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. .....

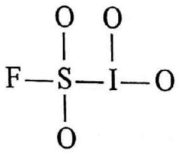
(vi) In nitrous acid (HNO_2) the two N—O bonds are equal in length. .....

(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*)

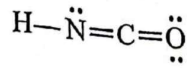
(*b*) (i) Draw the **most** acceptable Lewis dot-dash structure for the molecule ISO_4F. Its skeleton is given below.



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

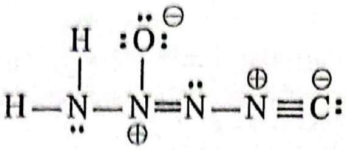
S ....., I .....

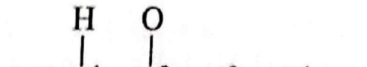
(iii) An acceptable (stable) Lewis dot-dash structure for the HNCO molecule is given below. Draw **two** more Lewis dot-dash structures (resonance structures) for this molecule and indicate their stabilities relative to the structure given by writing **stable** or **less stable** or **unstable** under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



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(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. $H—N^1$ H ..... N^1.....

II. $N^1—N^2$ N^1..... N^2.....

III. $N^2—O$ N^2..... O .....

IV. $N^2—N^3$ N^2..... N^3.....

V. $N^3—N^4$ N^3..... N^4.....

VI. $N^4—C$ N^4..... C .....

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

I. $N^2—N^3$ N^2..... N^3.....

II. $N^4—C$ N^4..... C .....

N^4..... C .....

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

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

(viii) Arrange the atoms N^1, N^2, N^3 and N^4 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^+, Mg^{2+}, Ca^{2+}, Al^{3+}, Cl^-, S^{2-} (ionic radius)

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

(12 *marks*)

100

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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

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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 $H_2CO_3(aq)$ acid are,

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

(i) Write the equilibrium reactions for the first and second dissociations of $H_2CO_3(aq)$.

(ii) Considering the first dissociation, calculate the concentrations of $H_3O^+(aq)$ and $HCO_3^-(aq)$ in 0.05 mol dm^{-3} $H_2CO_3(aq)$ solution at 25 °C.

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(iii) Considering the second dissociation, show that $\left[CO_3^{2-}(aq)\right]$ 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 mol dm^{-3} $Al^{3+}(aq)$ ions and 0.01 mol dm^{-3} $Ag^{+}(aq)$ ions at temperature 25 °C. To 1.0 dm^3 of this solution, a concentrated solution of $PO_4^{3-}(aq)$ ions was added dropwise with continuous stirring.

At temperature 25 °C,

$K_{sp}(AlPO_4) = 1.3 \times 10^{-20}$ mol^2 dm^{-6} and $K_{sp}(Ag_3PO_4) = 8.1 \times 10^{-12}$ mol^4 dm^{-12}.

(i) Neglecting any volume change that may occur when the $PO_4^{3-}(aq)$ 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.

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

(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 n write in thi colun

- 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 hydrohcloric 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

[see page nine

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இலங்கைப் பரீட்சைத் திணைக்களம் இலங்கைப் பரீட்சைத் திணைக்களம்
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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 $R = 8.314\ J\ K^{-1}\ mol^{-1}$
❊ 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*) A mixture of NO(g) and $O_2(g)$ 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*.

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$$

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 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,

$$2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$$

at the temperature determined in (iii) above.

(70 *marks*)

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

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

$$\frac{1}{2}N_2(g) + O_2(g) \rightarrow NO_2(g)\ \ \Delta H^\circ = 33\ kJ\ mol^{-1}$$

$$4NO_2(g) + O_2(g) \rightarrow 2N_2O_5(g)\ \ \Delta H^\circ = -102\ kJ\ mol^{-1}$$

(i) Calculate ΔH° at temperature 298 K for the reaction,

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

(ii) Calculate $\Delta H_f^\circ(N_2O_5(g))$ at temperature 298 K.

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

I. the sign of $\Delta S_f^\circ(N_2O_5(g))$

II. spontaneity of the reaction for the formation of $N_2O_5(g)$ from $N_2(g)$ and $O_2(g)$

(80 *marks*)

[*see page ten*

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** $\left(\overline{C_B^2}\right)$ at temperature $T = 300\frac{M_B}{M_A}$, is equal to the mean square speed of gas **A** $\left(\overline{C_A^2}\right)$ 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:	$A \longrightarrow P_1$	r_A	k_A	$(t_{1/2})_A$
②:	$B \longrightarrow P_2$	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 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.

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

(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.

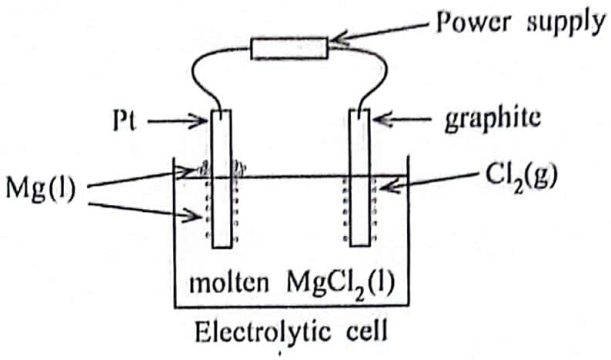
(35 *marks*)

[*see page eleven*

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.

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

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



Electrolytic cell

(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 $MgCl_2(l)$ is used instead of $MgCl_2(s)$ in this extraction process.

II. A solution of $MgCl_2(aq)$ cannot be used in this extraction process.

(v) If a 5.37 A current is passed through this cell for one hour and the $Cl_2(g)$ formed is collected at temperature 300 K and pressure 1 atm ($\sim 1.0 \times 10^5$ Pa), calculate the volume of $Cl_2(g)$ produced in dm^3. (1 F = 96 500 C)

(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.

Co^{3+}, K^+, NH_3, SO_4^{2-}, NO_2^-, Cl^-

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 $BaCl_2(aq)$ 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 $AgNO_3(aq)$, 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 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 $AgNO_3(aq)$ 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.

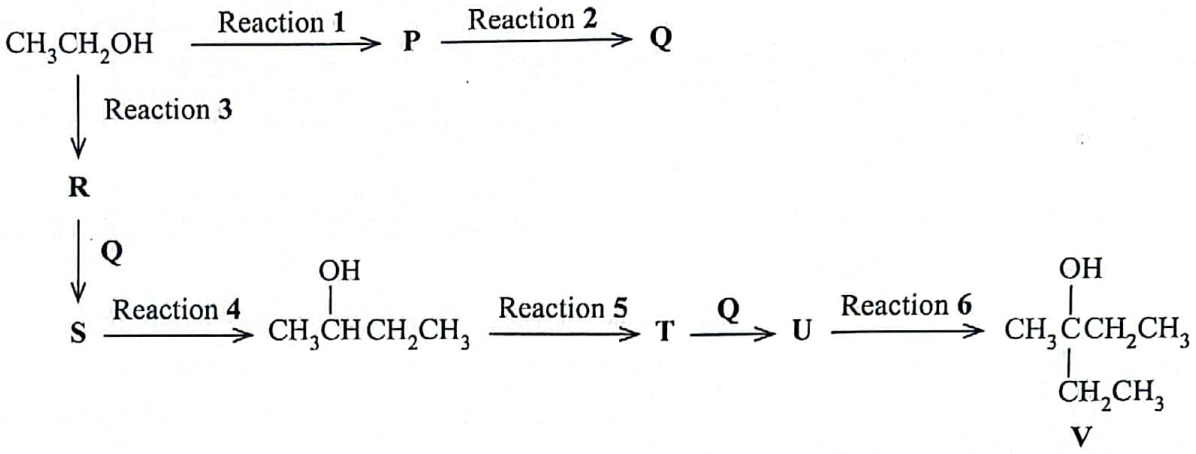
(75 *marks*)

[*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.

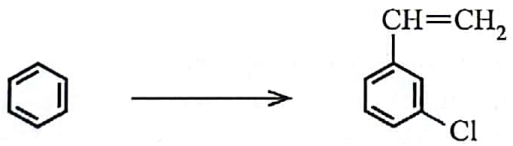


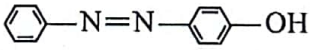
Complete the above reaction scheme by drawing the structures of compounds **P**, **Q**, **R**, **S**, **T** and **U** and writing the appropriate reagents for reactions **1** - **6** selected **only** from those given in the list below.

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  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*)

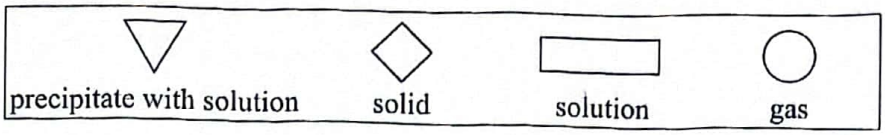
[*see page thirteen*

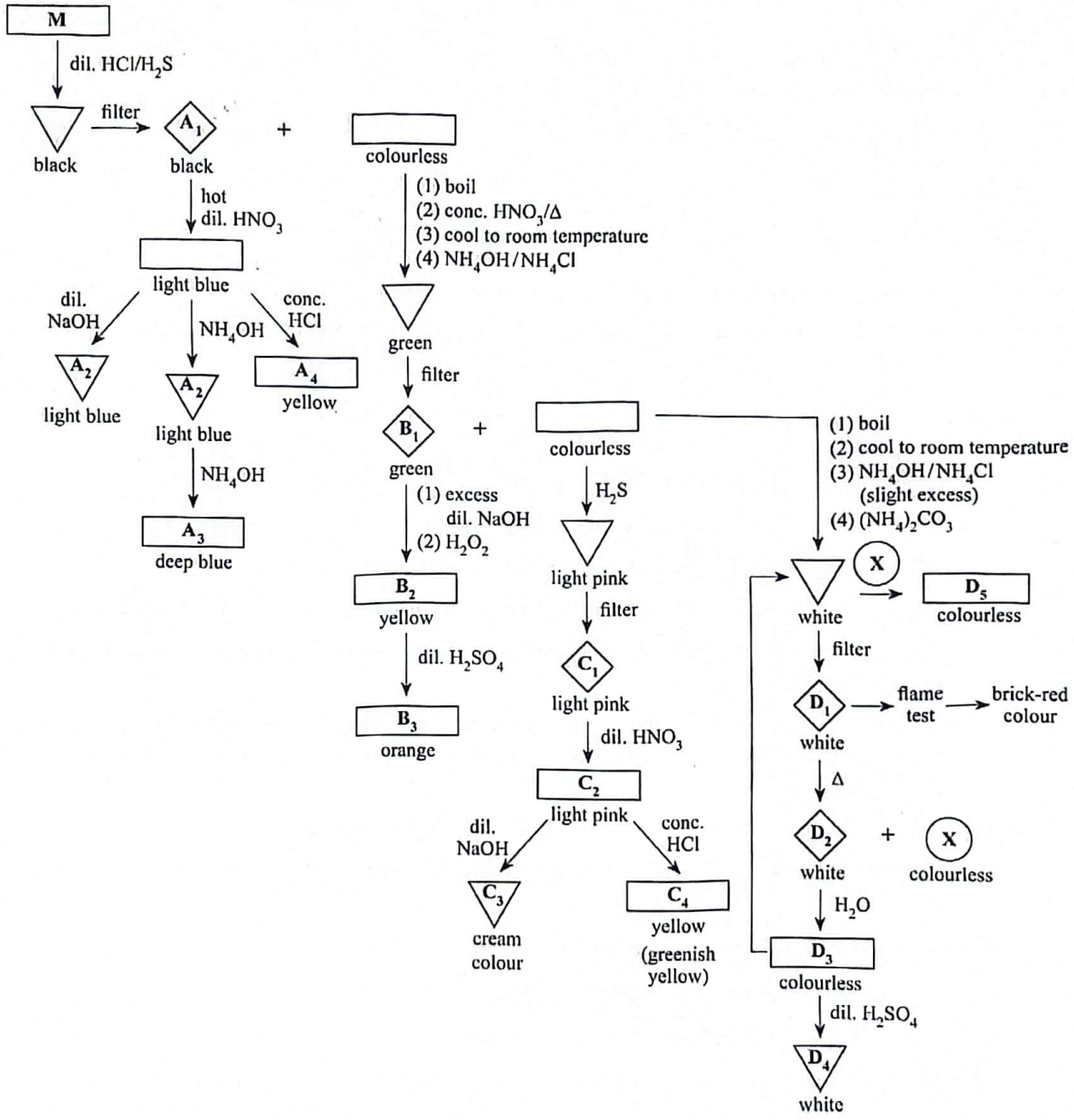
9. (*a*) The following question is based on the qualitative analysis of cations.

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.





A_1–A_4, B_1–B_3, C_1–C_4 and D_1–D_5 are compounds/species of the four cations of metals **A**, **B**, **C** and **D**. **X** is a gas.

Identify A_1, A_2, A_3, A_4, B_1, B_2, B_3, C_1, C_2, C_3, C_4, D_1, D_2, D_3, D_4, D_5, 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.

$$4FeS_2(s) + 15O_2(g) + 14H_2O(l) \xrightarrow{\text{soil microbes}} 4Fe(OH)_3(s) + 8H_2SO_4(aq)$$

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.

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

(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.

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

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

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

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

(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.

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

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

(50 *marks*)

(*b*) Briefly explain each of the following statements.

(i) Agriculture contributes to global warming.

(ii) Iron extraction contributes to global warming.

(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.

(50 *marks*)

[*see page fifteen*

(*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*)

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[*see page sixteen*