Royal College- Colombo 07

Third Term Test – November 2023

Grade 13

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name : ..... Index No. ..... Grade : .....

* Use of calculators is not allowed.
* Universal gas constant R = $8.314\ JK^{-1}\ mol^{-1}$
* Avogadro constant N_A = $6.022 \times 10^{23}\ mol^{-1}$
* Planc constant h = $6.626 \times 10^{-34}\ Js$
* Velocity of light C = $3.0 \times 10^{8}\ ms^{-1}$

Part A – Structured Essay (pages 2 – 9)

* 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 Essay (pages 10 – 17)

* At the end of the time allotted for this paper, tie the answers to the two Parts A and B together so that Part A is on top and hand them over to the Supervisor.
* You are permitted to remove only Parts of the question paper from the Examination Hall.

For Examiner's Use Only

Paper I	
Paper II	
Total	
Percentage	

Final Marks	

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

Part A – Structured Essay

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

(01) (a) State whether the following statements are true (T) or false (F). Reasons are not required.

1. The lattice dissociation enthalpy of $CaCl_{2(s)}$ is greater than that of $KCl_{(s)}$ .....
2. Hybridization of the central atom of a linear molecule is always sp .....
3. The electron which is represented by set of quantum numbers (3, 1, -1, +1/2) is in a dumble shape atomic orbital. .....
4. Enthalpy is an extensive property while Gibbs energy is an intensive property. .....
5. Boiling point of n – hexane is smaller than that of 2,2-dimethylbatane .....

(b) P, Q, and R are three elements found in two consecutive periods of the periodic table having atomic number less than 20. Two of them are in the same period, and their electronegativities are above 2.6 according to the Pauling scale. The skeleton of a molecule consisting of P, Q and R is given below (g).

i. Indensity the elements P, Q and R

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ii. Draw the most stable Lewis structure for the above molecule.

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iii. Draw three resonance structures for the above molecule and state the stability of them with reason.

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iv. Draw the resonance hybrid of the above molecule.

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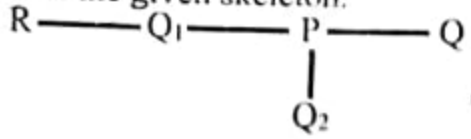
v. Complete the following table based on the structure drawn in part (ii) and numbering of atoms in the given skeleton.



	P	Q_1	Q_2
Electron pair Geometry			
Shape			
Hybridization			
Oxidation No			

vi. Identify the hybrid or atomic orbitals involve in the formation of σ bond.

1. $P - Q_1$ P ..... Q_1 .....
2. $P - Q_2$ P ..... Q_2 .....

vi. Sketch the shape of the Lewis structure drawn in part (i) above indicating approximate values of the bond angles.

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(c) i. State the inter molecular attraction operate among following chemical species?

1. $H_2S_{(g)}$ - .....
2. $H_2O_{2(l)}$ .....
3. $CH_3OH_{(l)}$ .....
4. Aueous amoniacal NaCl -.....

ii. Arrange the following species in the increasing order of the property given in paranthesis.

I. H_2OH , NH_4^+ , NF_2^- , NF_4^+ (lectronegtivity of N atom)

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II. BF_3 , BCl_3 , BBr_3 , BI_3 (Ability to act as Levis acid.)

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III. O, Na, Si, K, B (Convalent radius)

..... < ..... < ..... < ..... < .....

IV. SO_2, NO_2^-, BF_3, N_2O, NF_3 (Dipole moment)

..... < ..... < ..... < ..... < .....

V. $Ar_{(g)}$, $HCl_{(g)}$, $F_{2(g)}$ (entropy)

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VI. Na_2O , BeO , B_2O_3 , CO_2 (basicity)

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VII. $MgCl_{2(s)}$, $NaCl_{(s)}$, $AgCl_{(S)}$ (Lattice dissociation enthalpy)

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VIII. Ca, S, Si, Ar (third ionization enthalpy)

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(02) (a) s-block element X which has the atomic number less than 30, can **industrially be converted** to Y, but X does not react with excess of gaseous P to give Y but it gives product L. The element found just below X (next period) in the same group reacts with excess of P. The product so obtained gives Z when treated with water. Y reacts with water, giving Z, and the hydroxide of X, Z has disinfectant properties. Chloride of X gives a special color in the flame test. Sulphate and chromate of X well dissolve in water.

X reacts separately with colorless gases Q and R giving same product T. In addition to T, colorless diatomic gas U is given when X reacts with R. R gas is given back when T is treated with water. Filter paper which is moistrured with Nestller's reagent turns brown when exposed to gas R. Gas U reacts with X givin S and S reacts with water giving hydroxide of X and U.

i. Identify L, P, Q, R, S, T, U, X, Y and Z.

X	Y	P	Z	L	R	Q	T	U	S

ii. Balance the following reactions using actual element and appropriate product.

I. $Y + H_2O \longrightarrow$

II. $X + H_2O \longrightarrow$

III. $X + R$, $\longrightarrow$

IV. $X + Q \longrightarrow$

V. $T + H_2O \longrightarrow$

VI. $S + H_2O \longrightarrow$

(b) i. Choose a suitable chemical from the following list and write in the given box in each questions.

$AgNO_3$, Na_2SO_4, $Ca(NO_3)_2$, K_2SO_3, KCl, NaOH

I. Na_2CO_3 + [ ] A precipitate is formed and it dissolves in HCl giving a clear solution.

II. $BaCl_2$ + [ ] A precipitate is formed and it liberates a gas with HCl which can react with acidified $K_2Cr_2O_7$ turning the solution to green.

III. $Pb(NO_3)_2$ + [ ] Precipitate dissolves on heating and reform needle shape crystals on cooling.

IV. $Zn(NO_3)_2$ + [Excess] A clear solution is given. The white precipitate which formed on addition of HCl dropwise dissolves in excess of HCl.

V. $Na_2S_2O_3$ + [ ] White precipitate is given and it turns black on standing.

ii. Write the balanced chemical equations for the for the reactions of part (i) from I to V

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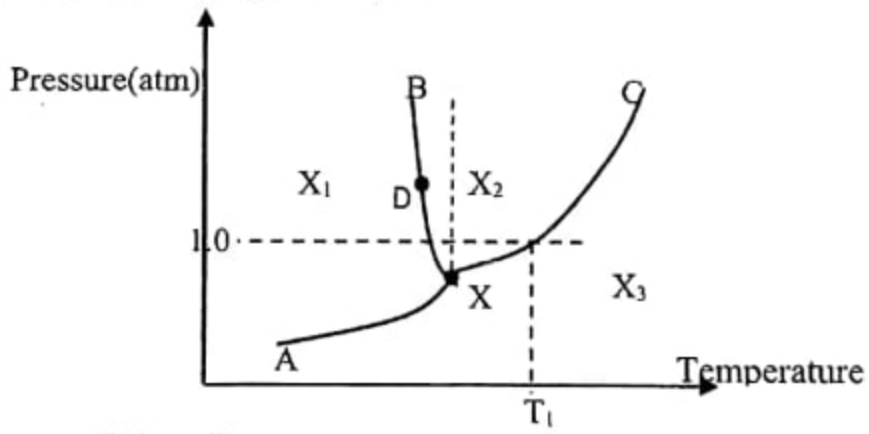
(03) (a) Phase diagram of water is given below.



i. Define the terms "**phase**".

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ii. Identify the phases labeled an X_1 , X_2 and X_3.

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iii. Name the pint X and clearly identify what is represented by point X (you may mention value, if any)

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iv. Identify the value of T_1.

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v. What are represented by the,

(a) Line X - B

(b) Curve X - C

vi. What do you expect for the melting point of the substance at point D, when the pressure is increased.

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(b) (i) Liquids X and Y are miscible in all proportions. Variation of the intermolecular forces of pure X and Y is $f_{(x-x)} > f_{y-y}$

X and Y forms an ideal solution in all proportions. Draw the vapour pressure - composition phase diagram for both phases for the X/Y mixture.

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(ii) A and B are two volatile liquids. The Vapour pressure of pure A at a particular temperature is twice that of pure B. In an ideal solution formed by A and B , which is in equilibrium with its vapour , the mole ratio in the liquid phase , $n_A : n_B = 3: 2$

Calculate the ratio , (total vapour pressure of the mixture) : (Vapour pressure of pure A)

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(c) i. Define the term **"catalyst"**.

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ii. Briefly explain how catalysts change the rate of chemical reaction.

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iii. How you would show that NaOH is a catalyst for the decomposition reaction of H_2O_2

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iv. Name the types of catalyss and give 2 examples for each type.

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v. Consider the reaction $2\ AB_2(aq) \rightarrow 2A_2(g) + B_2(g)$

The time taken to form n moles of the above gaseous mixture was measured by varying the initial concentration of $AB_2(aq)$

Initial concentration of $AB_2(aq)$ mol dm^{-3}	Time taken to form n moles of gases
0.07	60
0.05	118

Calculate the time taken to produce n moles of gases when the initial concentration of the reactant is 0.045 mol dm^{-3} (Assume that the change in the concentration during the period of study is small)

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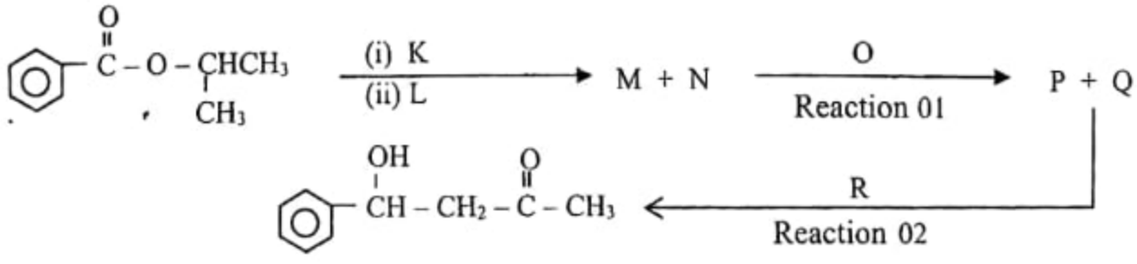
(04) (a) A , B and C are structural isomers of the molecular formular $C_5H_{12}O$. Only A shows optical isomerism when A , B and C are separately reacted with Conc H_2SO_4. A gives D , B gives D and E and C gives F. All D , E and F give the same product G on catalitic hydrogenation. Only A and C can be oxidized by PCC to obtain products H and I. Both H and I can be further oxidized by tollens' reagent.

i. Draw the structures of A, B, C, D, E, F, G, H and I in the boxes given below.

A	B	C
D	E	F
G	H	I

ii. Consider the reaction scheme given below.



I. Identify the reagents K, L, O and R.

K ..... L .....

O ..... R .....

II. Draw the structures of M, N, P and Q in the boxes given bellow.

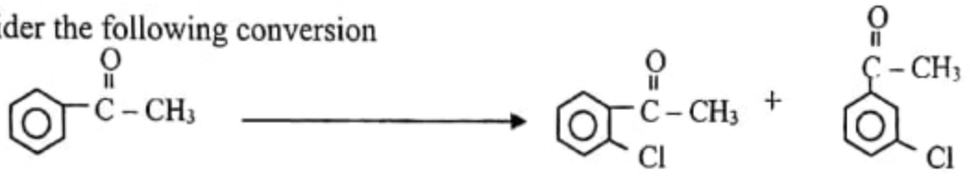
M	N	P	Q

III. Writing A_E, A_N, S_E, S_N or OX classify reaction 01 and reaction 02 as electrophilic addition(A_E), nucleophilic addition (A_N), electrophilic (S_E), nucleophilic substitution (S_N), or oxidation (OX) reaction.

Reaction 01 .....

Reaction 02 .....

(b) Consider the following conversion



Giving reason, identify the major product of the above reaction.

*** 30. 11. 2023 ***

Part B – Essay

Answer 2 questions only.

(05) (a) 1 mol of gas $XY_{(g)}$ was placed in 1 m^3 rigid vessel and allowed to reach equilibrium at 227^0C as follows.

$$X_{2(g)} + Y_{2(g)} \rightleftharpoons 2XY_{(g)} \quad \text{——————} \quad (1)$$

K_C for the reaction (1) at $227^0C = 4$

i. Calculate the number of moles of $X_{2(g)}$, $Y_{2(g)}$ and $XY_{(g)}$ at equilibrium.

ii. Calculate the K_P at 227^0C for the equilibrium.

iii. The rate constant of the forward reaction for the above reversible reaction is given as $K_f = 5\ mol^{-1}\ m^3\ s^{-1}$. Calculate the rate constant K_r for the reverse reaction.

iv. 0.5 mol of each of Y_2 and XY was added to the above equilibrium system at 227^0C. Show that to which direction the reaction occurs to reach new equilibrium position using suitable calculation and sketch a graph to depict concentration variation of product with time.

v. In addition to the above reaction following reaction also occurs when some amount of $Z_{2(S)}$ is added to the above equilibrium.

$$Y_{2(g)} + Z_{2(S)} \rightleftharpoons 2ZY_{(g)} \quad \text{——————} \quad (2)$$

Partical of ZY(g) is 4.157×10^2 Pa at equilibrium.

I. Calculate the moles of ZY and Y_2 at equilibrium.

II. Calculate the K_P for the (2) equilibrium at 227^0C.

III. Deduce the value of value of K_P of the following reaction and calculate the K_C using K_P at $227\ ^0C$.

$$2ZY_{2(g)} + X_{2(g)} \rightleftharpoons 2XY_{(g)} + Z_{2(S)}$$

(b) Consider the following thermochemical data at 27^0C.

$$A_{(g)} + B_{(g)} \longrightarrow C_{(g)} \qquad \Delta H = -150\ kJ\ mol^{-1} \qquad \Delta S = -100\ J\ K^{-1}\ mol^{-1}$$

i. Calculate the ΔG for the above reaction at $227\ ^0C$.

ii. Comment on the spontenity of the reaction with reason at 27^0C.

iii. Calculate the ΔG of following reaction using the data given in the table at 27^0C and comment on the spontenity. $B_{(g)} + D_{(g)} \rightarrow E_{(g)}$

	ΔH_f ($KJmol^{-1}$)	S ($JK^{-1}mol^{-1}$)
B	-50	100
D	-70	50
E	-150	225

iv. Calculate the ΔH for the reaction $A + E \rightarrow C + D$ at $27\ ^0C$.

v. Calculate the maximum temperature above which the reaction is not spontaneous.

(c) m g of compound A has been dissolved in water (Solution S). 200 cm^3 of S was separately shaken with two portions of 100 cm^3, in two consecutive times with the same aqueous solution. 80% of A extracted to first portion of ether (first extraction).

(i) Calculate the partition coefficient of A between ether and water.

(ii) What is the total percentage of A extracted to ether layer.

(iii) Dissolution enthalpy of A in water and ether are -18 kJ mol^{-1} and - 45 kJ mol^{-1} respectively. Explain how temperature can be used to enhance the extraction of A to ether using suitable calculation.

(06) (a) Consider 0.1 mol dm^{-3} Na_2A solution at 25^0C. A^{2-} is the anion of weak diprotic acid H_2A. The first and second dissociation constants of H_2A are Ka_1 and Ka_2 respectively.
(at 25^0C $Ka_1 = 1 \times 10^{-6}$ mol dm^{-3}, $Ka_2 = 1 \times 10^{-10}$ mol dm^{-3} , $K_W = 1 \times 10^{-14}$ $mol^2\ dm^{-6}$)

i. Write down an equation for the first dissociation constant Ka_1 of H_2A.

ii. First and second equilibrium constants for the hydrazation of A^{2-} in water are K_1 and K_2 respectively.

I. Write the balanced chemical equation for the hydrolysis of A^{2-}.

II. Show that $K_2 = K_W / Ka_1$

III. Calculate the K_2 at 25^0C using above relationship.

iii. Consider the titration of 25^0C of 0.1 mol dm^{-3} Na_2A solution with 0.1 $moldm^{-3}$ HCl solution.

I. Calculate the volume of HCl required to reach the first equalent point and show that $[H_3O^+_{(aq)}] = \{K_2[HA^-_{(aq)}]\}^{1/2}$ Kw at first equatent point. Then calculate the pH at the first equalent point.

II. Calculate the total volume of HCl used to reach the second equalent point and show that. $[H_3O^+_{(aq)}] = \{Ka_1\ [H_2A_{(aq)}]\}^{-1/2}$ at the second equalent point. Then calculate the pH of the solution at second equalent point.

III. Name two indicators witch can be used to identify the each equilibrium points in above titration.

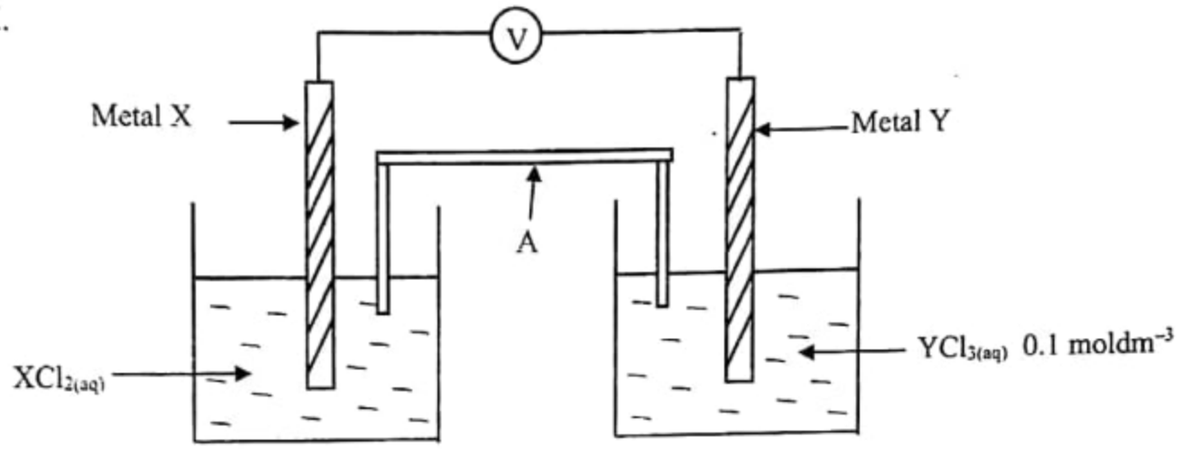
(b) pH of a 1.0 dm^3 of saturated H_2S (1 mol dm^{-3}) solution is maintained at 4 by adding HCl.

i. Show that $[S^{2-}_{(aq)}] = (Ka_1 \times Ka_2)\,[H_2S_{(aq)}] / [H^+_{(aq)}]^2$

ii. Calculate the $S^{2-}_{(aq)}$ concentration of the above given solution. (K_{a1} and K_{a2} of H_2S are 1×10^{-8} mol dm^{-3}, 1×10^{-12} mol dm^{-3} respectively)

iii. Show that wether a precipitate (MnS) is formed when 0.2 g of solid $MnCl_2.4H_2O$ is added to above solution with the help f suitable calculation.
(25^0C K_{SP} MnS = 5×10^{-15} mol^2dm^{-6} , Mn = 55 , O = 16 , H = 1 , Cl = 35.5)

(07) (a) I.



The above figure defict a cell constructed using metal X and Y dipping in their own metal ion solution.

$3X_{(S)} + 2Y^{3+}_{(aq)} \longrightarrow 3X^{2+}_{(aq)} + 2Y_{(S)}$, $E^0_{(Cu)} = 0.6V$

i. Identify the metal, which acts as the anode.

ii. What is the cathodic metal ?

iii. Write down the anodic reaction.

iv. Write down the cathodic reaction.

v. Given that the standared reduction poteitiol of Y as $E^0_{Y^{3+}_{(aq)}/Y_{(S)}}$ = 0.4 V. Calculate the standared reduction potential of X

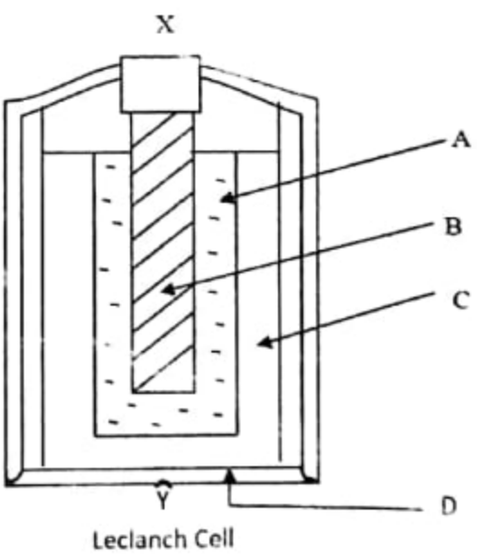
II. The following figure which shows a cross sectional of a Leclanche cell.

i. Identify A , B , C and D in the above diagram.

ii. Write down the Anode Cathode and cell reactions of Leclanche cell.

iii. One of the two components in mixture A is an element. What is the importance of having this element in the mixture?

iv. Identify the polarities of X and Y terminals.



Leclanch Cell

III. Question No (v) to (viii) are based on lead acid accumulator.

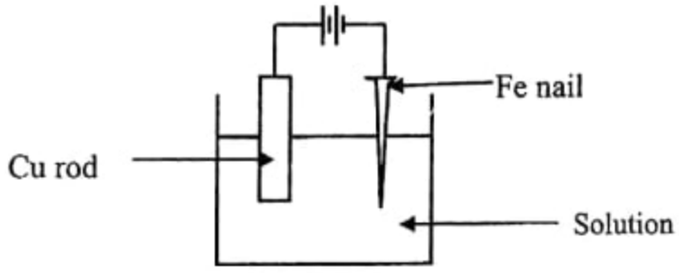
i. What are the materials used as the positive (+) and negative (-) electrodes in lead acid accumulator?

ii. State the anodic and cathodic reactions when current is drawn from the cell.

iii. State a similarity and difference of primary and secondary cell.

iv. State the balanced chemicals reactions which take place when lead acid accumulator is recharged.

IV. Following figure shows a setup used to in electroplating of cupper on an iron nail.



i. State a suitable solution for P.

ii. Identify the anode and cathode of the above cell.

iii. State the balanced cathodic reaction.

iv. Calculate the mass of Cu deposited on nail when 0.2 A current is passing through the cell for two minutes. F = 96 500 C Cu = 63.5

(b) A, B, C and D are four compounds with coordination complexes derived from the same oxidation state of Co, Ni and Cu. Their molecular formulars are $NiN_5H_{15}Cl_2$, $CoN_5H_{17}Cl_2O$, $CuN_4H_{16}Br_2O_2$ and $CoN_5H_{15}Cl_2$ (not in order). Following test were carried out to identify them separately.

i. 37.6 g of yellow precipitate which is soluble in concentrated ammonia was given when 0.1 mol of A is treated with excess of $AgNO_3$.

ii. B gives a white precipitate which is soluble in dill NH_3. When 0.01 mol of B is treated with excess of $AgNO_3$ 1.435 g of the precipitate was given. Solution B turns pink on dilution.

iii. White precipitate which is soluble in NH_3 was given when $AgNO_3$ is added to C. 0.1 mol of C gives 28.7 g of the precipitate. C turns pink on dilution.

iv. Solution of D turns green on dilution. 0.02 mol of D gives 2.87 g of white precipice with $AgNO_3$. (Ag = 108 , Cl = 35.5 , Br = 80)

I. Identify A , B , C and D write the molecular formular.

II. Deduce the structural formula of A , B , C and D.

III. Write the balanced reactions for the following observations in test I.

a) Formation of yellow precipitate.

b) Dissolution of precipitate in conc.NH_3.

IV. Write the balanced reactions for the following observations in test (II.)

(a) Formation of white precipitate.

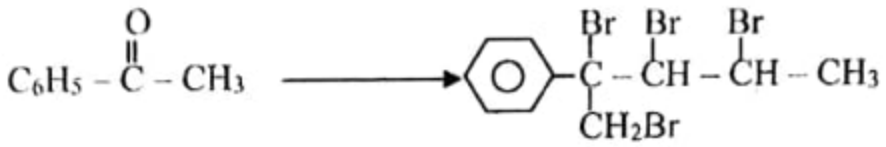
(b) Dissolution of precipitate in dil NH_3.

V. Give the IUPAC names of A , B , C and D.

Part C – Essay

Answer 2 questions only.

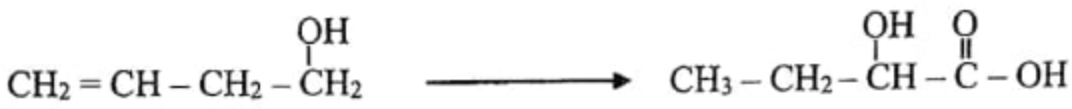
(08) (a) Using only the chemicals as required from given list show that, how you would carry out the following conversion not more than four steps.



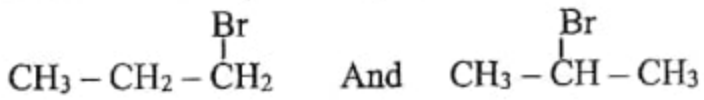
List of chemicals:-

CH_3OH, $BaSO_4$, Al_2O_3, H_2O, Br_2, H_2, HBr, $CH_3C{\equiv}CMgBr$, Pd, Quinoline, CCl_4 and $NaBH_4$

(b) Show that how you would carry out the following conversion not exceeding six steps.



(c) I) Show that how you are going to distinguish between following pair of compounds.



II) Write down the reaction mechanism for the following reaction.

(9) (a) The following procedure was carried to identify the salts A and B.

- A and B were separately dissolved in water. A gave colorless solution while B gave colored solution (B_1).
- Gas A_1 which turns red litmus into blue was given when A is heated with NaOH(aq).
- A_1 has both acidic and basic properties. Deep red A_2 solution was given when an aqueous solution of A is treated with $FeCl_3$.
- Reddish brown gas B_2 was liberated when an aqueous solution of B was treated with dil. H_2SO_4. (B_2) gives an acidic solution when dissolves in water.
- A_1 gas was passed through solution B. Pink precipitate B_3 was given and brown solution B_4 was given on passing excess of A_1. By reddish brown solution was given when B_5 was treated with H_2O_2.
- Aqueous solution of B turns blue when treated with conc HCl.

i. Identify the solts A and B. (reasons are not required)
ii. Identify the compounds / chemical species A_1 , A_2 , B_1 , B_2 , B_3 , B_4 , B_5 and B_6.
iii. State chemical reaction to show oxidation and reduction properties of gas A_1.
iv. Give name of another chemical test to identify the anion in salt B.
v. Write the IUPAC names of B_5 and B_6.
vi. Give two uses of the metal which forms the cation in B.
vii. Write the balanced chemical reaction for the dissolution of gas B_2 in water.

(b) Following procedure was used to determine concentrations of NO_2^-, Cr^{3+} and Pb^{2+} in an industrial wast water sample (s). (Pb – 207, Cr –52, O -16)

Step I 25.00 cm^3 of wast water sample was treated with 30 cm^3 of 0.20 mol dm^{-3} $KMnO_4$ in basic mediu. The brown black precipitate was formed and it was filtered and reacted with excess of KI in acidic medium. Then the solution was titrated with 0.40 mol dm^{-3} $Na_2S_2O_3$ solution in the pressence of starch as the indicator. 25.00 cm^3 of $Na_2S_2O_3$ solution was needed to reach the end point. Filtrate was used for step II.

Step II Filtrate from step I was treated with adequate amount of H_2O_2 and 0.2 moldm^{-3} K_2CrO_4 35.0 cm^3. The precipitate was filtered and dried until constent mass obtained. The mass the precipitate was 1.675 g.

Step III 27.0 cm^3 of the above filtrate (from step II) was warmed and titrated with 0.15 mol dm^{-3} Fe^{2+} solution. 30.0 cm^3 was needed to reach the end point. (Assume that Cr^{3+} does not react in step I and Mn^{2+} does not precipitate in step II)

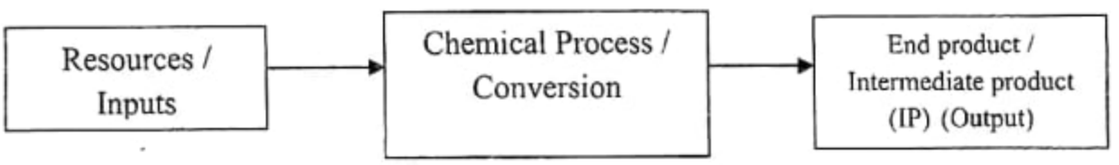
i. Write down balanced ionic/chemical reaction involve in above procedure.

ii. Calculate the concentrations of each ion in mol dm^{-3}.

I. NO_2^- II. Pb^{2+} III. Cr^{3+}

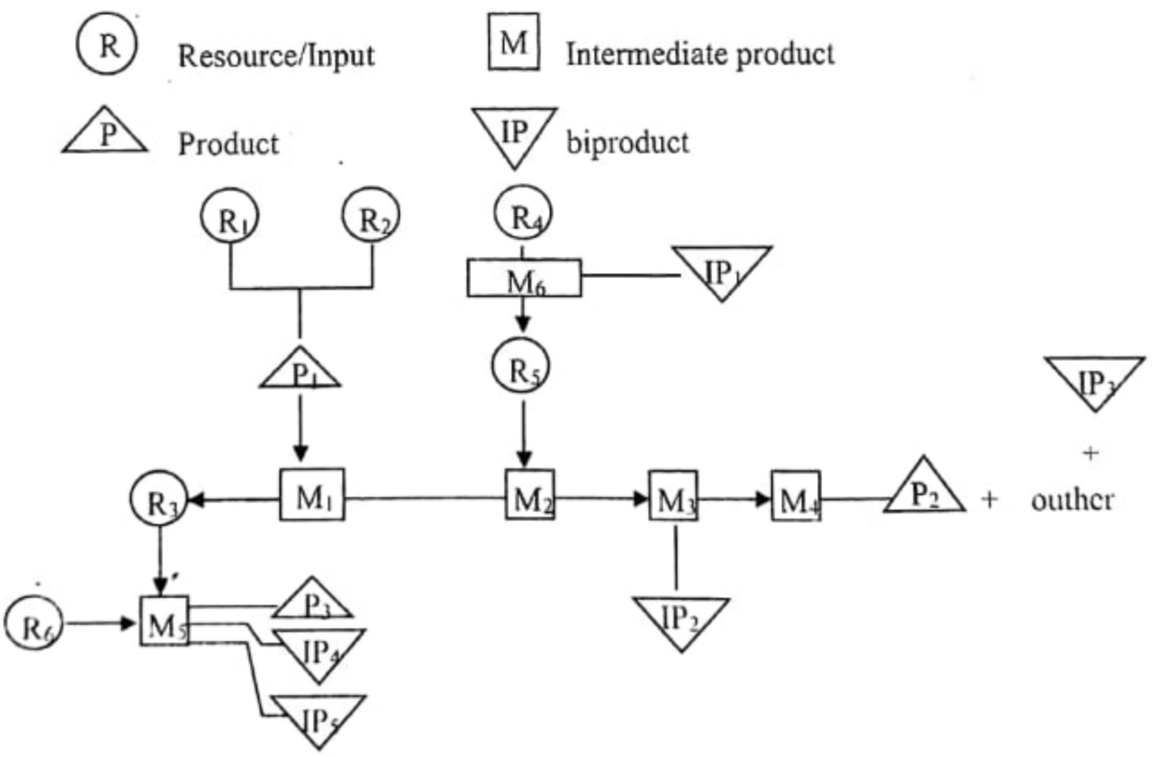
iii. Express the Cr^{3+} concentration in units of ppm. (Density of Cr^{3+} solution is 1.0 g cm^{-3})

(10) Chemical industries have a unique place among the industries. Number of key factors affect the successful operation of a chemical industry. Basic stages of a chemical industry can be given as follow.



(a) i. State four requirements to be considerate when establish a chemical industry.

ii. Flow chart of an intergrated chemical industry is given bellow.



R_5 plays a key role in iron extraction while reaction between IP_1 and IP_2 gives the P_1 . P_1 can be produced using IP_4 . R_2 and IP_4 are same while R_5 and IP_3 also the same.

1) Identify the resources / inputs from R_1 to R_6.
2) Identify the product from P_1 , P_2 and P_3.
3) Identify the processes from M_1 to M_6.
4) State the chemicals used as IP_1 to IP_5.

5) I. State the conditions use in the production of P_1.
   II. Natural gas is used to obtain R_2 in the production of P_1. What is the name of the process of by which R_2 is obtain.
   III. State two products which produce using P_1 (which are not mentioned in the question)

6) I. Name the process P_2.
   II. White down the balanced chemical reactions invol in (M_1 - M_4) in the production of P_2.
   III. State the differences between R_3 and the source of R_3.
   IV. What is the importance of having production sequence as M_1 and M_2.
   V. Write the balanced equations to obtain P_1 from IP_1 and IP_2.
   VI. Write the net reaction for the production of P_2.
   VII. What is / are the biproducts of above production.
   VIII. Identify the final byproduct of above production.

Answer either (07) or (08) only

07) Temperature is not equal all over the blast furnance in the iron extraction process. Briefly discuss how this temperature variation uses productively in the formation of IP_3 and all other reactions involve in the extraction process. Considerring (ΔG) and termal stabilities.

08) (a) i. What is the importance of process M_5 in the production of P_3?
   ii. State all reactions taking in M_5.
   iii. M_5 process is taking place in a special container. Identify this container.
   iv. Draw the lable diagram of above container.
   v. State three uses of P_3 .

(b) Chemical industries emit some environmental pollutant. Answer the following questions based on the CO_2, NO_2, CH_4, SO_2, water vapour, N_2O, O_3, CFC, HFC, HCFC, N_2, HFO

i. State environmental pollutant which emits due to natural processes and how tehey are given to the environment.

ii. Name human activities which are responsible for the emmition of hamful chemical species to the environment and name the chemical species.

iii. Copy-down the following table and fill it using chemical species caused for each.

Global warming	Depletion of ozone layer	Acid rain	Photochemical smog

iv. I. What does it mean by acid rain?

II. Combustion of coal or diesel cause for acid rain. Explain this using suitable chemical reactions.

III. State one post action and two measures that could be taken to reduce acid rain.

IV. State three adverse effects of acid rain.

v. Briefly explain the constribution of CFC in the deplection of ozone layer. With the help of relavent chemical reaction.

vi. State a carcinogenic gas (cancer casing gas) which is not contributed for the global warming or deplection of ozone layer.

(c) Answer the questions based on the following list of polymers.

PET, PE, PP, PVC, PTFE, nylon - 6, 6, Bakelite, rubber.

i. Distringuish between rubber and plastic.
ii. Classify the above polymers as linear or three dimentinal and addition or condensation.
iii. Give one use of each of above polymer.
iv. What is the purpose vulcanization of rubber ?

*** 30. 11. 2023 ***