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 are not required.

(i) Rules related to polarizing power of cations and polarizability of anions predict that the melting point of KBr is higher than that of LiI. .....

(ii) The electron gain energy of Be is positive. .....

(iii) The spacing between two adjacent lines in a given series of the atomic spectrum of hydrogen decreases gradually in the direction of decreasing wavelengths. .....

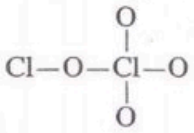
(iv) The de Broglie wavelength associated with the N_2 molecule is shorter than the de Broglie wavelength of the O_2 molecule when travelling at the same velocity. .....

(v) The effective nuclear charge (Z_{eff}) felt by a valence electron of C is greater than the effective nuclear charge felt by a valence electron of N. .....

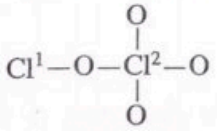
(vi) All C–O bonds in carbonic acid (H_2CO_3) are equal in length. .....

(24 *marks*)

(*b*) (i) Draw the **most** acceptable Lewis dot-dash structure for the molecule Cl_2O_4. Its skeleton is given below.

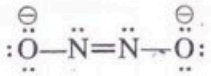


(ii) Give the oxidation states of the two chlorine atoms in the structure drawn in (i) above. The chlorine atoms are labelled as follows.

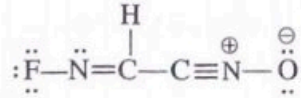


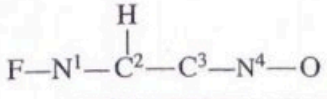
Cl^1 ..... , Cl^2 .....

(iii) The **most** stable Lewis dot-dash structure for the ion $N_2O_2^{2-}$ is shown below. Draw **two** additional Lewis dot-dash structures (resonance structures) for this ion.



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





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

[see page three

Do not write in this column.

● 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 the atomic/hybrid orbitals involved in the formation of σ bonds between the two atoms given below.

I.	N^1—F	N^1	F .....
II.	N^1—C^2	N^1	C^2 .....
III.	C^2—H	C^2	H .....
IV.	C^2—C^3	C^2	C^3 .....
V.	C^3—N^4	C^3	N^4 .....
VI.	N^4—O	N^4	O .....

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

I.	N^1—C^2	N^1	C^2 .....
II.	C^3—N^4	C^3	N^4 .....
		C^3	N^4 .....

(vii) State the approximate bond angles around N^1, C^2, C^3 and N^4 atoms.

N^1....., C^2 ....., C^3 ....., N^4.....

(viii) Arrange the atoms N^1, C^2, C^3 and N^4 in the **increasing** order of electronegativity.

..... < ..... < ..... < ..... **(54 *marks*)**

(*c*) (i) A laser emits photons of wavelength 695 nm.

I. To which region of the electromagnetic spectrum do these photons belong?

.....

II. Calculate the energy of a mole of these photons in kJ mol^{-1}.
Velocity of light $c = 3.00 \times 10^8$ m s^{-1} Planck constant $h = 6.63 \times 10^{-34}$ J s

(ii) A molecule of formula AX_3 has **three** A–X σ bonds. Here, A and X represent symbols of elements and A is the central atom.
Name the molecular shape(s) possible for AX_3 in I and II given below.

I. if AX_3 is polar .....

II. if AX_3 is non-polar .....

III. Give **one** example each, for the shapes stated by you in I and II above.
(**Note:** Molecular formulae are required.)

AX_3 is polar .....

AX_3 is non-polar .....

(22 *marks*)

100

[*see page four*

Do not write in this column.

2. The questions [(*a*)–(*d*)] given below relate to elements/species designated as **A**, **B**, **C** and **D**.

(*a*) **A** is a *s*-block element. It has an atomic number less than 20. It reacts with water vigorously with ignition to give a strongly basic solution, with the evolution of a gas. **A** reacts with excess $O_2(g)$ to give the superoxide. The naturally occurring ore Sylvite contains a compound of **A**.

(i) Write the chemical symbol of **A**. .....

(ii) Write the complete electronic configuration of **A**. .....

(iii) Name the gas evolved in the reaction of **A** with water. .....

(iv) What is the colour given by **A** in the flame test? .....

(v) Write the balanced chemical equation for the reaction of **A** with excess $O_2(g)$.

.....

(vi) Is the first ionization energy of **A** higher or lower than that of the element in the same group and the period above it in the Periodic Table? Briefly explain your answer.

.....

.....

(vii) Give the chemical formula of the compound of **A** in Sylvite. .....

(35 *marks*)

(*b*) **B** is an anion containing only the two elements **X** and **Y**, in the ratio 2:3 respectively. Both **X** and **Y** are *p*-block elements that belong to the same group in the Periodic Table. The atomic number of each element is less than 20. The electronegativity of **X** is less than the electronegativity of **Y**. When **X** reacts with hot concentrated sulfuric acid, a colourless gas with a pungent smell is evolved as one of the products.

(i) Write the chemical formula, including the charge, of **B**. .....

(ii) Draw the Lewis dot-dash structure of **B**.

(iii) Give the oxidation state of the central atom of **B**. .....

(iv) Give a chemical test to identify **B**. (**Note:** Observation(s) is/are also required.)

.....

.....

(v) Write the chemical formula for the compound which has **A** as the cation and **B** as the anion.

.....

(25 *marks*)

(*c*) **C** is an oxidizing agent. It is composed of three elements in the ratio 1:1:3. One of the elements of **C** is **A**. The other two elements belong to the *p*-block of the Periodic Table. One of these two elements is also present in **B**. The salt formed between Ag^+ and the anion of one of these elements is yellow in colour, and insoluble in concentrated ammonia solution. Write the chemical formula of **C**.

.....

(10 *marks*)

[*see page five*

Do not write in this column.

(*d*) **D** is a compound composed of two elements. Both these elements are also present in **C**.

(i) When C(aq) is mixed with an excess of **D**(aq) in acidic medium, a reddish-brown solution results.

I. Identify **D**. .....

II. Write the balanced **ionic** equation for the reaction that takes place.

.....

(ii) On addition of an excess of a solution containing **B**, to the reddish-brown solution obtained in (i) above, the reddish-brown solution becomes colourless. Write the balanced **ionic** equation for the reaction that takes place.

.....

(iii) The concentration of a solution containing **B** can be determined by volumetric analysis utilizing the reactions in (i) and (ii) above. State an indicator which can be used and give the expected colour change at the end point.

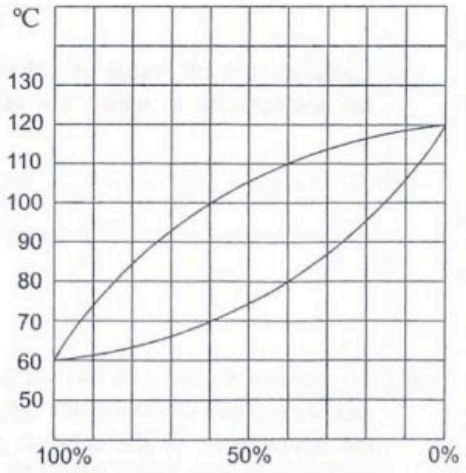
Indicator : .....

Colour change : .....

(30 *marks*)

100

3. (*a*) **X** and **Y** are two volatile liquids that form an ideal solution. The temperature-composition phase diagram (at a pressure of 1.0×10^5 Pa) for a system containing **X** and **Y** is given below.



● Parts (i) to (v) are based on the given phase diagram.

(i) Indicate the following regions on the phase diagram by writing the letters P, Q, R.

P – region where only the liquid phase is present

Q – region where only the vapour phase is present

R – region where the liquid phase and the vapour phase are in equilibrium

(ii) Give the boiling points of pure **X** and pure **Y**.

X ..... **Y** .....

(iii) What is the temperature at which a liquid mixture of **X** and **Y** containing 40 mol% of **X** begins to boil?

.....

(iv) What is the lowest temperature at which a mixture of **X** and **Y** containing 60 mol% of **X** is completely converted to vapour?

.....

[*see page six*

Do not write in this column.

(v) Calculate the saturated vapour pressure of X at the temperature of 100 °C.

(vi) In a separate experiment, a mixture containing X and Y was allowed to reach equilibrium in a **closed rigid** container at temperature T. It was then found that the liquid phase in equilibrium with the vapour phase contained 0.10 mol of X and 0.10 mol of Y. Saturated vapour pressures of X and Y at this temperature are 4.0×10^5 Pa and 2.0×10^5 Pa, respectively. Using Raoult law, calculate the partial pressures of X and Y.

(50 *marks*)

(*b*) The concentration of an aqueous solution of acetic acid (solution **Z**) was determined by titrating with an aqueous solution of NaOH. A volume of 12.50 cm^3 of solution **Z** required 25.00 cm^3 of NaOH solution of concentration 0.050 mol dm^{-3} to reach the end point.

(i) Calculate the concentration of acetic acid in solution **Z**.

(ii) Calculate the pH value of solution **Z**. Acid dissociation constant of acetic acid (K_a) at the temperature at which the experiment was carried out is 1.80×10^{-5} mol dm^{-3}.

(iii) To another portion (100.00 cm^3) of solution **Z**, 0.200 g of pure solid NaOH was added and dissolved. Calculate the pH value of this solution assuming that the volume and the temperature of the solution remain unchanged.
[Relative atomic mass: Na = 23, O = 16, H = 1]

[see page seven

Do not write in this column.

(iv) Does the solution described in (iii) above behave as a buffer solution? Explain your answer.

.....

.....

(v) In a separate experiment, 0.800 g of pure solid NaOH was dissolved in a 100.00 cm^3 volume of solution **Z**. Does this solution behave as a buffer solution? Explain your answer using a suitable calculation. Assume that the volume and temperature of the solution remain unchanged.

.....

.....

.....

.....

100

(50 *marks*)

4. (*a*) **A**, **B** and **C** are structural isomers having the molecular formula $C_5H_{11}Br$. Of these three isomers, only **B** exhibits optical isomerism. **A** and **C** are positional isomers of each other. When **A**, **B** and **C** were reacted separately with aqueous NaOH, compounds **D**, **E** and **F** having the molecular formula $C_5H_{12}O$ were formed respectively. **D**, **E** and **F** were treated separately with PCC. **F** did not react with PCC. **D** and **E** reacted with PCC and gave **G** and **H** respectively. Both compounds **G** and **H** gave coloured precipitates with 2,4–dinitrophenylhydrazine (2,4–DNP) and silver mirrors with ammonical $AgNO_3$.

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

A

B

C

D

E

F

G

H

(56 *marks*)

[see page eight

Do not write in this column.

(*b*) Draw the structures of the products **I**, **J**, **K** and **L** of the following reactions, in the given boxes.

(i) $CH_3\overset{O}{\overset{\|}{C}}OCH_3$ $\xrightarrow[(2)\ H^+ / H_2O]{(1)\ CH_3MgBr\ (excess)/dry\ ether}$

I

(ii) $C_2H_5C \equiv CH$ $\xrightarrow{dilute\ H_2SO_4 / Hg^{2+}}$

J

(iii) $CH_3\overset{O}{\overset{\|}{C}}CH_3$ $\xrightarrow[(2)\ H^+ / \Delta]{(1)\ aqueous\ NaOH}$

K

(iv)  $\xrightarrow{KI}$

L

(24 *marks*)

(*c*) Give the mechanism and the structure of the product formed for the reaction between $CH_3CH = CHCH_3$ and Br_2/CCl_4.

(20 *marks*)

100

* *

[*see page nine*

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கல்விப் பொதுத் தராதரப் பத்திர (உயர் தர)ப் பரீட்சை, 2021(2022)
General Certificate of Education (Adv. Level) Examination, 2021(2022)

රසායන විද්‍යාව	II
இரசாயனவியல்	II
Chemistry	**II**

02 E II

* Universal gas constant $R = 8.314\ J\ K^{-1}\ mol^{-1}$

* Avogadro constant $N_A = 6.022 \times 10^{23}\ mol^{-1}$

PART B — ESSAY

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

5. (*a*) (i) A gas mixture containing CH_4, C_2H_6 and excess O_2 was introduced into an evacuated closed rigid container. The volume of the container was $8.314 \times 10^{-3}\ m^3$. The pressure of the container at 400 K was 4.80×10^6 Pa. Calculate the total number of moles of gases in the container. Assume that all the gases behave ideally and that there is no reaction at this temperature.

(ii) All the hydrocarbons in the container were completely combusted by increasing the temperature of the container to 800 K. The pressure of the container after the combustion reactions at 800 K was 1.00×10^7 Pa. Calculate the total number of moles of gases in the container after combustion. Assume that H_2O is present as a gas under these conditions.

(iii) Write balanced chemical equations (giving physical states, at 800 K) for the combustion reactions of the gases given below.

I. $CH_4(g)$

II. $C_2H_6(g)$

(iv) Only one of the two hydrocarbons above contributes to the change in the number of moles of gases before and after combustion.
Calculate the number of moles of this hydrocarbon initially introduced into the container.

(v) The container was then cooled to 300 K and the water was removed. Then the pressure of the container was 2.10×10^6 Pa.
Calculate the following.

I. Total number of moles of H_2O produced

II. Number of moles of H_2O produced from the combustion of C_2H_6

III. Number of moles of H_2O produced from the combustion of CH_4

IV. Number of moles of O_2 introduced initially into the container **(75 *marks*)**

(*b*) (i) Using a **thermochemical cycle** and the data given, calculate the standard enthalpy change for the reaction given below.

$$4\ CH_4(g) + O_2(g) \longrightarrow 2\ C_2H_6(g) + 2\ H_2O(g)$$

	$\left(\Delta H_f^\circ\right)$ (kJ mol^{-1})	S° (J mol^{-1} K^{-1})
$CH_4(g)$	–74.8	186.3
$C_2H_6(g)$	–84.7	229.6
$CO_2(g)$	–393.5	213.7
$H_2O(g)$	–214.8	188.8
C(s), graphite	0.0	5.7
$O_2(g)$	0.0	205.1
$H_2(g)$	0.0	130.7

[*see page ten*

(ii) Calculate the standard entropy change for the reaction in (*b*)(i) above.

(iii) Calculate the standard Gibbs energy change (ΔG°) for the reaction in (*b*)(i) above at 500 K.

(iv) State, giving reasons, whether increase in temperature favours the reaction in (*b*)(i) above. Assume that the enthalpy change and entropy change are independent of temperature.

(75 *marks*)

6. (*a*) (i) Consider the reversible reaction $\mathbf{a\,A(aq) \rightleftharpoons b\,B(aq) + c\,C(aq)}$ that occurs in the aqueous medium. Considering that both forward and reverse steps are elementary reactions, write expressions for the rate of the forward reaction (R_1) and the rate of the reverse reaction (R_2). Rate constants for the forward reaction and the reverse reaction are k_1 and k_2, respectively.

(ii) Write the relationship between R_1 and R_2 at equilibrium.

(iii) Write down the expression for equilibrium constant K_C. Also give the relationship between K_C, k_1 and k_2.

(iv) To study the above equilibrium, three experiments were carried out at a constant temperature. In these experiments, different amounts of A, B and C were mixed, and the system was allowed to reach equilibrium. The following data were obtained at equilibrium.

Experiment Number	Concentration at equilibrium (mol dm^{-3})		
	[A]	[B]	[C]
1	1.0×10^{-1}	1.0×10^{-2}	1.0×10^{-3}
2	1.0×10^{-2}	1.0×10^{-3}	1.0×10^{-3}
3	1.0×10^{-2}	1.0×10^{-2}	1.0×10^{-5}

I. Obtain three relationships by substituting the concentrations of A, B and C given in the table for experiments 1, 2 and 3 in the equilibrium constant expression written in (*a*)(iii) above.

II. Prove that a = b = 2c using these relationships.

III. Using the smallest integers for the stoichiometric coefficients a, b and c, calculate the value of the equilibrium constant, K_C of the above reaction.

(80 *marks*)

(*b*) Consider the reaction, $\mathbf{p\,P(g) \rightleftharpoons q\,Q(g) + r\,R(g)}$ that takes place in gas phase.

(i) The enthalpy change and activation energy of the forward reaction, $\mathbf{p\,P(g) \longrightarrow q\,Q(g) + r\,R(g)}$ are 50.0 kJ mol^{-1} and 90.0 kJ mol^{-1}, respectively. Draw the labelled energy diagram (the graph of energy vs reaction coordinate) for this reaction. Show the positions of P, Q and R by marking them on the energy diagram. Also, mark the position of the activated complex as 'activated complex' on it.

(ii) Calculate the activation energy for the reverse reaction.

(iii) Explain the effect of increasing temperature on the equilibrium constant of this reaction.

(iv) Explain the effect of a catalyst

I. on the rates of forward and reverse reactions.

II. on the equilibrium constant.

(70 *marks*)

[*see page eleven*

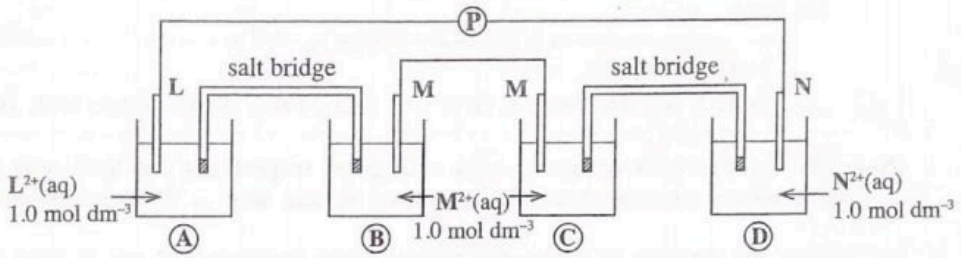
7. (*a*) You are provided with the three metal rods **L**, **M**, **N** and the three solutions L^{2+} (1.0 mol dm^{-3}), M^{2+} (1.0 mol dm^{-3}), N^{2+} (1.0 mol dm^{-3}). When the metal **N** is dipped in the solution of M^{2+} ions, M^{2+} is reduced to **M**, whereas when **N** is dipped in the solution of L^{2+} ions, L^{2+} does not get reduced to **L**.

(i) Giving reasons arrange the three metals, **L**, **M** and **N** in the increasing order of their reducing ability.

(ii) Electromotive forces of the two electrochemical cells prepared using $L^{2+}(aq)/\ L(s)$ electrode and each of the other two electrodes are +0.30 V and +1.10 V. Using this information and your answer to (i) above, calculate $E^{\circ}_{M^{2+}(aq)/M(s)}$ and $E^{\circ}_{N^{2+}(aq)/N(s)}$.

$\left(E^{\circ}_{L^{2+}(aq)/L(s)} = -0.80\ V\right)$

(iii) You are provided with the following arrangement, where a potentiometer (**P**) is connected between the metal rods **L** and **N**.



I. Calculate the potentiometer reading.

II. Write the electrode reactions that occur at each of the electrodes Ⓐ, Ⓑ, Ⓒ and Ⓓ separately when the potentiometer is removed and **L** and **N** are connected by a conductor.

(75 *marks*)

(*b*) The following questions are based on the element manganese (Mn).

(i) Write the complete electronic configuration of Mn.

(ii) Write **three** common oxidation states of Mn.

(iii) When $MnSO_4 \cdot H_2O$ is dissolved in water, solution **P** is obtained.

I. State the colour of solution **P**.

II. Give the chemical formula and the IUPAC name of the species responsible for this colour.

(iv) What would you observe when

I. dilute NaOH is added to solution **P**?

II. the mixture from (iv)(I) above is exposed to air?

III. conc. HCl is added to the mixture from (iv)(I) above?

(v) Give the chemical formulae of **five** oxides of Mn, and write the oxidation state of Mn in each. State the nature of each of the oxides as basic, weakly basic, amphoteric, weakly acidic, acidic.

(vi) Give the chemical formula of the most common oxoanion of Mn.

(vii) Give balanced ionic half equations to indicate how the oxoanion given by you in (vi) above behaves as an oxidizing agent in acidic and basic media.

(viii) State **one** use of $MnSO_4$ in the analysis of water quality parameters.

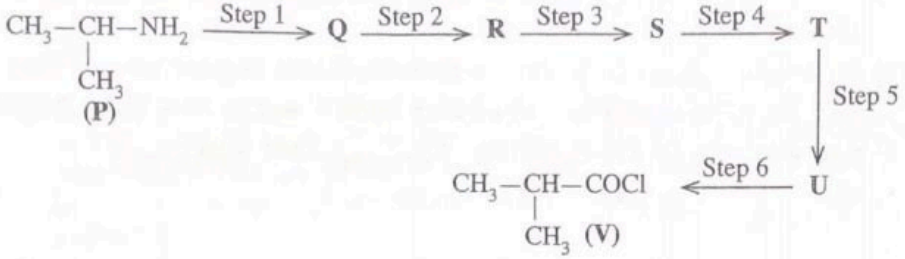
(75 *marks*)

[*see page twelve*

PART C — ESSAY

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

8. (*a*) Compound **P** was converted to compound **V** using the reaction scheme given below.



(i) Complete the above reaction sequence by drawing the structures of compounds **Q**, **R**, **S**, **T** and **U** and writing the reagents for steps 1–6 selected only from those given in the list below.

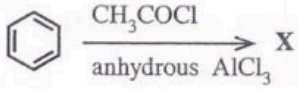
List of reagents
HCHO, Mg/dry ether, $H^+/K_2Cr_2O_7$, PCl_5, PBr_3, $NaNO_2$/dilute HCl, H^+/H_2O

(**Note:** The reaction of a compound with a Grignard reagent and the hydrolysis of the resultant magnesium alkoxide should be considered as **one step** in the above reaction sequence.)

(ii) Draw the structure of the product formed when compounds **P** and **V** react with each other. (**65** ***marks***)

(*b*) (i) Propose a method to prepare a mixture of *o*-nitrobenzoic acid and *p*-nitrobenzoic acid from benzene using not more than **three** (03) steps.

(ii) Give the structure of the product **X** and the mechanism of the following reaction.



(**65** ***marks***)

(*c*) The structure of benzene is represented as the resonance hybrid of the following two hypothetical six membered cyclic structures (cyclohexatriene).

Using the standard enthalpy data of hydrogenation given below, show that benzene is more stable than hypothetical 'cyclohexatriene'.

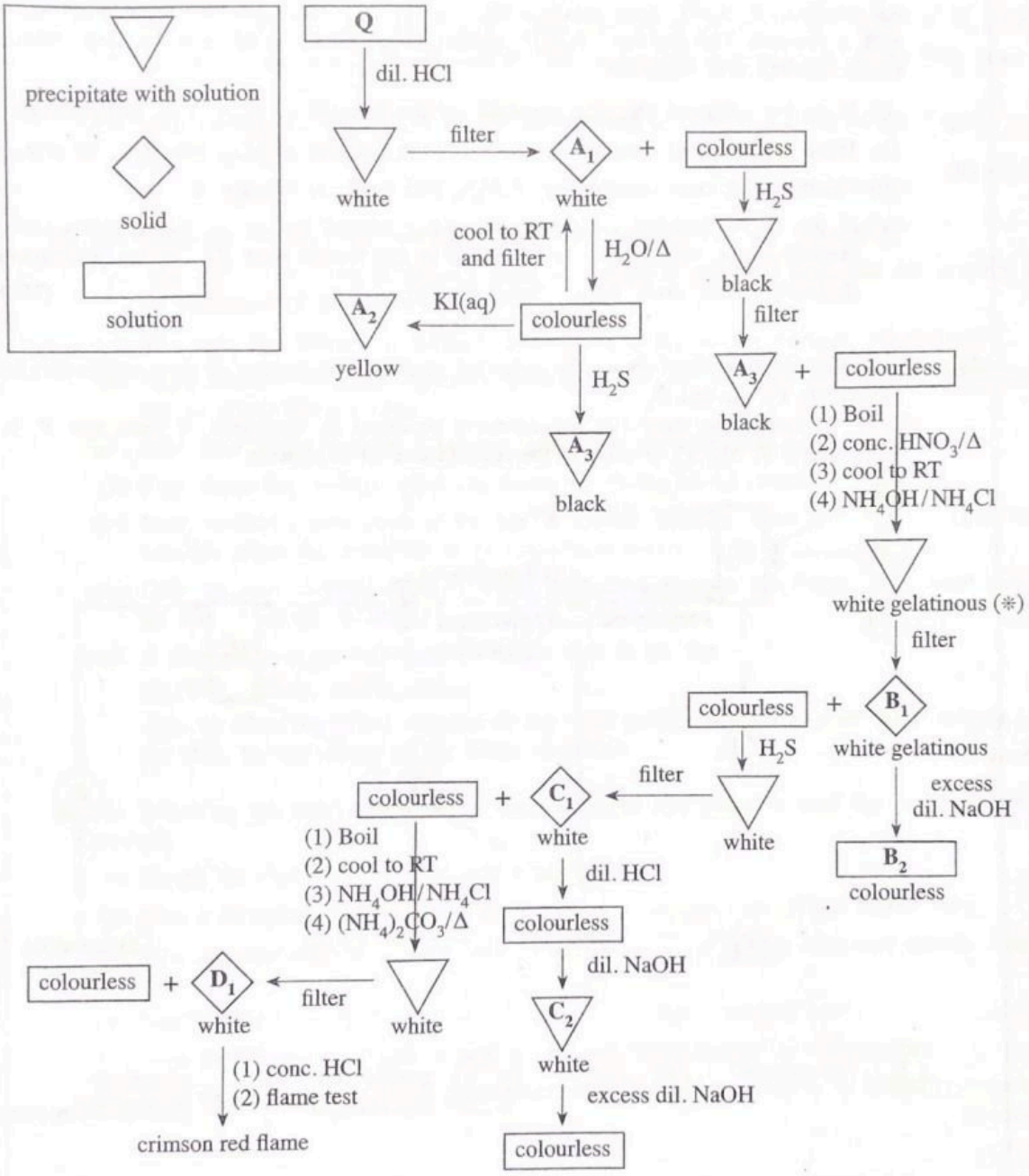
$\Delta H^\circ = -120$ kJ mol^{-1}

Benzene + $3\,H_2$ ⟶ cyclohexane $\Delta H^\circ = -208$ kJ mol^{-1}

(**20** ***marks***)

[*see page thirteen*

9. (*a*) The following question is based on the qualitative analysis of cations.
An aqueous solution **Q** contains **four** cations of metals **A**, **B**, **C** and **D**. **Q** is subjected to the reactions given in the scheme below.
The symbols given in the box are used to represent precipitates with solutions, solids and solutions.
(**Note**: RT – room temperature)



(i) $\mathbf{A_1}$, $\mathbf{A_2}$, $\mathbf{A_3}$, $\mathbf{B_1}$, $\mathbf{B_2}$, $\mathbf{C_1}$, $\mathbf{C_2}$, and $\mathbf{D_1}$ are compounds/species of the four cations **A**, **B**, **C**, and **D**. Identify $\mathbf{A_1}$, $\mathbf{A_2}$, $\mathbf{A_3}$, $\mathbf{B_1}$, $\mathbf{B_2}$, $\mathbf{C_1}$, $\mathbf{C_2}$, and $\mathbf{D_1}$.
(**Note**: Write **only** chemical formulae. Chemical equations and reasons are **not** required.)

(ii) Give a reason for the use of NH_4OH/NH_4Cl as a reagent when obtaining the white gelatinous precipitate (*). **(75 *marks*)**

[*see page fourteen*

(*b*) A mixture **X** contains only aluminium sulfide (Al_2S_3) and ferric sulfide (Fe_2S_3). The following procedure was carried out to calculate the mass percentages of Al_2S_3 and Fe_2S_3 in **X**.

When a mass **m** of mixture **X** was heated at high temperature under H_2 gas, Al_2S_3 remains unchanged but Fe_2S_3 was converted to iron (Fe) metal. The final mass obtained was 0.824 g.

When another mass **m** of mixture **X** was heated at high temperature in air, both Al_2S_3 and Fe_2S_3 decomposed, giving SO_2 gas. This SO_2 gas was bubbled through a solution of H_2O_2 and oxidized to H_2SO_4 acid, which is the only product. When this entire solution was titrated with a standard 1.00 mol dm^{-3} NaOH solution in the presence of phenolpthalein indicator, the burette reading was 36.00 cm^3.

(i) Write the balanced chemical equation for the reaction of Fe_2S_3 with hydrogen gas.

(ii) Write the balanced chemical equation for the reaction of SO_2 with H_2O_2 to give H_2SO_4.

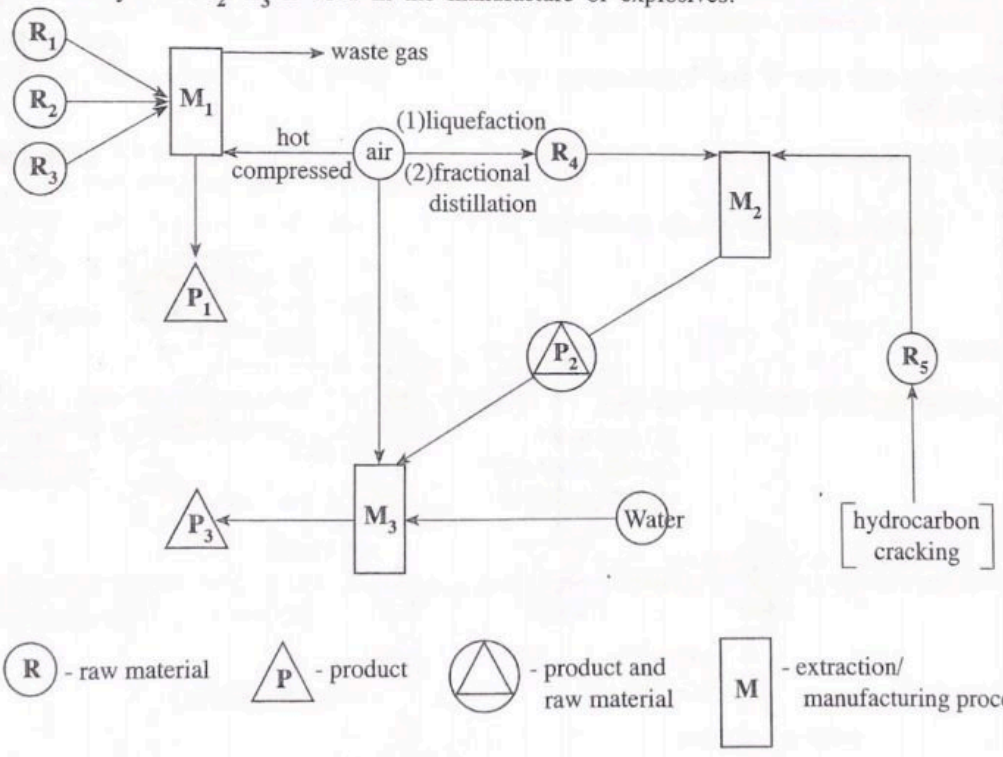
(iii) Calculate the mass percentages of Al_2S_3 and Fe_2S_3 in mixture **X**.

(iv) If the above titration is carried out using methyl orange as the indicator instead of phenolpthalein, would there be a change in the burette reading? Explain your answer.

(Relative atomic mass: Al=27, S=32, Fe=56) **(75 *marks*)**

10. (*a*) The following flow chart shows the industrial extraction/production of three important elements/ compounds $\mathbf{P_1}$, $\mathbf{P_2}$ and $\mathbf{P_3}$.

There is evidence to show that our ancestors produced $\mathbf{P_1}$ thousands of years ago. $\mathbf{P_1}$ is used as a catalyst in $\mathbf{M_2}$. $\mathbf{P_3}$ is used in the manufacture of explosives.



R - raw material; P - product; - product and raw material; M - extraction/ manufacturing process

(i) Name the manufacturing processes $\mathbf{M_2}$ and $\mathbf{M_3}$. (e.g.: Manufacture of Na_2CO_3 is named as Solvay process.)

(ii) Identify the process $\mathbf{M_1}$ and name the main constituent of its waste gas.

(iii) Give the common names of the raw materials $\mathbf{R_1}$, $\mathbf{R_2}$ and $\mathbf{R_3}$ used in $\mathbf{M_1}$.

(**Note**: $\mathbf{R_1}$ functions as a reducing agent as well as an energy source in $\mathbf{M_1}$; $\mathbf{R_2}$ is a naturally occurring source which can be used to obtain $\mathbf{P_1}$.)

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(iv) Write a balanced chemical equation for the role of $\mathbf{R_1}$ as a reducing agent in $\mathbf{M_1}$ process.

(v) Identify $\mathbf{R_4}$ and $\mathbf{R_5}$.

(vi) Give balanced chemical equations for reactions taking place in the processes $\mathbf{M_1}$, $\mathbf{M_2}$ and $\mathbf{M_3}$. Appropriate conditions (temperature, pressure, catalysts, etc.) must be stated as required.
(**Note**: For the $\mathbf{M_1}$ process, give only the reactions showing the conversion of $\mathbf{R_2}$ to $\mathbf{P_1}$.)

(vii) Give **two** uses each of $\mathbf{P_1}$, $\mathbf{P_2}$ and $\mathbf{P_3}$ (**other than** what is indicated in the flow chart or given in the question).

(viii) State whether the $\mathbf{M_2}$ process would be favoured at very high temperatures. Explain your answer using ΔH, ΔS and ΔG.

(50 *marks*)

(*b*) The following questions are based on photochemical smog and water pollution.

(i) State the major types of gaseous chemical pollutants and conditions that are required for the formation of photochemical smog.

(ii) State why the strength of photochemical smog is low in the morning and evening.

(iii) Using balanced chemical equations, explain how ozone is formed in the lower atmosphere due to photochemical smog.

(iv) State **four** major products (excluding ozone) of photochemical smog.

(v) State **three** free radicals produced during the formation of photochemical smog.

(vi) Many countries now promote the use of electric vehicles. State how the use of electric vehicles affect the formation of photochemical smog.

(vii) State an environmental problem, other than photochemical smog, that could ease due to the use of electric vehicles.

(viii) A ship carrying the following chemicals sank in the sea.

Na_2HPO_4, HNO_3, $Pb(CH_3COO)_2$

State an effect from each chemical on the water quality parameters of the water surrounding the ship, by the release of the above chemicals.

(50 *marks*)

(*c*) The following questions are based on natural rubber and additives used for polymer related products.

(i) Sketch the repeating unit of natural rubber.

(ii) Give a compound that can be used to prevent coagulation of natural rubber latex.

(iii) State a compound that can be used to coagulate natural rubber latex and explain how it acts.

(iv) Briefly state how the 'vulcanization' of natural rubber is carried out.

(v) State **two** types of substances used to increase the efficiency of vulcanization.

(vi) Give **three** properties, which can be enhanced by adding additives to polymer products.

(50 *marks*)

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