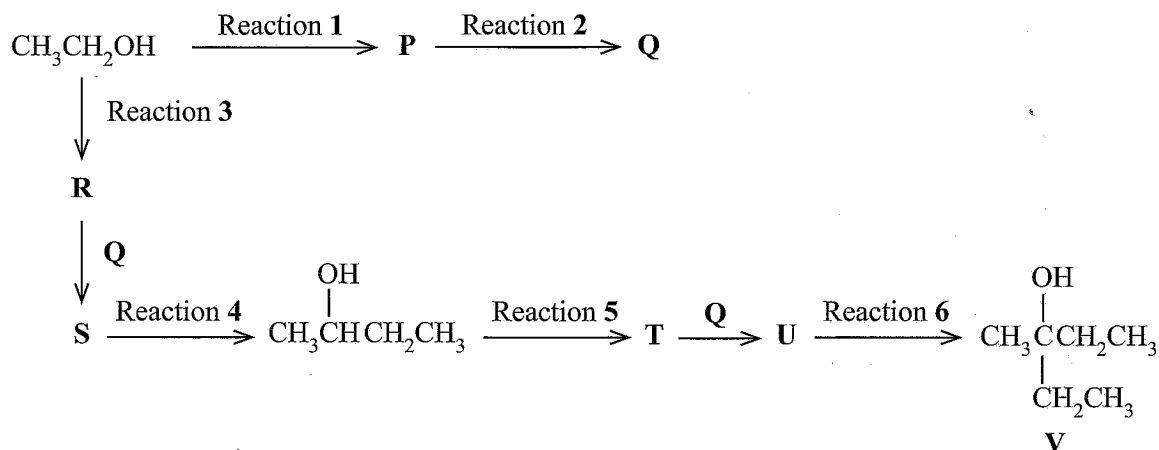
(75 marks)

[see page twelve]

PART C — ESSAY

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

8. (a) Given below is a reaction scheme for the preparation of compound **V** using ethanol as the only organic starting material.



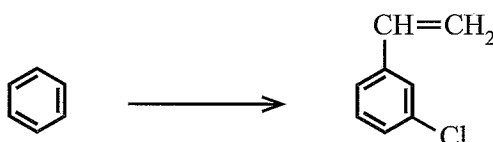
Complete the above reaction scheme by drawing the structures of compounds **P**, **Q**, **R**, **S**, **T** and **U** and writing the appropriate reagents for reactions **1 - 6** selected **only** from those given in the list below.

Reagents:

Dilute H_2SO_4 , Mg /dry ether, PBr_3 , Pyridinium chlorochromate (PCC)

(60 marks)

- (b) (i) Show how you would carry out the following conversion in not more than **four (04)** steps.



- (ii) Propose a method to prepare $\text{C}_6\text{H}_5\text{N}=\text{NC}_6\text{H}_4\text{OH}$ from aniline in not more than **two (02)** steps.

(40 marks)

- (c) (i) Write the product and the mechanism of the reaction that takes place between benzene and bromine in the presence of anhydrous FeBr_3 .
- (ii) Draw the resonance structures of benzene and aniline.
- (iii) Considering the above resonance structures, explain why the benzene nucleus in aniline is more reactive towards electrophilic substitution reactions than benzene itself.
- (iv) Draw the structure of the product formed when aniline reacts with bromine.

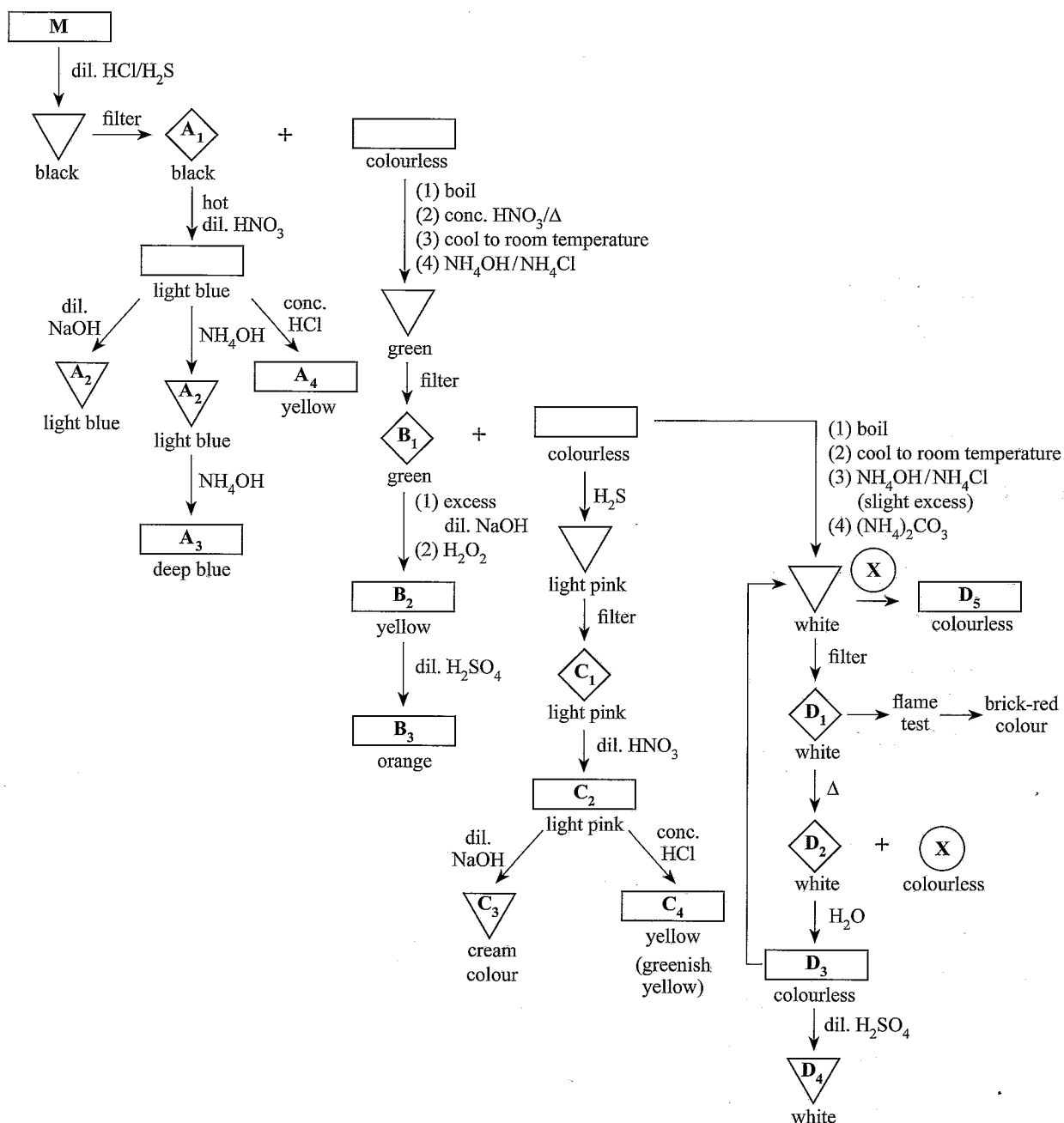
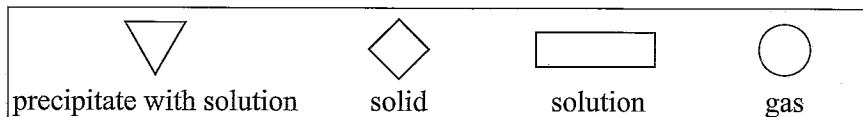
(50 marks)

9. (a) The following question is based on the qualitative analysis of cations.

An aqueous solution **M** contains one cation of each of the metals **A**, **B**, **C** and **D**.

M is analysed according to the scheme given below.

The symbols given in the box are used to represent precipitate with solution, solids, solutions and gases.



A₁–A₄, **B₁–B₃**, **C₁–C₄** and **D₁–D₅** are compounds/species of the four cations of metals **A**, **B**, **C** and **D**. **X** is a gas.

Identify **A₁**, **A₂**, **A₃**, **A₄**, **B₁**, **B₂**, **B₃**, **C₁**, **C₂**, **C₃**, **C₄**, **D₁**, **D₂**, **D₃**, **D₄**, **D₅**, and **X**.

(Note : Write **only** chemical formulae. Chemical equations and reasons are **not** required.)

(75 marks)

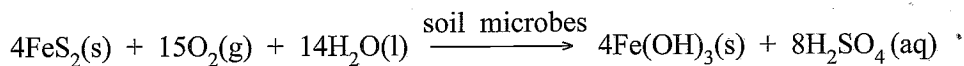
[see page fourteen]

- (b) The main compound present in iron pyrite is FeS_2 . A 1.50 g sample of iron pyrite was oxidized under laboratory conditions and all the sulphur in FeS_2 was converted to SO_4^{2-} . The resultant SO_4^{2-} was precipitated as BaSO_4 . The dry weight of BaSO_4 obtained was 4.66 g.

(i) Calculate the weight percentage of FeS_2 present in iron pyrite.

FeS_2 in 20.0 g of iron pyrite was subjected to oxidation by soil microbes under natural conditions for 120 hours.

This oxidation reaction is represented in the following equation.



H_2SO_4 that was produced in this reaction after 120 hours was quantitatively separated and precipitated as BaSO_4 . The dry weight of BaSO_4 obtained was 31.13 g.

- (ii) Calculate the percentage conversion of FeS_2 in iron pyrite to SO_4^{2-} after 120 hours by soil microbes.

$$\text{Note : Percentage conversion} = \frac{\text{Experimentally obtained mass using soil microbes}}{\text{Theoretical mass}} \times 100$$

- (iii) Calculate the amount of iron pyrite required to produce 8 kg of H_2SO_4 by soil microbes when the conversion percentage of FeS_2 in iron pyrite to SO_4^{2-} is 100%.
(Relative atomic mass : O = 16, S = 32, Fe = 56, Ba = 137)

(75 marks)

10.(a) The following questions are based on the Solvay process.

- What is the main product of the Solvay process?
- What is the main by-product of the Solvay process?
- What are the raw materials (starting materials) used in the Solvay process?
- Which one of these raw materials in (iii) above is not consumed in the process but is recycled repeatedly?
- Identify the first step of the Solvay process in which raw materials are mixed inside a tower which consists of perforated clay trays. Explain why this is carried out at a low temperature.
- Give **three** uses of the main product of the Solvay process.
- Give **three** reasons contributing to the economic profitability of the Solvay process.

(50 marks)

(b) Briefly explain each of the following statements.

- Agriculture contributes to global warming.
- Iron extraction contributes to global warming.
- Transportation contributes to photochemical smog.

In your answer indicate how the chemical species responsible for the given environmental effect in each of the statements above is/are formed.

(50 marks)

(c) (i) The following questions are based on vinegar production.

- I. State what is the process used in the production of natural vinegar.
- II. Write the name of the active chemical ingredient present in natural vinegar.
- III. Name the titrant and the indicator used in the quantitative determination of the active chemical ingredient in natural vinegar.
- IV. State the difference in composition between natural vinegar and artificial vinegar.

(ii) The following questions are based on the extraction of essential oils from plants.

- I. Name **three** methods that can be used to extract essential oils.
- II. State which of the above methods is based on the application of Daltons Law of partial pressures.
- III. Name the major compound present in each of the essential oils given below.
 - Citronella oil
 - Cinnamon root oil
 - Cinnamon leaf oil

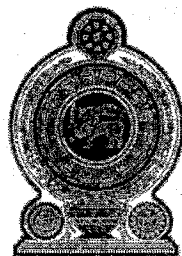
(50 marks)

* * *

The Periodic Table

1	1																	2
	H																	He
2	3	4											5	6	7	8	9	10
	Li	Be											B	C	N	O	F	Ne
3	11	12											13	14	15	16	17	18
	Na	Mg											Al	Si	P	S	Cl	Ar
4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	55	56	La-	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
	Cs	Ba	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	87	88	Ac-	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
	Fr	Ra	Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr



Department of Examinations – Sri Lanka
G.C.E. (A/L) Examination – 2024

02 - Chemistry
Marking Scheme

This has been prepared for the use of marking examiners. Some changes would be made according to the views presented at the Chief Examiners' meeting.

Amendments to be included

G.C.E. (A/L) Examination - 2024**02 - Chemistry****Distribution of Marks**

Paper I : 1 X 50 = 50

Paper II :

Part A : 100 X 4 = 400

Part B : 150 X 2 = 300

Part C : 150 X 2 = 300

Total = 1000

Paper II - Final Marks = 100

Common Techniques of Marking Answer Scripts.

It is compulsory to adhere to the following standard method in marking answer scripts and entering marks into the mark sheets.

1. Use a red color ball point pen for marking. (Only Chief/Additional Chief Examiner may use a mauve color pen.)
2. Note down Examiner's Code Number and initials on the front page of each answer script.
3. Write off any numerals written wrong with a clear single line and authenticate the alterations with Examiner's initials.
4. Write down marks of each subsection in a \triangle and write the final marks of each question as a rational number in a \square with the question number. Use the column assigned for Examiners to write down marks.

Example:

Question No. 03

(i)

.....
.....
.....

✓

\triangle
 $\frac{4}{5}$

(ii)

.....
.....
.....

✓

\triangle
 $\frac{3}{5}$

(iii)

.....
.....
.....

✓

\triangle
 $\frac{3}{5}$

$$\textcircled{03} \quad (i) \quad \frac{4}{5} \quad + \quad (ii) \quad \frac{3}{5} \quad + \quad (iii) \quad \frac{3}{5} \quad = \quad \square \begin{array}{c} 10 \\ 15 \end{array}$$

MCQ answer scripts: (Template)

1. Marking templates for G.C.E.(A/L) and GIT examination will be provided by the Department of Examinations itself. Marking examiners bear the responsibility of using correctly prepared and certified templates.
2. Then, check the answer scripts carefully. If there are more than one or no answers Marked to a certain question write off the options with a line. Sometimes candidates may have erased an option marked previously and selected another option. In such occasions, if the erasure is not clear write off those options too.
3. Place the template on the answer script correctly. Mark the right answers with a 'v' and the wrong answers with a '0' against the options column. Write down the number of correct answers inside the cage given under each column. Then, add those numbers and write the number of correct answers in the relevant cage.

structured essay type and assay type answer scripts:

1. Cross off any pages left blank by candidates. Underline wrong or unsuitable answers. Show areas where marks can be offered with check marks.
2. Use the right margin of the overland paper to write down the marks.
3. Write down the marks given for each question against the question number in the relevant cage on the front page in two digits. Selection of questions should be in accordance with the instructions given in the question paper. Mark all answers and transfer the marks to the front page, and write off answers with lower marks if extra questions have been answered against instructions.
4. Add the total carefully and write in the relevant cage on the front page. Turn pages of answer script and add all the marks given for all answers again. Check whether that total tallies with the total marks written on the front page.

Preparation of Mark Sheets.

Except for the subjects with a single question paper, final marks of two papers will not be calculated within the evaluation board this time. Therefore, add separate mark sheets for each of the question paper. Write paper 01 marks in the paper 01 column of the mark sheet and write them in words too. Write paper II Marks in the paper II Column and write the relevant details.

ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව

Department of Examinations – Sri Lanka
අ.පො.ස.(උ.පෙළ)විභාගය/G.C.E. (A/L) - 2024

විෂය අංකය
Subject No

02

විෂය
Subject

Chemistry

ලකුණු දීමේ පටිපාටිය/Marking Scheme
I පත්‍රය/Paper I

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

විශේෂ උපදෙස්/Special Instructions:

එක් පිළිතුරකට ලකුණු 01 බැගින්/ 01 Mark for each question

මුළු ලකුණු/Total Marks 01 × 50 = 50

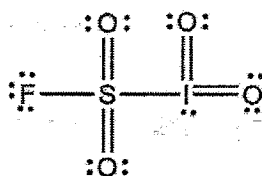
PART A — STRUCTURED ESSAY*Answer all four questions on this paper itself. (Each question carries 100 marks.)*

1. (a) State whether the following statements are **true** or **false** on the dotted lines. Reasons **not** required.

- | | |
|---|----------------|
| (i) Particles in both cathode rays and β rays have the same charge to mass ratio (e/m). |
true |
| (ii) In a copper (Cu) atom there are 6 electrons having magnetic quantum number, $m_l = -1$. |
true |
| (iii) The F_2ClO^+ ion has a trigonal planar shape. |
false |
| (iv) Sulphur (S) has the lowest first ionization energy among the elements F, S and Cl. |
true |
| (v) Rules related to polarizing power of cations and polarizability of anions, predict that the melting point of LiCl is higher than that of KF. |
false |
| (vi) In nitrous acid (HNO_2) the two N—O bonds are equal in length. |
false |
| (vii) The number of Lewis dot-dash structures (resonance structures) that can be drawn for the ion CN_2^{2-} is 3. |
true |
| (viii) The boiling point of hexane is higher than that of 2,2-dimethylbutane. |
true |

(04 marks X 8 = 32 marks)**1(a): 32 marks**

(b) (i) Draw the **most** acceptable Lewis dot-dash structure for the molecule ISO_4F . Its skeleton is given below.

**(06 marks)**

(ii) Give oxidation numbers of the S and I atoms in the structure drawn in (i) above.

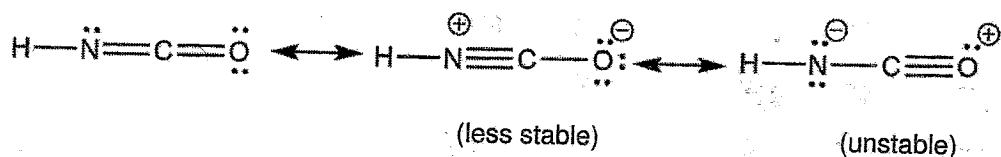
S +5 or +V I +4 or +IV

.....

(01) + (01)

Award marks for (ii) only if the Lewis structure in (i) is correct.

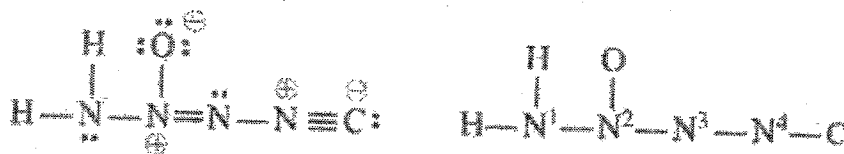
- (iii) An acceptable (stable) Lewis dot-dash structure for the HNCO molecule is given below. Draw **two** more Lewis dot-dash structures (resonance structures) for this molecule and indicate their stabilities relative to the structure given by writing **stable** or **less stable** or **unstable** under these structures.



(02 marks structure) + (01 mark stability)

(06 marks)

- (iv) Complete the table based on the Lewis dot-dash structure and its labelled skeleton given below.



		N ¹	N ²	N ³	N ⁴
I	The number of VSEPR pairs around the atom	4	3	3	2
II	electron pair geometry around the atom	tetrahedral	trigonal planar	trigonal planar	linear
III	Shape around the atom	pyramidal / trigonal pyramidal	trigonal planar	angular / V / bent	linear
IV	Hybridization of the atom	sp ³	sp ²	sp ²	sp

(01 mark X 16 = 16 marks)

- Parts (v) to (viii) are based on the Lewis dot-dash structure given in part (iv) above. Labelling of atoms is as in part (iv).

(v) Identify atomic/hybrid orbitals involved in the formation of σ bonds between the two atoms given below.

I.	H	1s	N ¹	sp ³
II.	N ¹	sp ³	N ²	sp ²
III.	N ²	sp ²	O	2p / sp ³
IV.	N ²	sp ²	N ³	sp ²
V.	N ³	sp ²	N ⁴	sp
VI.	N ⁴	sp	C	2p / sp

(01 mark X 12 = 12 marks)

(vi) Identify the atomic orbitals involved in the formation of π bonds between the two atoms given below.

I.	N ²	2p	N ³	2p
II.	N ⁴	2p	C	2p
	N ⁴	2p	C	2p

(01 mark X 6 = 06 marks)

(vii) State approximate bond angles around the N¹, N², N³ and N⁴ atoms.

N ¹ (107° ± 1)	N ² (120° ± 1)
N ³ (117° ± 2)	N ⁴ (180° ± 1)

(01 mark X 4 = 04 marks)

(viii) Arrange the atoms N¹, N², N³ and N⁴ in **increasing** order of their electronegativities.

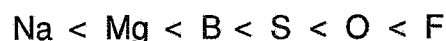
..... N¹ < N³ < N² < N⁴

(04 marks)

1(b): 56 marks

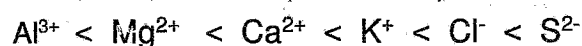
(c) Arrange the following species in the **increasing** order of the property indicated in parenthesis.
(Reasons are **not** required)

(i) B, O, F, S, Na, Mg (electronegativity)



(06 marks)

(ii) K^+ , Mg^{2+} , Ca^{2+} , Al^{3+} , Cl^- , S^{2-} (ionic radius)



(06 marks)

1(c): 12 marks

2. (a) (i) I. X is an orange coloured ionic compound. It is composed of three elements in the ratio 7:2:2 (not in the order of writing the chemical formula). Of these, two are metals that belong to the same row of the Periodic Table. One of these two metals belongs to the *s*-block and the other to the *d*-block. The *d*-block metal is widely used for electroplating.



II. Y is a mineral acid. It is composed of three elements in the ratio 1:2:4 (not in the order of writing the chemical formula). One of the elements in Y is also found in X. Y is used in the manufacture of phosphate fertilizer.



III. Z is a tri-atomic gas with a pungent smell. It has a V-shape. It is used in the manufacture of Y.



(06 marks x 3 = 18 marks)

(ii) Write the oxidation numbers and the electronic configurations of the two metals in X.

metal K oxidation number +I electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6$
or $1s^2 2s^2 2p^6 3s^2 3p^4 s^1$

metal Cr oxidation number +VI electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6$
or $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$

(02 marks x 6 = 12 marks)

- (iii) I. Name the process by which Y is manufactured using Z.
Contact Process

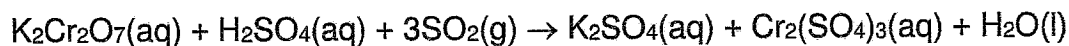
(02 marks)

- II. When the gas formed on reaction of Z with $O_2(g)$ is dissolved in a concentrated solution of Y, the compound P is formed. When compound P reacts with water, Y is obtained again. Write the name and the chemical formula of compound P.

name Oleum / pyrosulfuric acid / chemical formula (P) $H_2S_2O_7$
fuming sulfuric acid / disulfuric acid

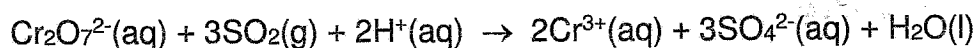
(04 marks x 2 = 08 marks)

- (iv) Write the balanced chemical equation for the reaction taking place when X, Y and Z are reacted together.



(10 marks)

or



(06 marks)

Physical states are not required.

2(a): 50 marks

- (b) A student is provided with eight bottles labelled A, B, C, D, E, F, G and H with aqueous solutions of BaCl_2 , NaI , $\text{Pb}(\text{NO}_3)_2$, dil. HCl , $\text{Al}_2(\text{SO}_4)_3$, AgNO_3 , conc. NH_4OH and dil. NH_4OH (not in order). Some useful observations for their identification on mixing two solutions at a time are given below.

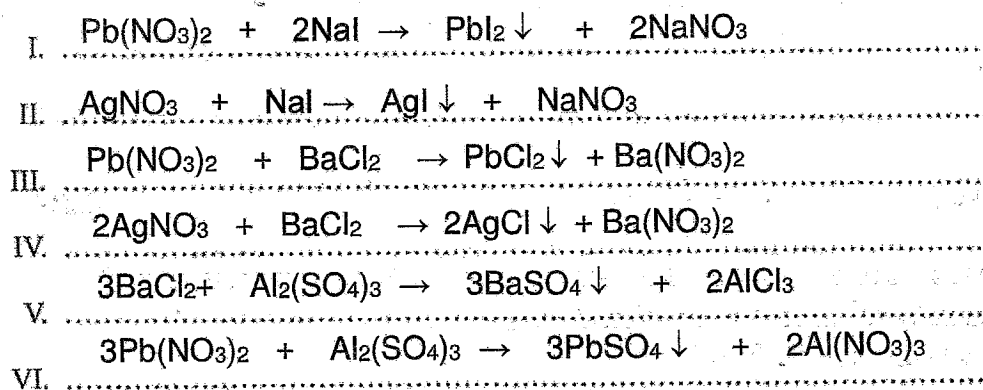
	Solutions Mixed	Observation
I.	A + C	a yellow precipitate soluble in hot water
II.	B + C	a yellow precipitate insoluble in H
III.	A + E	a white precipitate soluble in hot water
IV.	B + E	a white precipitate soluble in D
V.	E + F	a white precipitate insoluble in G
VI.	A + F	a white precipitate insoluble in G
VII.	D + G	a colourless solution
VIII.	H + G	a colourless solution

- (i) Identify A to H.

A	$\text{Pb}(\text{NO}_3)_2$	E	BaCl_2
B	AgNO_3	F	$\text{Al}_2(\text{SO}_4)_3$
C	NaI	G	dil HCl
D	dil NH_4OH	H	conc NH_4OH

(04 marks x 8 = 32 marks)

- (ii) Give balanced chemical equations for the formation of precipitates, in each of the reactions I to VI. Use the symbol \downarrow to indicate precipitates.



(03 marks x 6 = 18 marks)

Note: Deduct 01 mark if precipitates are not indicated the using symbol \downarrow

2(b): 50 marks

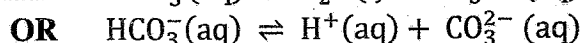
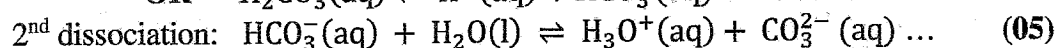
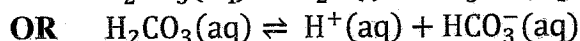
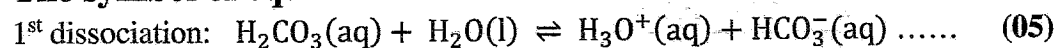
3. (a) At temperature 25 °C, dissociation constants of $\text{H}_2\text{CO}_3(\text{aq})$ acid are,

$$K_1 = 4.5 \times 10^{-7} \text{ mol dm}^{-3} \text{ and } K_2 = 4.7 \times 10^{-11} \text{ mol dm}^{-3}$$

(i) Write the equilibrium reactions for the first and second dissociations of $\text{H}_2\text{CO}_3(\text{aq})$.

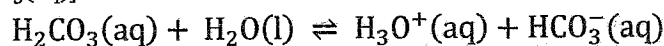
i. **NOTE: PHYSICAL STATES ARE NECESSARY**

The symbol of equilibrium \rightleftharpoons also needed for all the reactions



(ii) Considering the first dissociation, calculate the concentrations of $\text{H}_3\text{O}^+(\text{aq})$ and $\text{HCO}_3^-(\text{aq})$ in 0.05 mol dm^{-3} $\text{H}_2\text{CO}_3(\text{aq})$ solution at 25 °C.

ii. $K_1 = \frac{[\text{H}_3\text{O}^+(\text{aq})][\text{HCO}_3^-(\text{aq})]}{[\text{H}_2\text{CO}_3(\text{aq})]}$ (05)



Initial con.	0.05	0	0	mol dm^{-3}
Change con.	-x	x	x	mol dm^{-3}
Equi. con.	$0.05 - x$	x	x	mol dm^{-3}

(05)

$$K_1 = 4.50 \times 10^{-7} = \frac{x \cdot x}{0.05 - x} \approx \frac{x^2}{0.05}$$
 (05)

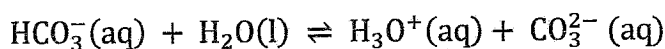
$$x^2 = 225 \times 10^{-10}$$

$$x = 1.5 \times 10^{-4} \text{ mol dm}^{-3}$$
 (04 + 01)

$$[\text{H}_3\text{O}^+(\text{aq})] = [\text{HCO}_3^-(\text{aq})] = 1.5 \times 10^{-4} \text{ mol dm}^{-3}$$
 (04 + 01)

(iii) Considering the second dissociation, show that $[\text{CO}_3^{2-}(\text{aq})]$ of the solution is approximately equal to K_2 . State any assumption/s made.

iii. $K_2 = \frac{[\text{H}_3\text{O}^+(\text{aq})][\text{CO}_3^{2-}(\text{aq})]}{[\text{HCO}_3^-(\text{aq})]}$ (05)



Initial con.	1.5×10^{-4}	1.5×10^{-4}	0	mol dm^{-3}
Change con.	-y	$1.5 \times 10^{-4} + y$	y	mol dm^{-3}
Equi. con.	$1.5 \times 10^{-4} - y$	$1.5 \times 10^{-4} + y$	y	mol dm^{-3}

(05)*

$$K_2 = 4.70 \times 10^{-11} = \frac{(1.5 \times 10^{-4} + y) \cdot y}{(1.5 \times 10^{-4} - y)} \approx y$$
 (05)*

***If student writes in words that the amount dissociated from HCO_3^- is very small and amount accumulated in H_3O^+ is very small, therefore concentration change of the two species are negligible, award these 05 + 05 marks.**

$$[\text{CO}_3^{2-}(\text{aq})] \approx K_2$$
 (05)

Assumption: 2nd dissociation is much less compared to the 1st. (05)

3(a): 60 marks

- (b) You are provided with an aqueous solution containing $0.01 \text{ mol dm}^{-3} \text{ Al}^{3+}(\text{aq})$ ions and $0.01 \text{ mol dm}^{-3} \text{ Ag}^{+}(\text{aq})$ ions at temperature 25°C . To 1.0 dm^3 of this solution, a concentrated solution of $\text{PO}_4^{3-}(\text{aq})$ ions was added dropwise with continuous stirring.

At temperature 25°C ,

$$K_{sp}(\text{AlPO}_4) = 1.3 \times 10^{-20} \text{ mol}^2 \text{ dm}^{-6} \text{ and } K_{sp}(\text{Ag}_3\text{PO}_4) = 8.1 \times 10^{-12} \text{ mol}^4 \text{ dm}^{-12}.$$

- (i) Neglecting any volume change that may occur when the $\text{PO}_4^{3-}(\text{aq})$ solution is added, state which metal ion (Al^{3+} or Ag^{+}) will precipitate first from the mixture. Give reasons for your answer based on a suitable calculation.

i. The precipitates formed are AlPO_4 and Ag_3PO_4

For AlPO_4

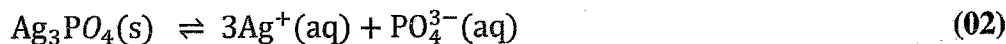


$$K_{sp} = [\text{Al}^{3+}(\text{aq})][\text{PO}_4^{3-}(\text{aq})] \quad (02)$$

$$1.30 \times 10^{-20} = 0.01 \times [\text{PO}_4^{3-}(\text{aq})] \quad (04)$$

$$[\text{PO}_4^{3-}(\text{aq})] = 1.30 \times 10^{-18} \text{ mol dm}^{-3}; \text{ needed to precipitate } \text{AlPO}_4(\text{s}) \quad (03+01)$$

For Ag_3PO_4



$$K_{sp} = [\text{Ag}^{+}(\text{aq})]^3[\text{PO}_4^{3-}(\text{aq})] \quad (02)$$

$$8.10 \times 10^{-12} = (0.01)^3 \times [\text{PO}_4^{3-}(\text{aq})] \quad (04)$$

$$[\text{PO}_4^{3-}(\text{aq})] = 8.10 \times 10^{-6} \text{ mol dm}^{-3}; \text{ needed to precipitate } \text{Ag}_3\text{PO}_4(\text{s}) \quad (03+01)$$

$$[\text{PO}_4^{3-}(\text{aq})]_{\text{AlPO}_4(\text{s})} < [\text{PO}_4^{3-}(\text{aq})]_{\text{Ag}_3\text{PO}_4(\text{s})} \quad (04)$$

$$\text{AlPO}_4(\text{s}) \text{ precipitates first.} \quad (04)$$

- (ii) Calculate the concentration of the ion which precipitated first when the second ion starts to precipitate.

$$[\text{Al}^{3+}(\text{aq})] \text{ left in the solution after precipitation of } \text{AlPO}_4(\text{s}) = \frac{K_{sp}(\text{AlPO}_4(\text{s}))}{8.10 \times 10^{-6}} \quad (04)$$

$$\begin{aligned} [\text{Al}^{3+}(\text{aq})] \text{ left in the solution} &= \frac{1.30 \times 10^{-20}}{8.10 \times 10^{-6}} \\ &= 1.6 \times 10^{-15} \text{ mol dm}^{-3} \end{aligned} \quad (03+01)$$

3(b): 40 marks

4. (a) • The organic compound A having the molecular formula $C_5H_{10}O_3$ reacts with excess PCl_5 to give compound B, having a relative molecular mass of 155. Compound A liberates CO_2 with aqueous Na_2CO_3 . (C = 12.0, H = 1.0, O = 16.0, Cl = 35.5)

(i) Write the functional groups present in compound A.

OH / hydroxy/ hydroxyl, $COOH$ / carboxylic acid

Note: no marks if 'acid' is not written

(05 marks x 2 = 10 marks)

- Compound A does not exhibit optical isomerism. Compound A reacts with pyridinium chlorochromate to give compound C. Compound C gives a silver mirror with ammoniacal $AgNO_3$. Compound B reacts with water to form compound D. Compound D reacts with alcoholic KOH to give the product E which contains a double bond.

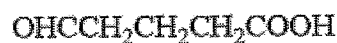
(ii) Draw the structures of A, B, C, D and E in the relevant boxes.



A



B



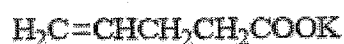
C



D



OR



E

(07 marks x 5 = 35 marks)

- Compound F is a structural isomer of A. Compound F reacts with excess PCl_5 to give compound G having a relative molecular mass of 155. Compound F does not liberate CO_2 with aqueous Na_2CO_3 . Compound F exhibits optical isomerism. Compound F does not give a turbidity when treated with conc. HCl /anhydrous ZnCl_2 . Compound F forms a coloured precipitate with 2,4-dinitrophenylhydrazine (2,4-DNP) and gives a silver mirror with ammoniacal AgNO_3 .

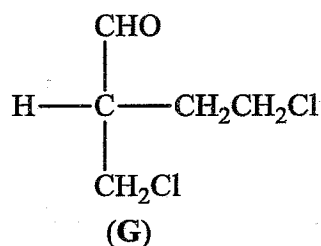
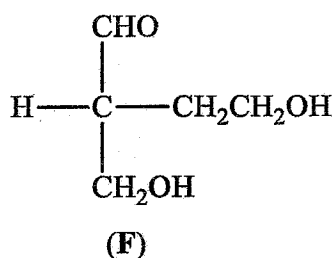
(iii) Write the functional groups present in F.

CHO / aldehyde, OH / hydroxy/ hydroxyl

Note: If both are correct, award 09 marks. If only one is correct, award 05 marks only.

(05 marks + 04 marks = 09 marks)

(iv) Draw the structures of F and G in the relevant boxes.

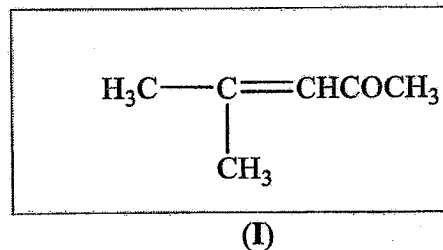
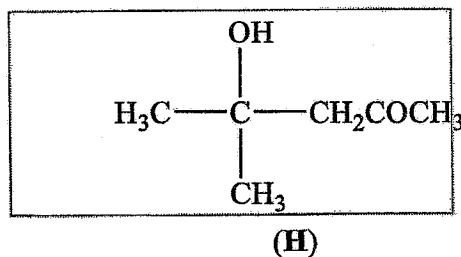


(07 marks x 2 = 14 marks)

4(a): 68 marks

(b) (i) Draw the structure of the product H formed in the relevant box when acetone is reacted with dilute aqueous NaOH .

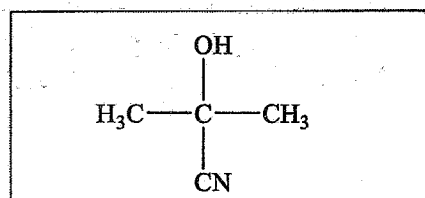
(ii) Draw the structure of the product I formed in the relevant box when H is heated with hydrochloric acid.



(06 marks x 2 = 12 marks)

4(b): 12 marks

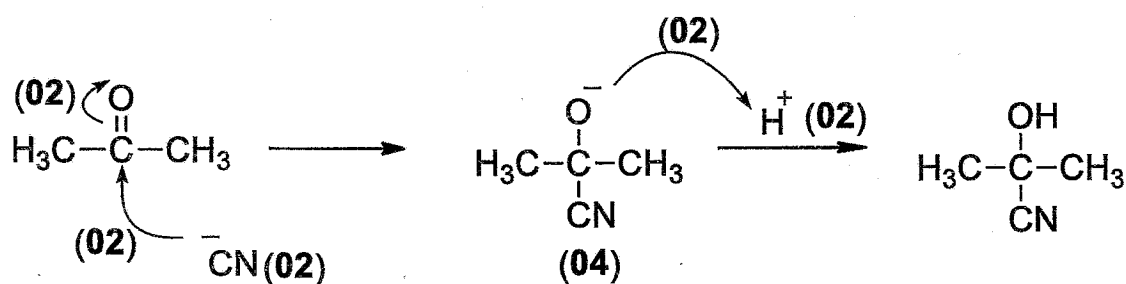
- (c) (i) Draw the structure of the product J formed in the relevant box from the reaction between acetone and HCN.



(J)

(06 marks)

- (ii) Write the mechanism of the above reaction.

**Notes:**

IF HCN is used instead of CN^- deduct the 02 marks allocated for CN^- .

(14 Marks)

4(c): 20 marks

PART B — ESSAY

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

NOTE: PHYSICAL STATES ARE NECESSARY

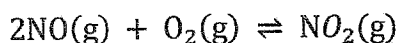
5. (a) A mixture of NO(g) and O₂(g) in 2:1 molar ratio respectively, was introduced to a rigid closed container of volume 10 dm³ and allowed to react at temperature *T*. After a certain time, the system reached the equilibrium as given below, at temperature *T*.



At equilibrium, the following observations were noted.

- The pressure of the gaseous mixture was $32 \times 8.314 \times 10^3$ Pa.
- The total number of moles of the three gases was 0.64.
- The mass of O₂ was 6.4 g.

- (i) Calculate the concentration of each gaseous species in mol dm⁻³ at equilibrium. (O = 16)



$$\text{Moles of O}_2(\text{g}) = \frac{6.4 \text{ g}}{32 \text{ g mol}^{-1}} = 0.20 \quad (02)$$

$$\text{Con. of O}_2(\text{g}) = \frac{0.20 \text{ mol}}{10 \text{ dm}^3} = 2.0 \times 10^{-2} \text{ mol dm}^{-3} \quad (02+01)$$

$$\text{Moles of NO}(\text{g}) = 0.40 \text{ (2:1 ratio given)} \quad (02)$$

$$\text{Con. of NO}(\text{g}) = \frac{0.40 \text{ mol}}{10 \text{ dm}^3} = 4.0 \times 10^{-2} \text{ mol dm}^{-3} \quad (02+01)$$

$$\text{Moles of NO}_2(\text{g}) = 0.64 - (0.40 + 0.20) = 0.04 \quad (02)$$

$$\text{Con. of NO}_2(\text{g}) = \frac{0.04 \text{ mol}}{10 \text{ dm}^3} = 4.0 \times 10^{-3} \text{ mol dm}^{-3} \quad (02+01)$$

- (ii) Calculate the equilibrium constant, *K_c* at temperature *T*.

$$K_c = \frac{[\text{NO}_2(\text{g})]^2}{[\text{O}_2(\text{g})][\text{NO}(\text{g})]^2} \quad (05)$$

$$K_c = \frac{[4.0 \times 10^{-3} \text{ mol dm}^{-3}]^2}{[2.0 \times 10^{-2} \text{ mol dm}^{-3}][4.0 \times 10^{-2} \text{ mol dm}^{-3}]^2} \quad (05)$$

$$K_c = 0.50 \text{ mol}^{-1} \text{ dm}^3 \quad (05)$$

- (iii) Calculate the value of temperature T (in K) under these conditions. State any assumption/s made.

Assuming ideal gas behavior

$$PV = nRT$$

$$T = \frac{PV}{nR}$$

$$T = \frac{32 \times 8.314 \times 10^3 \text{ Pa} \times 10 \times 10^{-3} \text{ m}^3}{0.64 \text{ mol} \times 8.314 \text{ J K}^{-1} \text{ mol}^{-1}}$$

$$T = 500 \text{ K}$$

(03)

(02)

(05)

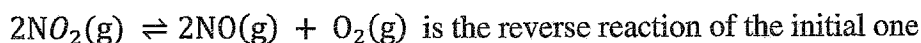
(04+01)

- (iv) Calculate the equilibrium constant K_p for the reaction,



at the temperature determined in (iii) above.

Reaction of concern is



(05)

If the equilibrium constant is K'_C

$$K'_C = \frac{1}{K_C}$$

(05)

$$= \frac{1}{0.50} = 2 \text{ mol dm}^{-3}$$

(04+01)

$$K_p = K_C (RT)^{\Delta n} \quad \Delta n = 1$$

(03+02)

$$K_p = 2 (8.314 \text{ J K}^{-1} \text{ mol}^{-1} \times 500 \text{ K})$$

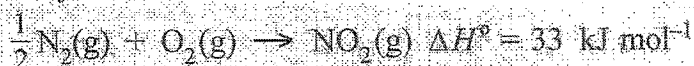
$$K_p = 8.314 \times 10^3 \text{ Pa}$$

(04+01)

5(a): 70 marks

- (b) Consider the information given below at temperature 298 K.

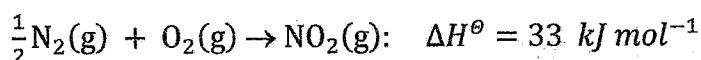
$$\Delta H_f^\circ(\text{NO}(\text{g})) = 90 \text{ kJ mol}^{-1}$$



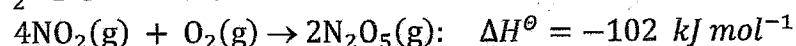
b. Information given:

$$\Delta H_f^\circ(\text{NO}(\text{g})) = 90 \text{ kJ mol}^{-1}$$

(A)

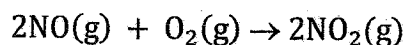


(B)



(C)

i. Reaction needed:



From (A), $\Delta H_f^\theta(\text{NO}(\text{g}))$: $\frac{1}{2}\text{N}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{NO}(\text{g})$: $\Delta H^\theta = 90 \text{ kJ mol}^{-1}$. (D) (05)

(B) - (D) : $\frac{1}{2}\text{O}_2(\text{g}) + \text{NO}(\text{g}) \rightarrow \text{NO}_2(\text{g}) \dots\dots$ (E) (05)

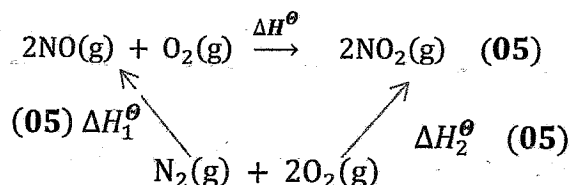
$$\Delta H^\theta = (33 - 90) = -57 \text{ kJ mol}^{-1} \quad (05+05)$$

(E) $\times 2$: $2\text{NO}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}_2(\text{g})$ $\Delta H^\theta = -114 \text{ kJ mol}^{-1}$ (04+01)

OR: (B) $\times 2$ - (D) $\times 2$: $2\text{NO}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}_2(\text{g})$ (05+05)

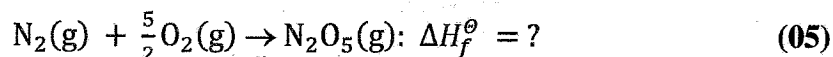
$$\Delta H^\theta = (66 - 180) \text{ kJ mol}^{-1} \quad (05+05)$$

$$\Delta H^\theta = -114 \text{ kJ mol}^{-1} \quad (04+01)$$

OR

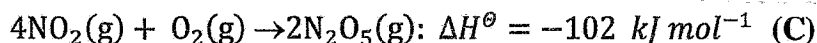
From Hess's law: $\Delta H^\theta = \Delta H_2^\theta - \Delta H_1^\theta = (2 \times 33 - 2 \times 90) \text{ kJ mol}^{-1}$ (05)

$$= -114 \text{ kJ mol}^{-1} \quad (04 + 01)$$

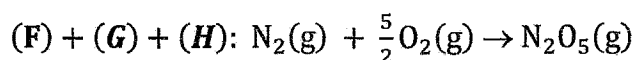
OR other acceptable method(s)ii. Formation reaction of $2\text{N}_2\text{O}_5(\text{g})$:

Information: $\frac{1}{2}\text{N}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{NO}(\text{g})$: $\Delta H^\theta = 90 \text{ kJ mol}^{-1} \dots\dots$ (D)

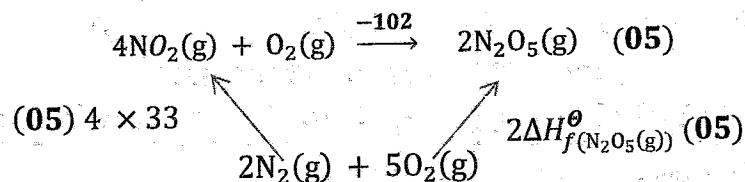
(D) $\times 2$: $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}(\text{g})$: $\Delta H^\theta = 180 \text{ kJ mol}^{-1} \dots\dots$ (F) (05+05)



(C) $\div 2$: $2\text{NO}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{N}_2\text{O}_5(\text{g})$: $\Delta H^\theta = -51 \text{ kJ mol}^{-1} \dots\dots$ (H) (05)



$$\Delta H_f^\theta(\text{N}_2\text{O}_5(\text{g})) = [180 + (-114) + (-51)] \text{ kJ mol}^{-1} = 15 \text{ kJ mol}^{-1} \quad (05+04+01)$$

OR

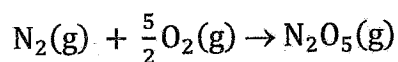
From Hess's law: $2\Delta H_f^\theta(\text{N}_2\text{O}_5(\text{g})) = (4 \times 33 - 102) \text{ kJ mol}^{-1} \quad (05 + 05)$

$$\Delta H_f^\theta(\text{N}_2\text{O}_5(\text{g})) = 15 \text{ kJ mol}^{-1} \quad (04 + 01)$$

OR other acceptable method(s)

(iii) Using the results obtained in (ii) above, predict the following.

I. the sign of $\Delta S_f^\theta(\text{N}_2\text{O}_5(\text{g}))$



3.5 moles \rightarrow 1 mole : number of moles decreased (05)

$\Delta H_s^\theta(\text{N}_2\text{O}_5(\text{g}))$ is negative (< 0) (05)

II. spontaneity of the reaction for the formation of $\text{N}_2\text{O}_5(\text{g})$ from $\text{N}_2(\text{g})$ and $\text{O}_2(\text{g})$

$$\Delta G^\theta = \Delta H^\theta - T\Delta S^\theta \quad (05)$$

$$= +ve - (+ve)(-ve) = +ve \quad (05)$$

The reaction is non-spontaneous at 298 K (05)

5(b): 80 marks

NOTE: PHYSICAL STATES ARE NECESSARY

6. (a) According to the kinetic molecular theory of gases, for an ideal gas at temperature T , $PV = \frac{1}{3} mN\overline{C^2}$. Here P is the pressure of the gas, V is the volume of the gas, m is the mass of a gas molecule, N is the number of molecules of gas and $\overline{C^2}$ is the mean square speed of the gas.

- (i) Show that $\overline{C^2} = \frac{3RT}{M}$ for an ideal gas. M is the molar mass of the gas.

$$PV = \frac{1}{3} mN\overline{C^2} = \frac{1}{3} m(nN_A)\overline{C^2} \quad : n - \text{moles}, N_A - \text{Avogadro no} \quad (04)$$

$$= \frac{1}{3} nM\overline{C^2} \quad : M - \text{molar mass} \quad (04)$$

$$PV = nRT = \frac{1}{3} nM\overline{C^2} \quad (04)$$

$$\overline{C^2} = \frac{3RT}{M} \quad (04)$$

- (ii) A and B are two ideal gases with molar masses M_A and M_B respectively. Show that the mean square speed of gas B ($\overline{C_B^2}$) at temperature $T = 300 \frac{M_B}{M_A}$, is equal to the mean square speed of gas A ($\overline{C_A^2}$) at $T = 300$. (Temperatures are given in kelvin)

$$\text{For gas A: } \overline{C_A^2} = \frac{3RT}{M_A} = \frac{3R \times 300}{M_A} \quad (1)$$

$$\text{For gas B: } \overline{C_B^2} = \frac{3RT}{M_B} = \frac{3R \times 300 \left(\frac{M_B}{M_A}\right)}{M_B} = \frac{3R \times 300}{M_A} \quad (2) \quad (04+04)$$

$$(1) = (2): \quad \overline{C_A^2} = \overline{C_B^2} \quad (04)$$

- (iii) Derive an expression for the ratio between the molar kinetic energies of the two gases A and B at any given temperature T .

$$\text{For gas A: } (KE)_A = \frac{3RT_A}{2} \quad (04)$$

$$\text{For gas B: } (KE)_B = \frac{3RT_B}{2} \quad (04)$$

$$\text{As } T_A = T_B: (KE)_A = (KE)_B \quad (04)$$

OR- Kinetic energy of a gas depends only on the absolute temperature

$$(KE)_A = (KE)_B \quad (12)$$

6(a): 40 marks

- (b) (i) Define the term 'an elementary reaction'.

Elementary Reaction: A reaction occurs through a single step (without involving an intermediate).

(05)*

- (ii) Define the term 'molecularity' of a reaction.

Molecularity: Total number of reacting molecules participating in an elementary reaction or in the rate determining step of a reaction.

(05)

- (iii) For an elementary reaction what is the relationship between 'reaction order' and 'molecularity'?

Elementary reaction : Reaction order = Molecularity

(05)*

- (iv) The following table gives the variation of the concentration of the reactant in a reaction with time.

Time (minutes)	0	10	20	30	40
Reactant concentration (mol dm ⁻³)	1.6	0.8	0.4	0.2	0.1

Reaction order = Molecularity

In 10 minutes time the concentration decreased to half of the initial concentration (05)

This is consistent with all the 10 min time intervals

(05)

I) Reaction is first order

(05)

II) Half-life ($t_{1/2}$) of the reaction is 10 min

(05)

* Note: If student has attempted Q 6 (b), award marks for parts i and iii

- (v) Consider the information given below for two first order reactions ① and ② at a given temperature.

	Reaction	Reaction rate/ mol dm ⁻³ s ⁻¹	Rate constant/s ⁻¹	Half-life/s
①:	$A \rightarrow P_1$	r_A	k_A	$(t_{1/2})_A$
②:	$B \rightarrow P_2$	r_B	k_B	$(t_{1/2})_B$
	(P ₁ , P ₂ = Products)			

A first order reaction with rate constant, k has a half-life, $t_{1/2} = \frac{0.693}{k}$.

If $r_B = 3r_A$ when $[B] = 2[A]$, show that $2(t_{1/2})_A = 3(t_{1/2})_B$.

As the reactions are first order,

$$r_A = k_A[A]: \quad k_A = \frac{r_A}{[A]} \quad (03+02)$$

$$r_B = k_B[B]: \quad k_B = \frac{r_B}{[B]} \quad (03+02)$$

Given that: $[B] = 2[A]$, $r_B = 3r_A$ and $t_{1/2} = \frac{0.693}{k}$

We can write; $k_A = \frac{r_A}{[A]}$ (I)

$$k_B = \frac{3r_A}{2[A]} \text{(II)} \quad (05)$$

$$(I) \div (II) \text{ gives } \frac{k_A}{k_B} = \frac{2}{3} \quad (05+05)$$

$$\frac{(t_{1/2})_A}{(t_{1/2})_B} = \frac{0.693/k_A}{0.693/k_B} = \frac{k_B}{k_A} = \frac{3}{2} \quad (05+05)$$

$$2(t_{1/2})_A = 3(t_{1/2})_B \quad (05)$$

6(b): 75 marks

(c) At temperature 25°C , 50.0 cm^3 of 0.30 g dm^{-3} iodine aqueous solution was shaken well with 10.0 cm^3 of CCl_4 . When the system reached equilibrium the concentration of iodine in the water layer was found to be 0.02 g dm^{-3} .

(i) Calculate the concentration of iodine in the CCl_4 layer at equilibrium.

$$\text{Initial } I_2 \text{ mass in water layer} = 0.30 \text{ g dm}^{-3} \times 50 \times 10^{-3} \text{ dm}^3 = 0.015 \text{ g} \quad (03)$$

$$\text{Equilibrium } I_2 \text{ mass in water layer} = 0.02 \text{ g dm}^{-3} \times 50 \times 10^{-3} \text{ dm}^3 = 0.001 \text{ g} \quad (03)$$

$$\text{Equilibrium } [I_2]_{H_2O} = \frac{(0.001 \text{ g})}{50 \times 10^{-3} \text{ dm}^3} = 0.02 \text{ g dm}^{-3}$$

$$\text{Equilibrium } I_2 \text{ mass in } \text{CCl}_4 \text{ layer} = (0.015 - 0.001) \text{ g} = 0.014 \text{ g} \quad (03)$$

$$\text{Equilibrium } [I_2]_{\text{CCl}_4} = \frac{(0.014 \text{ g})}{10 \times 10^{-3} \text{ dm}^3} = 1.4 \text{ g dm}^{-3} \quad (03+03+01)$$

(ii) At temperature 25°C , calculate the partition co-efficient of I_2 between CCl_4 and water.

$$K_D = \frac{[I_2]_{\text{CCl}_4}}{[I_2]_{H_2O}} = \frac{1.4 \text{ g dm}^{-3}}{0.02 \text{ g dm}^{-3}} = 70 \quad (03+03)$$

(iii) If the above experiment was done at 25°C with 20.0 cm^3 of CCl_4 instead 10.0 cm^3 , calculate the concentration of iodine in the water layer at equilibrium.

At this stage take I_2 mass in H_2O layer as x

$$K_D = 70 = \frac{[I_2]_{\text{CCl}_4}}{[I_2]_{H_2O}} = \frac{(0.015-x)/20}{x/50} \quad (05)$$

$$x = 0.0005 \text{ g}$$

$$(04)[I_2]_{H_2O} = \frac{(0.0005 \text{ g})}{50 \times 10^{-3} \text{ dm}^3} = 0.01 \text{ g dm}^{-3} \quad (03+01)$$

Alternate answer:

At this stage take I_2 mass in CCl_4 layer as x

$$K_D = 70 = \frac{[I_2]_{CCl_4}}{[I_2]_{H_2O}} = \frac{x/20}{(0.015-x)/50} \quad (05)$$

$$x = 0.0145 \text{ g} \quad (02)$$

$$I_2 \text{ mass in water layer} = 0.0150 - 0.0145 = 0.0005 \text{ g} \quad (02)$$

$$[I_2]_{H_2O} = \frac{(0.0005 \text{ g})}{50 \times 10^{-3} \text{ dm}^3} = 0.01 \text{ g dm}^{-3} \quad (03+01)$$

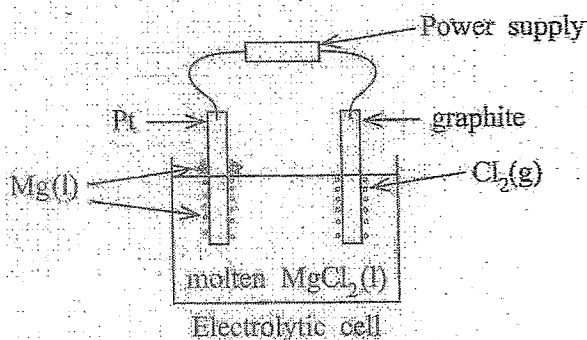
6(c): 35 marks

NOTE: PHYSICAL STATES ARE NECESSARY

- 7.(a) Mg metal can be extracted by the electrolysis of molten $MgCl_2(l)$ using inert electrodes (examples: Pt, graphite). A simple setup for this is shown in the diagram.

$$E^\circ_{Mg^{2+}(l)/Mg(s)} = -2.37 \text{ V}$$

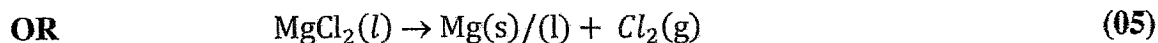
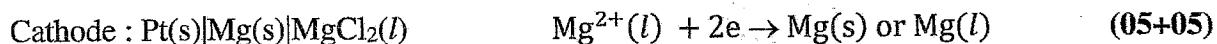
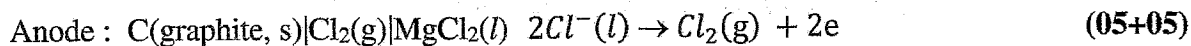
$$E^\circ_{H_2O(l)/H_2(g)} = -0.63 \text{ V}$$



- (i) Identify the anode and the cathode. Write the half reaction taking place at each electrode.

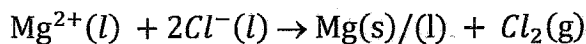
Electrode

Half-reaction



(ii) Write the overall cell reaction.

Overall cell reaction:



OR



(iii) State the direction of electron flow through the external circuit as the cell operates.

from C(graphite, s)|Cl₂(g) anode to Pt(s)|Mg(s) cathode (05)

(iv) Explain the following:

I. Molten MgCl₂(l) is used instead of MgCl₂(s) in this extraction process.

Solid or crystalline MgCl₂(s) has no movable ions. Molten state has ionic

Mg²⁺(l) and Cl⁻(l). (05)

II. A solution of MgCl₂(aq) cannot be used in this extraction process.

Water molecules would reduce to H₂(g) instead of Mg²⁺(l) (05)

(v) If a 5.37 A current is passed through this cell for one hour and the Cl₂(g) formed is collected at temperature 300 K and pressure 1 atm (~1.0 × 10⁵ Pa), calculate the volume

$$Q = It \quad (05)$$

$$= 5.37 \text{ A} \times (60 \times 60) = 19300 \text{ C} \quad (04+01)$$

$$\text{Moles of electrons} = 19300/96500 = 0.2 \text{ mol} \quad (05)$$

$$2 \text{ mol of electrons} \equiv 1 \text{ mol of Cl}_2(\text{g})$$

$$\text{Moles of Cl}_2(\text{g}) \text{ produced} = 0.10 \text{ mol} \quad (05)$$

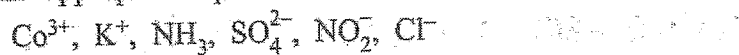
Assuming an ideal gas behavior: PV = nRT (05)

$$V = \frac{nRT}{P} = \frac{0.10 \text{ mol} \times 8.314 \text{ J K}^{-1} \text{ mol}^{-1} \times 300 \text{ K}}{1 \times 10^5 \text{ Pa}} \quad (05)$$

$$= 249.4 \times 10^{-5} \text{ m}^3 \text{ or } 2.49 \text{ dm}^3 \quad (04+01)$$

7(a): 75 marks

- (b) (i) **P, Q, R, S** and **T** are coordination compounds of **Co(III)**. They have an octahedral geometry. Give the structural formulae or draw the structures of these coordination compounds, selecting the appropriate species from the list given below.



Note: In the above coordination compounds NO_2^- behaves as a monodentate ligand when attached to the metal ion.

P – Only neutral ligands are coordinated to the metal ion. On reaction of an aqueous solution of **P** with dil. HCl , reddish-brown fumes are evolved. **P** gives four ions in aqueous solution.

Q – Two types of ligands are coordinated to the metal ion. They are neutral ligands and mono-atomic anionic ligands. A white precipitate insoluble in dilute acid is formed on addition of $\text{BaCl}_2(\text{aq})$ to an aqueous solution of **Q**. **Q** gives two ions in aqueous solution.

R – Two types of ligands are coordinated to the metal ion. They are neutral ligands and multi-atomic anionic ligands. **R** shows geometric isomerism. On reaction of an aqueous solution of **R** with $\text{AgNO}_3(\text{aq})$, a white precipitate is formed. This precipitate is soluble in dil. NH_4OH . **R** gives two ions in aqueous solution.

S – It is a non-ionic compound. An equal number of neutral ligands and multi-atomic anionic ligands are coordinated to the metal ion.

T – Only mono-atomic anionic ligands are coordinated to the metal ion. **T** gives four ions in aqueous solution.

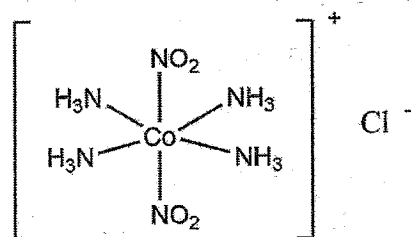
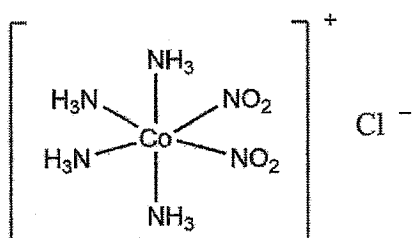


(7 (b) (i) 50 marks)

- (ii) I. Write the IUPAC name of **T**.

potassium hexachloridocobaltate(III) (10)

II. Draw the structures of the geometric isomers of R.



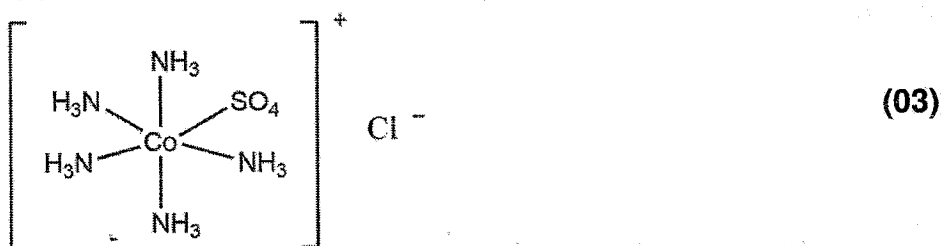
(05 marks)*

(If both are correct 05 marks. If only one is correct 03 marks)

***Note:** Although geometric isomerism is commonly taught in A/Levels, students may not be familiar with them in coordinate complexes. Therefore, as a concession, marks will be awarded in the following manner for 7 b (i) R and (ii) II.

(i) R: $[\text{Co}(\text{NH}_3)_5(\text{SO}_4)]\text{Cl}$ (06)

(ii) II.



(03)

(iii) X is a coordination compound of Co(III) with an octahedral geometry. The ligands H_2O and CO_3^{2-} are coordinated to the metal ion. On treatment of an aqueous solution of X with $\text{AgNO}_3(\text{aq})$ a pale yellow precipitate, soluble in conc. NH_4OH is formed. X gives two ions in aqueous solution. Give the structural formula or draw the structure of X.

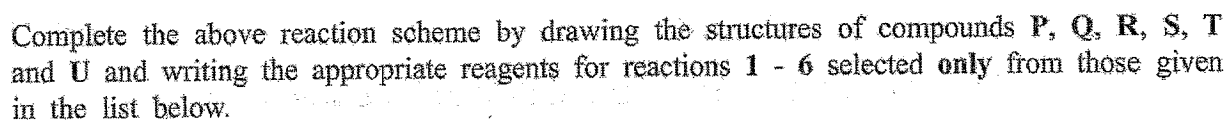
Note: CO_3^{2-} coordinates to the metal ion through two oxygen atoms.

$[\text{Co}(\text{H}_2\text{O})_4(\text{CO}_3)]\text{Br}$ (10)

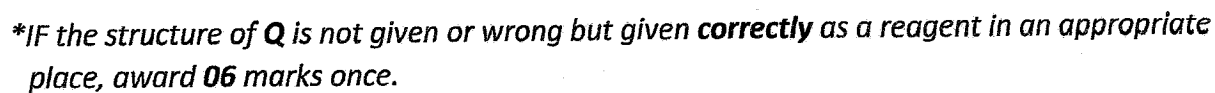
7(b): 75 marks

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

8. (a) $\text{CH}_3\text{CH}_2\text{OH} \xrightarrow{\text{Reaction 1}} \text{P} \xrightarrow{\text{Reaction 2}} \text{Q}$

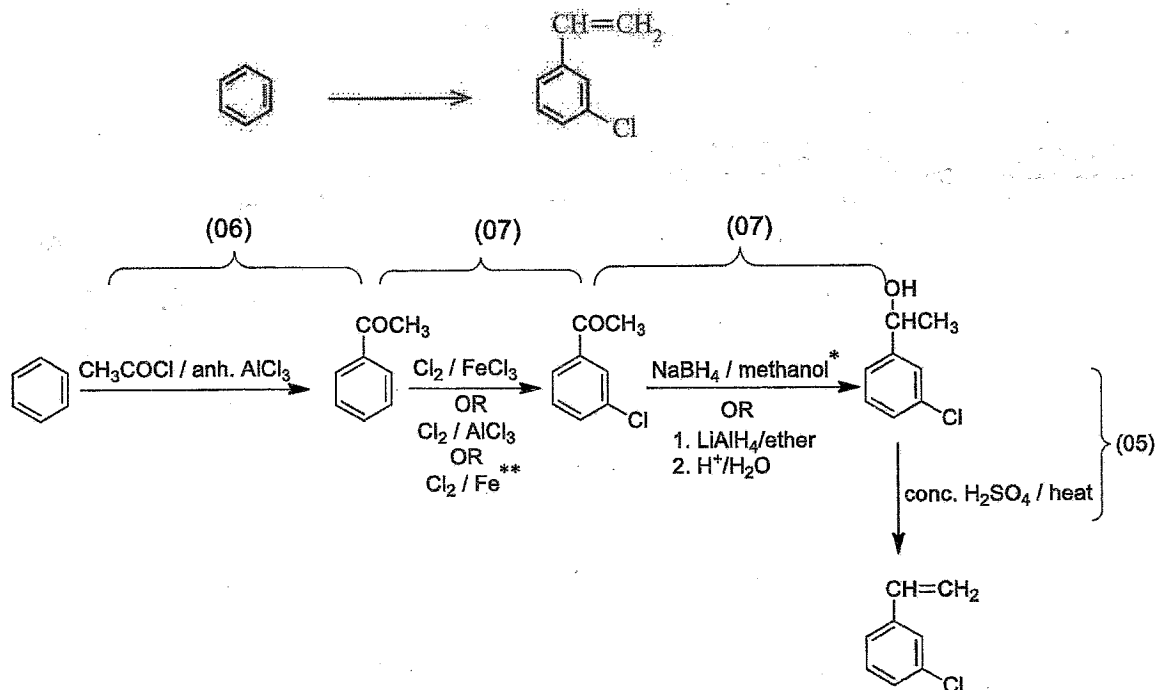


Dilute H_2SO_4 , Mg/dry ether, PBr_3 , Pyridinium chlorochromate (PCC)



8(a): 60 marks

(b) (i) Show how you would carry out the following conversion in not more than four (04) steps.



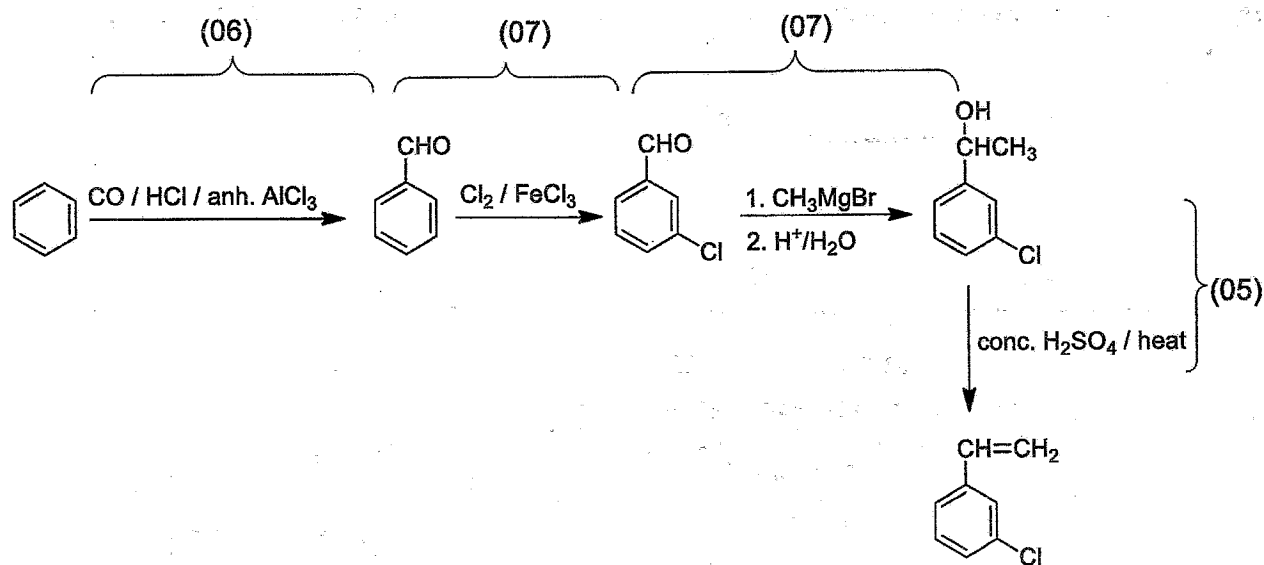
*Methanol is necessary for the reaction. If methanol is not written deduct 01 mark.

**This is obsolete and not given in the syllabus or in the teacher guide. But it seems that it has been continuously taught in certain schools. Hence in fairness to the students it is included in the marking scheme.

(25 marks)

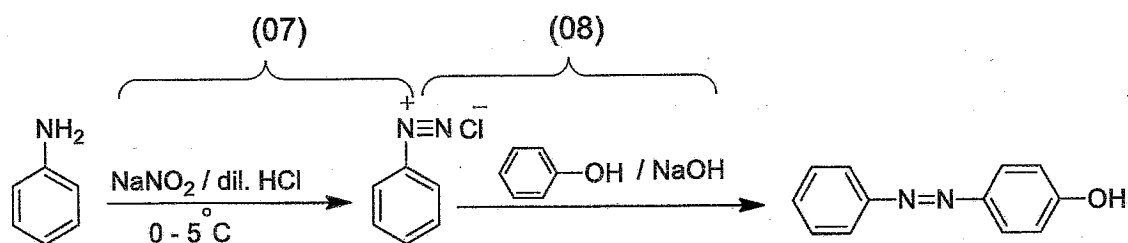
Alternative answer:

Although the conversion of benzene to benzaldehyde is not given in the syllabus or in the teacher guide, it seems that it has been continuously taught in certain schools. Hence in fairness to the students the following alternative answer is included in the marking scheme.



(25 marks)

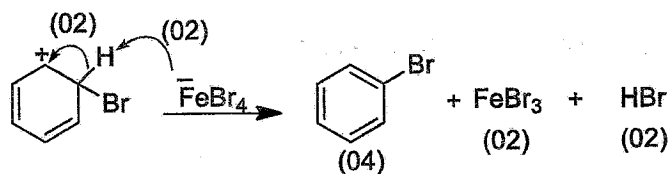
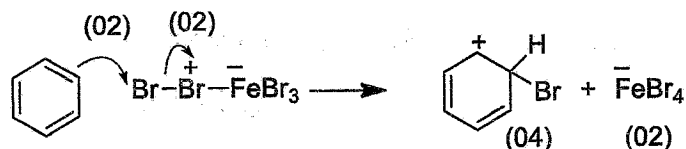
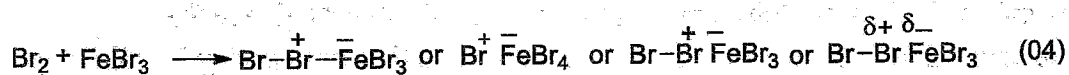
(ii) Propose a method to prepare $\text{C}_6\text{H}_5\text{N}=\text{NC}_6\text{H}_4\text{OH}$ from aniline in not more than two (02) steps.



(15 marks)

8(b): 40 marks

- (c) (i) Write the product and the mechanism of the reaction that takes place between benzene and bromine in the presence of anhydrous FeBr_3 .



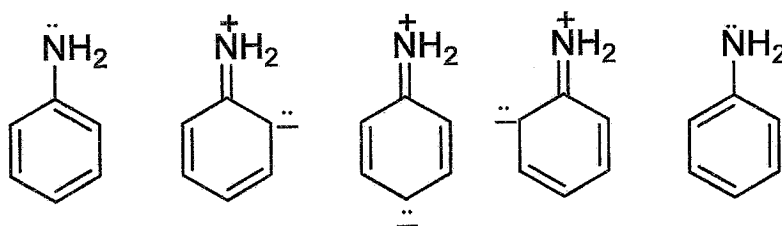
(26 marks)

- (ii) Draw the resonance structures of benzene and aniline.

Resonance structures of benzene



Resonance structures of aniline



Note: IF the lone pair is not written, deduct 02 marks once.

(02 marks x 7 = 14 marks)

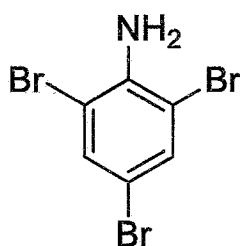
- (iii) Considering the above resonance structures, explain why the benzene nucleus in aniline is more reactive towards electrophilic substitution reactions than benzene itself.

The benzene ring in aniline is electron rich compared to benzene (03 marks) due to the delocalization of the lone pair of electrons on the nitrogen atom, into the benzene ring in aniline (03 marks).

Therefore, benzene ring in aniline is more reactive towards electrophiles, than benzene.

(06 Marks)





- (iv) Draw the structure of the product formed when aniline reacts with bromine.

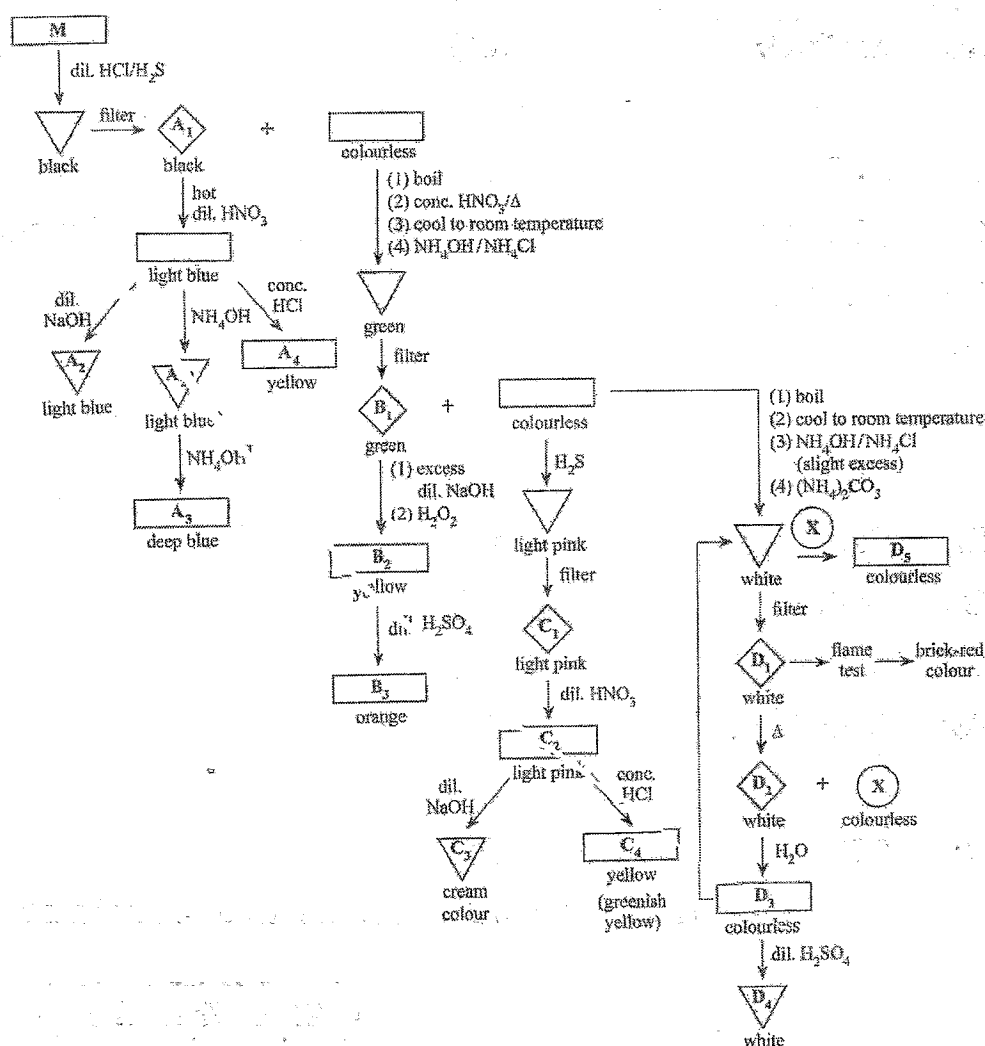


(04 marks)

8(c): 50 marks

M is analysed according to the scheme given below.

			
precipitate with solution	solid	solution	gas



(Note : Write **only** chemical formulae. Chemical equations and reasons are **not** required.)

A₁:	CuS	(06)
A₂:	Cu(OH)₂	(04)
A₃:	[Cu(NH₃)₄]²⁺	(04)
A₄:	[CuCl₄]²⁻	(04)
B₁:	Cr(OH)₃	(06)
B₂:	Na₂CrO₄	(04)
B₃:	Na₂Cr₂O₇	(04)
C₁:	MnS	(06)
C₂:	[Mn(H₂O)₆]²⁺	(04) Note: If Mn²⁺(aq) only 02 marks
C₃:	Mn(OH)₂	(04)
C₄:	[MnCl₄]²⁻	(04)
D₁:	CaCO₃	(06)
D₂:	CaO	(04)
D₃:	Ca(OH)₂	(04)
D₄:	CaSO₄	(04)
D₅:	Ca(HCO₃)₂	(04)
X:	CO₂	(03)

(06 marks x 4 + 04 marks x 12 + 03 marks x 1)

9(a): 75 marks

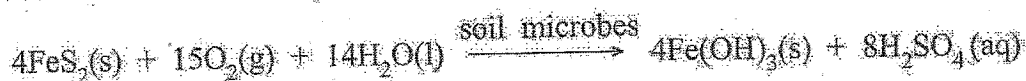
(b) The main compound present in iron pyrite is FeS_2 . A 1.50 g sample of iron pyrite was oxidized under laboratory conditions and all the sulphur in FeS_2 was converted to SO_4^{2-} . The resultant SO_4^{2-} was precipitated as BaSO_4 . The dry weight of BaSO_4 obtained was 4.66 g.

(i) Calculate the weight percentage of FeS_2 present in iron pyrite.

H_2SO_4 that was produced in this reaction after 120 hours was quantitatively separated and precipitated as BaSO_4 . The dry weight of BaSO_4 obtained was 31.13 g.

FeS_2 in 20.0 g of iron pyrite was subjected to oxidation by soil microbes under natural conditions for 120 hours.

This oxidation reaction is represented in the following equation.



$$\text{BaSO}_4 - \text{Molar mass} = 137 + 32 + 64 = 233 \text{ g mol}^{-1} \quad (03)$$

$$\text{FeS}_2 - \text{Molar mass} = 56 + 64 = 120 \text{ g mol}^{-1} \quad (03)$$

$$\text{Moles of BaSO}_4 = \frac{4.66}{233} = 0.02 \text{ mol} \quad (03)$$

$$1 \text{ mole of FeS}_2 \text{ gives 2 moles BaSO}_4 \quad (03)$$

$$\therefore \text{moles of FeS}_2 = \frac{0.02}{2} = 0.01 \text{ mol} \quad (03)$$

$$\therefore \text{weight of FeS}_2 = 0.01 \times 120 = 1.20 \text{ g} \quad (03)$$

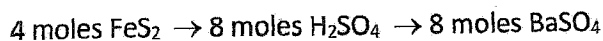
$$\therefore \text{weight percentage of FeS}_2 \text{ in iron pyrite} = \frac{1.20}{1.50} \times 100 \quad (03)$$

$$= 80\% \quad (04)$$

(9b(i): 25 marks)

(ii) Calculate the percentage conversion of FeS_2 in iron pyrite to SO_4^{2-} after 120 hours by soil microbes.

$$\text{Note: Percentage conversion} = \frac{\text{Experimentally obtained mass using soil microbes}}{\text{Theoretical mass}} \times 100$$



$$\text{Amount of FeS}_2 \text{ in 20.0 g of iron pyrite} = 20.0 \times \frac{80}{100} \quad (03)$$

$$= 16.0 \text{ g} \quad (03)$$

Calculation of theoretical mass of BaSO₄

According to the equation

4 moles FeS₂ gives 8 moles of BaSO₄ (03)

∴ 4 x 120 g FeS₂ gives 8 x 233 g of BaSO₄ (03)

∴ 16 g FeS₂ gives $\frac{8 \times 233}{4 \times 120} \times 16$ g of BaSO₄ (03)

Theoretical mass of BaSO₄ = 62.13 g (03)

Experimental mass of BaSO₄ = 31.13 g

% conversion = $\frac{31.13}{62.13} \times 100$ (03)

= 50.1% (04)

(9b(ii): 25 marks)

ALTERNATE ANS 1

4 moles FeS₂ → 8 moles H₂SO₄ → 8 moles BaSO₄

Mass of FeS₂ in 20.0 g of iron pyrite = $20.0 \times \frac{80}{100}$ (03)

= 16.0 g (03)

Moles of BaSO₄ = $\frac{31.13}{233}$ mol

Moles of H₂SO₄ = $\frac{31.13}{233}$ mol (03)

Moles of FeS₂ reacted = $\frac{1}{2} \times \frac{31.13}{233}$ mol (03)

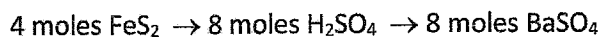
Experimental mass of FeS₂ reacted = $\frac{1}{2} \times \frac{31.13}{233} \text{ mol} \times 120 \text{ g mol}^{-1}$ (03)

= 8.016 g (03)

% conversion = $\frac{8.016 \text{ g}}{16 \text{ g}} \times 100\%$ (03)

= 50.1% (04)

(9b(ii): 25 marks)

ALTERNATE ANS 2

$$\text{Mass of FeS}_2 \text{ in 20.0 g of iron pyrite} = 20.0 \text{ g} \times \frac{80}{100} \quad (03)$$

$$= 16.0 \text{ g} \quad (03)$$

$$\text{Moles of FeS}_2 = \frac{16.0}{120} \text{ mol} \quad (03)$$

$$\text{Theoretical mass of BaSO}_4 = \frac{16}{120} \times 2 \text{ mol} \times 233 \text{ g mol}^{-1} \quad (03)$$

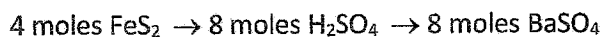
$$= 62.13 \text{ g} \quad (03)$$

$$\text{Experimental mass of BaSO}_4 \text{ reacted} = 31.13 \text{ g} \quad (03)$$

$$\% \text{ conversion} = \frac{31.13 \text{ g}}{62.13 \text{ g}} \times 100\% \quad (03)$$

$$= 50.1\% \quad (04)$$

(9b(ii): 25 marks)

ALTERNATE ANS 3

$$\text{Mass of FeS}_2 \text{ in 20.0 g of iron pyrite} = 20.0 \text{ g} \times \frac{80}{100} \quad (03)$$

$$= 16.0 \text{ g} \quad (03)$$

$$\text{Moles of FeS}_2 = \frac{16.0}{120} \text{ mol} \quad (03)$$

$$\text{Theoretical moles of H}_2\text{SO}_4 = \frac{16}{120} \times 2 \text{ mol}$$

$$\begin{aligned} \text{Theoretical mass of H}_2\text{SO}_4 &= \frac{16}{120} \times 2 \text{ mol} \times 98 \text{ g mol}^{-1} \\ &= 26.13 \text{ g} \end{aligned} \quad (03)$$

$$\text{Moles of BaSO}_4 = \frac{31.13}{233} \text{ mol}$$

$$\text{Moles of H}_2\text{SO}_4 = \frac{31.13}{233} \text{ mol}$$

$$\text{Experimental mass of H}_2\text{SO}_4 = \frac{31.13}{233} \text{ mol} \times 98 \text{ g mol}^{-1} \quad (03)$$

$$= 13.09 \text{ g} \quad (03)$$

$$\% \text{ conversion} = \frac{13.09 \text{ g}}{26.13 \text{ g}} \times 100\% \quad (03)$$

$$= 50.1\% \quad (04)$$

(9b(ii): 25 marks)

(iii) Calculate the amount of iron pyrite required to produce 8 kg of H_2SO_4 by soil microbes when the conversion percentage of FeS_2 in iron pyrite to SO_4^{2-} is 100%.
(Relative atomic mass : O = 16, S = 32, Fe = 56, Ba = 137)

$$\text{H}_2\text{SO}_4 = 8 \text{ kg} = 8000 \text{ g} \quad (03)$$

$$\text{Molar mass H}_2\text{SO}_4 = 98 \quad (03)$$

$$\text{Moles H}_2\text{SO}_4 = \frac{8000}{98} \quad (03)$$

If the conversion is 100%

$$\therefore \text{moles of FeS}_2 \text{ required} = \frac{8000}{98} \times \frac{1}{2} \quad (03)$$

$$= 40.8 \text{ moles} \quad (03)$$

$$= 40.8 \times 120 \text{ g}$$

$$= 4896 \text{ g} \quad (03)$$

$$\therefore \text{amount of iron pyrite required to produce 8 kg of H}_2\text{SO}_4 = \frac{4896}{80} \times 100 \text{ g} \quad (03)$$

$$= 6120 \text{ g}$$

$$= 6.12 \text{ kg} \quad (04)$$

9b(iii): 25 marks

9(b): 75 marks

10.(a) The following questions are based on the Solvay process.

(i) What is the main product of the Solvay process?

Na_2CO_3 / sodium carbonate

(04)

(ii) What is the main by-product of the Solvay process?

CaCl_2 / calcium chloride

(04)

(iii) What are the raw materials (starting materials) used in the Solvay process?

NH₃ gas, (04)

CO₂ gas, (04)

Brine (purified concentrated NaCl solution free from Ca²⁺, Mg²⁺ and SO₄²⁻ made from sea water (04)

(10a(iii): 12 marks)

(iv) Which one of these raw materials in (iii) above is not consumed in the process but is recycled repeatedly?

NH₃ gas (04)

(v) Identify the first step of the Solvay process in which raw materials are mixed inside a tower which consists of perforated clay trays. Explain why this is carried out at a low temperature.

Ammonification (mixing NH₃ gas and Brine using the counter current principle) (02)

Ammonification is an exothermic process (03)

If the temperature increases, efficiency of dissolving NH₃ gas in Brine decreases and hence low temperature is maintained. (03)

OR

Dissolution of ammonia is exothermic ($\Delta H < 0$) (01)

and the entropy change (ΔS) is negative ($\Delta S < 0$) (01)

According to $\Delta G = \Delta H - T\Delta S$ (01)

When ΔS is negative, $-T\Delta S$ term is +ve. (01)

When temp increases ΔG becomes less negative, (01)

This reduces efficiency of dissolving in water; therefore low Temp more suitable (03)

(vi) Give three uses of the main product of the Solvay process.

To remove hardness of water

Used in glass industry

Used in paper industry

Used in soap and detergent industry to improve the cleaning action

Used as a powerful cleaning agent (washing soda)

Any three (03 marks x 3 = 09 marks)

(vii) Give three reasons contributing to the economic profitability of the Solvay process.

NaCl and CaCO₃ can be obtained easily with low cost

NH₃ is not used and can be used repeatedly by recycling

Portion of CO₂ can be reused

(03 marks x 03 = 09 marks)

10(a): 50 marks

(b) Briefly explain each of the following statements.

(i) Agriculture contributes to global warming.

Related to agriculture:

- N₂O (02) and CH₄ (02) contribute to global warming
- Both are greenhouse gases (02)
- Increase in their concentration contributes to global warming. (02)

Formation of N₂O:

- Action of denitrifying bacteria (02) on
- nitrogen containing fertilizers (02) produce N₂O

Formation of CH₄:

- Paddy cultivation in marsh and water logged area (02) favour anaerobic decomposition of organic matter to produce CH₄. (01)
- Decomposition of organic matter disposed indiscriminately (02) undergo anaerobic decomposition to produce CH₄. (01)
- Digestion of organic/cellulose matter in guts of ruminant animals (cows, goat, sheep) undergoing bacterial decomposition under anaerobic conditions (02) produce CH₄

(10b(i): 20 marks)

(ii) Iron extraction contributes to global warming.

Related to iron extraction:

- CO₂ contributes to global warming
- CO₂ is a greenhouse gas and
- increase in concentration contributes to global warming

(02x3)

Formation of CO₂:

Fossil fuels and coke used in iron extraction are converted to CO₂ during combustion

(04)

(10b(ii): 10 marks)

(iii) Transportation contributes to photochemical smog.

In your answer indicate how the chemical species responsible for the given environmental effect in each of the statements above is/are formed.

Related to transportation:

Species that contribute to photochemical smog

NO and volatile hydrocarbons (CH₃(CH₂)_nCH₃, n = 1-4)

(02x2)

- NO and volatile hydrocarbons undergo reactions in the presence of sunlight to produce volatile short chain aldehydes and other toxic chemicals (PAN, PBN)
- Aldehydes are further polymerized to produce suspended particles in the atmosphere
- These particles can form large particles by deposition of dust, water vapour, etc
- These large particles can scatter sunlight reducing the visibility/transparency of the atmosphere and appear like a mist in the lower atmosphere

(02 x 8 = 16)

(10b(iii): 20 marks)

10(b): 50 marks

(c) (i) The following questions are based on vinegar production.

I. State what is the process used in the production of natural vinegar.
microbial activity / microbial fermentation

(04)

II. Write the name of the active chemical ingredient present in natural vinegar.
acetic acid

(04)

III. Name the titrant and the indicator used in the quantitative determination of the active chemical ingredient in natural vinegar.

Titrant – NaOH

(04)

Indicator – Phenolphthalein

(04)

IV. State the difference in composition between natural vinegar and artificial vinegar.

Natural vinegar contains salts, simple sugars, esters and alcohols in minute quantities.

(01x4)

However, synthetic vinegar contains only acetic acid.

(02)

(ii) The following questions are based on the extraction of essential oils from plants.

I. Name three methods that can be used to extract essential oils.

steam distillation

solvent extraction

pressing

(04 marks x 3 = 12 marks)

II. State which of the above methods is based on the application of Daltons Law of partial pressures.

steam distillation

(04 marks)

III. Name the major compound present in each of the essential oils given below.

● Citronella oil

● Cinnamon root oil

● Cinnamon leaf oil

citronella – geraniol

cinnamon root – camphor

cinnamon leaf - eugenol

(04 marks x 3 = 12 marks)

10(c): 50 marks