SECTION A (40 MARKS)

Answer **ALL** questions

Question 1

a) **For each question, there are four alternatives A, B, C and D. Choose the correct alternative and circle it. DO NOT circle more than ONE alternative. If there is more than ONE circled alternative, NO score shall be awarded.** **[25]**

i. The table below represents the aqueous solutions of a non-electrolyte and their corresponding concentrations expressed in different units.

Solution	Concentration
X	0.5 N
Y	0.5 M
Z	0.5 m

The statement that is true regarding the boiling point of the three solutions is

A boiling points of X and Y are same.

B boiling points of all the solutions are same.

C boiling point of Y is slightly higher than Z.

D boiling point of X is slightly higher than Y.

ii. A dilute solution contains $[H_3O^+]$ = 0.00025 M at 25°C. The pOH of the solution at the same temperature is

A 3.6.

B 0.25.

C 10.4.

D 13.75.

iii. A galvanic cell is represented as $Ni(s)|Ni^{2+}(aq)\ //Ag^{2+}(aq)/Ag(s)$.

Which of the following conditions enable the generation of the highest EMF of the given cell?

A low concentration of silver ions

B high concentration of nickel ions

C low concentration of nickel ions

D same concentration of ions in both the half-cells

iv. Which statement correctly describes the activation energy of a reversible exothermic reaction?

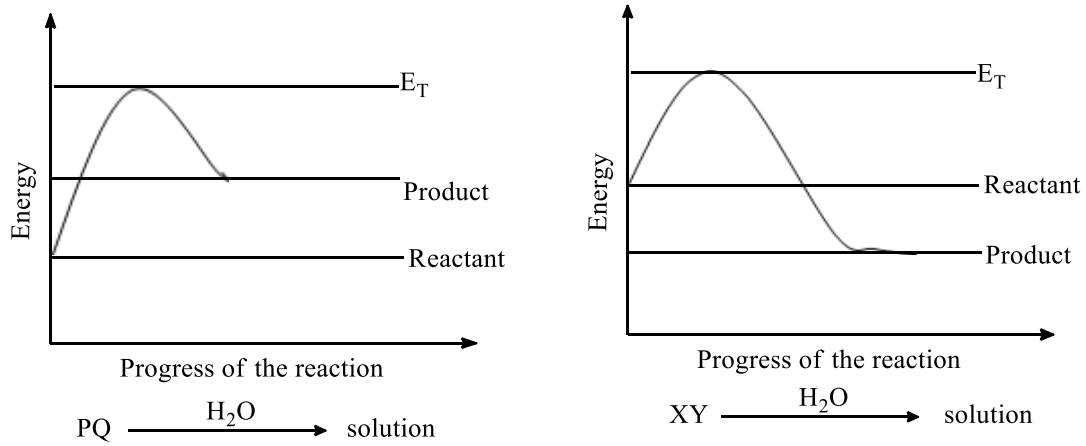
A E_a (forward) < E_a (backward)

B E_a (forward) > E_a (backward)

C E_a (forward) = E_a (backward)

D E_a (forward) = - E_a (backward)

v. A teacher provided a graphical representation of the reactions of two compounds, 'PQ' and 'XY' and he asked the students to study the graphs to decide on the compound required to design a cold pack.



The compound that is suitable for designing a cold pack is

A PQ.

B XY.

C Both PQ and XY.

D Neither of the compounds can be used.

vi. Acetaldehyde is used for the silvering of mirrors. This is possible because of its tendency to undergo

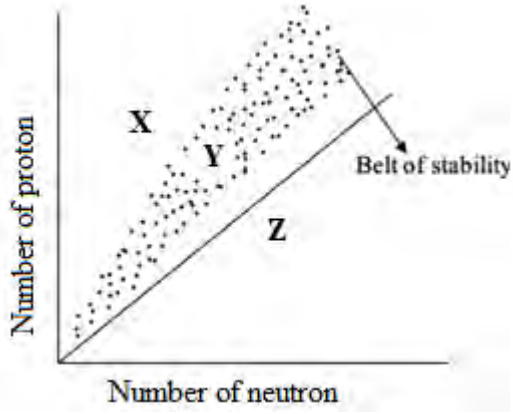
A addition reaction.

B reduction reaction.

C oxidation reaction.

D substitution reaction.

vii. The chart given below can be used to study the nature of isotopes.



Which of the isotopes undergoes the electron-capture process?

A X

B Y

C Z

D X, Y and Z

viii. EDTA can be used as a reagent to estimate water hardness as it tends to form stable complex ions with calcium and magnesium. EDTA has a denticity of 6 and an ionic charge of -4. What is the formula of the complex ion formed when it combines with magnesium ion?

A $[Mg(EDTA)]^{2-}$

B $[Mg(EDTA)_2]^{6-}$

C $[Mg(EDTA)_6]^{4-}$

D $[Mg(EDTA)]^{2+}$

ix. The relative strength of carboxylic acids is given below:

$HCOOH > CH_3COOH > CH_3CH_2COOH$

If you were to compare the acidity of butyric acid ($CH_3CH_2CH_2COOH$) with that of carboxylic acids, which statement will help you make the right comparison?

A bigger alkyl group exerts high -I effect

B bigger alkyl group exerts high +I effect

C bigger alkyl group weakens the O-H bond

D bigger alkyl group produces stable carboxylate ions

x. Production of soap and biodiesel follow similar processes which are termed as saponification and transesterification respectively.

I by-product of both processes is glycerol

II presence of water in the oil affects transesterification

III transesterification process uses short-chain alcohol

IV saponification process can be catalyzed by both an acid and a base

Which of the above statements are true for both the processes?

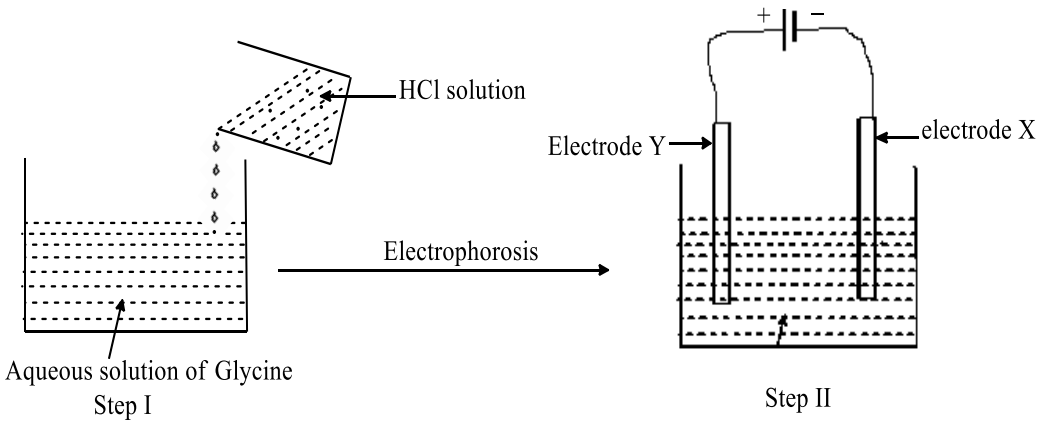
A I only

B I and III

C I, II and III

D I, III and IV

xi. Rinchen conducted an experiment to study the behaviour of glycine in a different chemical environment. The steps of the experiment are given below:



Which of the following explains the nature of glycine in the solution in step II?

A Exist as $H_2N - CH_2 – COO^-$ and migrate towards Y

B Exist as $H_3N^+ - CH_2 – COO^-$ and migrate towards X

C Exist as $H_3N+ - CH_2 – COOH$ and migrate towards X

D Exist as $H_2N - CH_2 – COOH$ and remains in the solution

xii. The preparation of amines from alkyl halide and ammonia requires the careful approximation of the reactants used to get the desired product. Which amine is likely to form, if excess alkyl halide is used during the preparation?

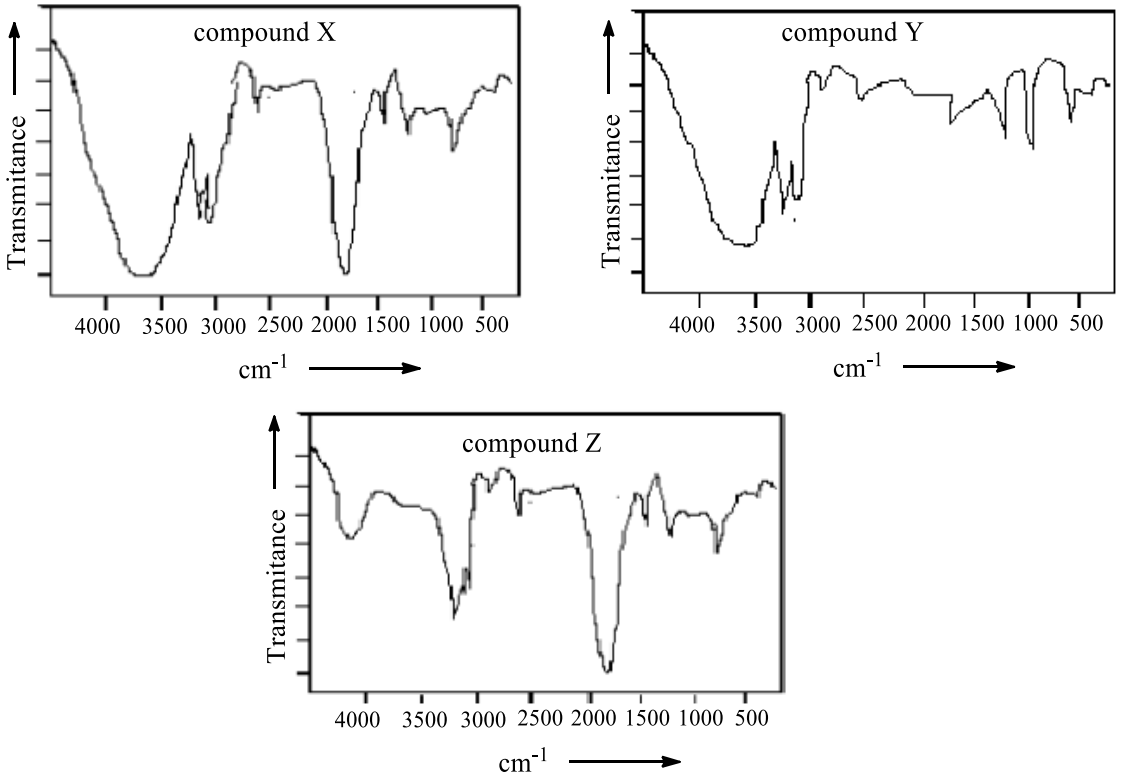
A CH_3NH_2

B $(CH_3)2NH$

C $(CH_3)3N$

D $[(CH_3)4N]^+ I^-$

xiii. Following are the IR spectra of three compounds X, Y and Z.



Based on the above IR spectra, the compounds X, Y and Z respectively could be

A ethanol, acetone and ethanoic acid.

B ethanoic acid , propanol and acetone.

C acetaldehyde, ethanoic acid and ethanol.

D formic acid, acetone and propionic acid.

xiv. The car engine combusts the fuel using atmospheric oxygen to produce water and carbon dioxide. All of the following conditions affect the combustion reaction rate in the car engine **EXCEPT**

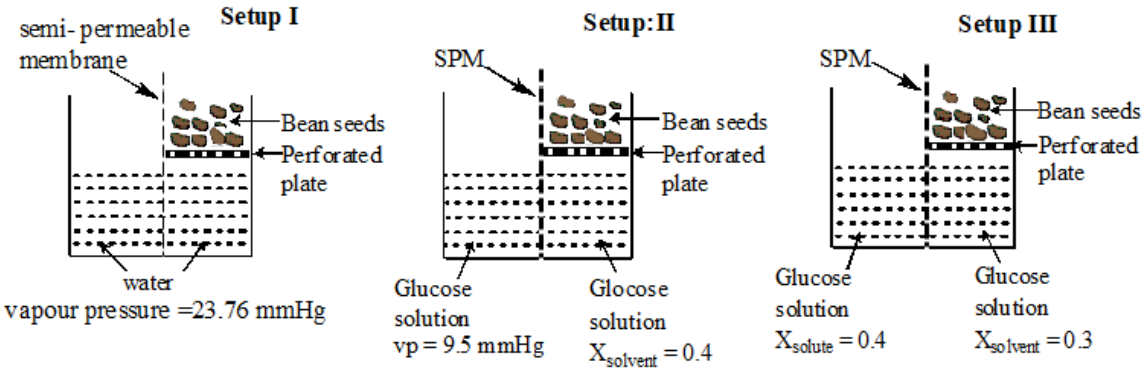
A temperature.

B nature of fuel.

C oxygen supply.

D volume of fuel.

xv. The following setups are used to study and compare the osmotic pressure of solutions.



In which of the above setups, do bean seeds get soaked and change their size?

A setup I

B setup II

C setup III

D in all of the setups

xvi. A half-cell of a certain electrode is coupled with a standard hydrogen electrode to measure the standard electrode potential. The EMF of the cell was found to be – 0.77 V. What was wrong with the set-up?

A The salt bridge was not properly immersed.

B Electrodes were connected to opposite terminals.

C The electrolyte in the half-cells were contaminated.

D The electrolyte used in the half-cells were not suitable.

xvii. A solution containing an equal molar concentration of ammonium hydroxide and ammonium chloride has a pH of 9.25. What changes will be evident if a small amount of HCl is added?

I dissociation with NH_4OH will be enhanced

II pH of the solution decreases

III dissociation equilibrium of NH_4Cl shifts towards left

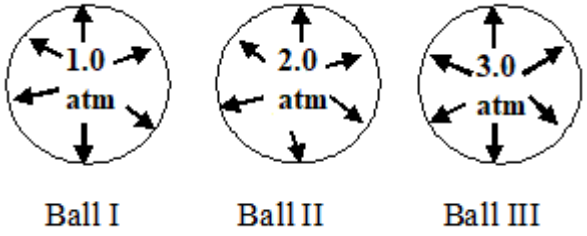
A I and II

B I and III

C II and III

D I, II and III

xviii. The pressure exerted by a gas on the walls of three balls with fixed volume is illustrated below.



Which of the following statement is most appropriate regarding work done by the gas?

A work done is maximum in Ball I

B work done is maximum in Ball II

C work done is maximum in Ball III

D work done in all the balls is zero

xix. $^{58}_{30}Zn$ decayed by the emission of an alpha particle followed by 2 beta particles. Which of the following best describes the nature of the daughter nucleus?

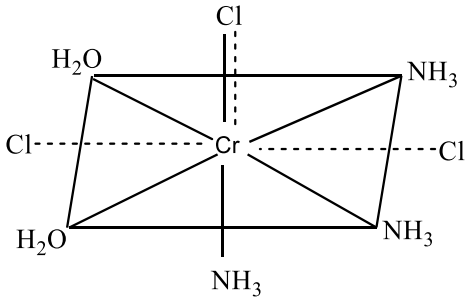
A n/p ratio is equal to 1

B has more protons than the parent nucleus

C has more neutrons than the parent nucleus

D parent and daughter elements are isotopes

xx. Study the diagram given below.



When 1 mole of the compound is treated with an aqueous solution of $AgNO_3$, how many moles of AgCl will be precipitated?

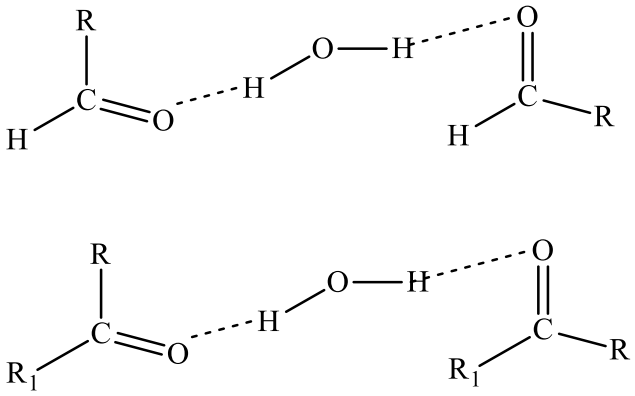
A 0

B 1

C 2

D 3

xxi. Ketones and aldehydes show similar physical properties. One of the properties is depicted in the following figures.



Which of the following properties of aldehydes and ketones is described by the figures?

A solubility

B polar nature

C boiling point

D physical state

xxii. An organic compound in NaOH forms a salt and when it is warmed in alcohol in presence of conc. H_2SO_4, it produces a sweet smell. The compound described in the statement is

A ester.
B ketone.
C aldehyde.
D carboxylic acid.

xxiii. When the NMR spectrums of benzaldehyde and benzoic acid were analysed. The spectrum would show differences in

A peak height.
B chemical shift.
C number of peaks.
D splitting of a peak.

xxiv. Aniline is less basic than methyl amine. What nature of the aryl group is depicted in the statement?

A cyclic structure
B resonance effect
C hydrophobic nature
D presence of double bonds

xxv. A chemist used mass spectrometry to identify an unknown chemical compound. The spectrum showed the presence of 6 ions. Which compound is to be discarded from the findings?

A NH_3
B CH_4
C CH_3OH
D CH_3COOH

b) Match each item under column A with the most appropriate item in column B. [5]
Write the correct alphabet under the 'answer' column in the space provided.

Answer	Column A	Column B
	i. Higher concentration of solution	a) salt bridge
	ii. Water molecule as ligand	b) ΔH = negative
	iii. Constant electrical charges in half-cell solutions	c) ketone
	iv. Concentration of reactants is unity	d) normality
	v. Spontaneity of reaction	e) solvent
	vi. Formation of the ring structure of complex compound	f) k = rate
	vii. Oxidation of secondary alcohol	g) lewis base
	viii. Oxidation of cane sugar	h) redox reaction
	ix. Number of gram equivalents in 1000 mL solution	i) oxalic acid
	x. Highest distance travelled on the TLC plate	j) chelation
		k) 1.0 molal
		l) solute

c) Fill in the blanks with the most appropriate word(s). [5]

i.	If sulphuric acid, a diprotic acid has a molarity of 2.0 then its normality will be _____.	
ii.	When a few drops of acid is added to ammonium acetate solution the pH _____.	
iii.	Hydrogen gas is produced from an acid if the reduction potential of hydrogen is _____than that of the metal.	
iv.	At a given temperature, the rate constant will _____ when the concentration of the reactant is increased.	
v.	In a adiabatic process, the change in the internal energy of the system is equal to the _____.	

vi.	In complex compounds, the secondary and primary valencies of metal respectively represent it's_____ and _____.	
vii.	The reactivity of aldehydes and ketones towards nucleophile depends on the polarity of the_____.	
viii.	Fermented alcohol on prolonged exposure to air turns sour due to the formation of _____.	
ix.	The analytical technique that is done through the study of bond vibration in the molecule is _____.	

d) Circle the appropriate letter T for True and F for False against each statement. **[5]**

i.	A solution containing more solute turns into ice faster than the solution with less solute. T / F	
ii.	The solution with a higher pK_a value is relatively acidic. T / F	
iii.	The reactivity of halogens increases with increase in their electrode potential. T / F	
iv.	The boiling point of acetyl chloride is higher than that of acetic acid. T / F	
v.	The molality of the same solution at 5^0C and 70^0C is the same. T / F	
vi.	All amino acids exist as zwitter ions at pH 7. T / F	
vii.	Dissolution of weak electrolytes increases upon decreasing concentration. T / F	
viii.	The EMF of a cell depends on the nature of the electrode used. T / F	
ix.	Amino acids form dipolar ions by accepting a proton from an acid. T / F	
x.	In the preparation of acetamide from ammonium acetate, glacial acetic acid prevents the hydrolysis of acetamide into CH_3COOH and NH_3. T /F	

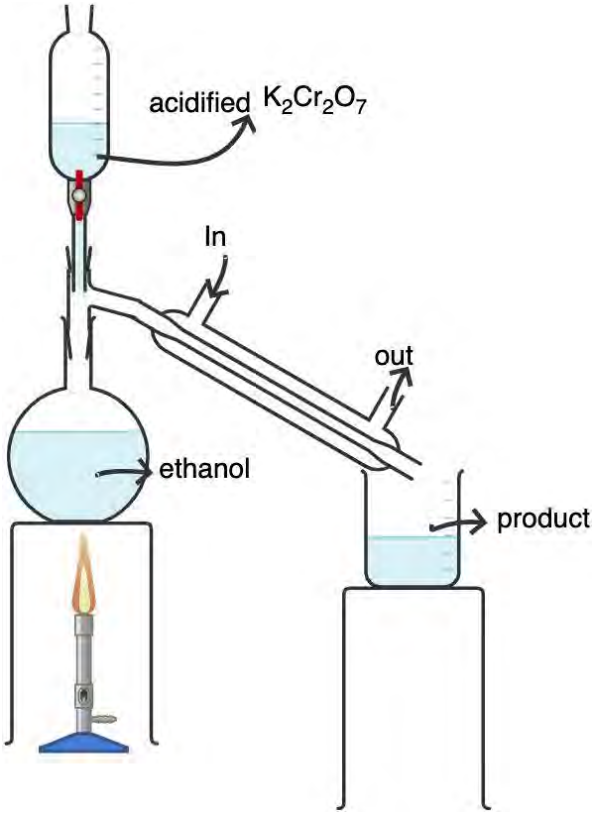
SECTION B (60 MARKS)

Attempt **ANY SIX** questions

Question 2

a) Write any **TWO** uses of oxalic acid. **[1]**

b) An experimental set for the preparation of an organic compound is shown below.



i. What are the possible outcomes of this experiment? **[1]**

ii. What is observed when products from the above experiment are heated with iodine in the presence of KOH? **[1]**

c) Sangay constructed a galvanic cell using manganese and aluminum electrodes. His galvanic cell is represented as follows:

$Mn(s) / Mn^{2+}(aq)\ (0.1M) // Al^{3+}(aq)\ (0.1M)/Al(s)$

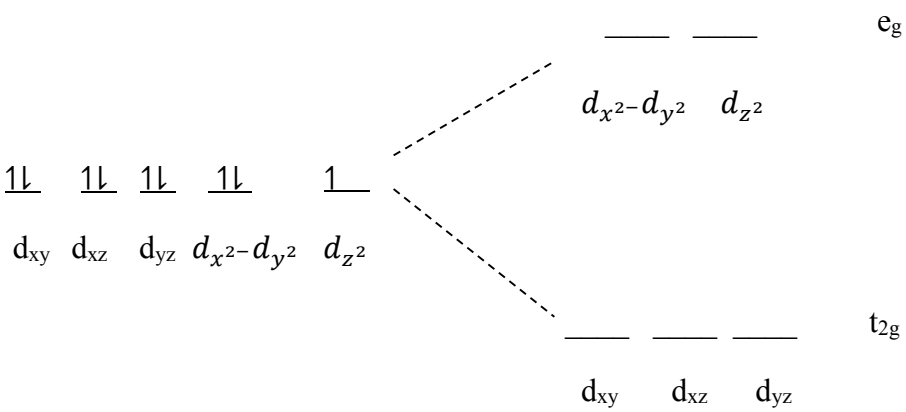
Given that: [$E^0_{Mn^{2+}|Mn}$ = -1.05 V and $E^0_{Al^{3+}|Al}$ = -1.67 V]

i. Calculate the EMF of the cell. **[2]**

ii. Is the galvanic cell functional? $[\frac{1}{2}]$

iii. Write the redox reaction of the functional cell. $[\frac{1}{2}]$

d) An incomplete crystal field splitting of Cu (II) ion for the octahedral complex is given below: **[2]**

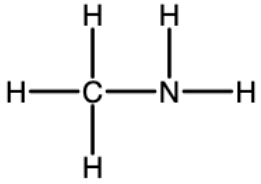


Use the above crystal field splitting of copper (II) ion to explain, why $CuSO_4.5H_2O$ is blue in colour while $CuSO_4$ is colourless.

e) The Bhutanese diet consists of high carbohydrates and fats. Is it a healthy diet? Support your answer with **TWO** reasons. **[2]**

Question 3

a) Study the structural formula of a compound and answer the questions that follow:



i. Give the IUPAC name of the compound. $[\frac{1}{2}]$

ii. How does this compound respond to litmus solution? $[\frac{1}{2}]$

b) Study the nature of the reactions A and B to answer the questions that follow.

Reaction 1: $HCl + NH_3 \rightleftharpoons NH_4^+ + Cl^-$

Reaction 2: $CH_3COOH + NH_3 \rightleftharpoons NH_4^+ + CH_3COO^-$

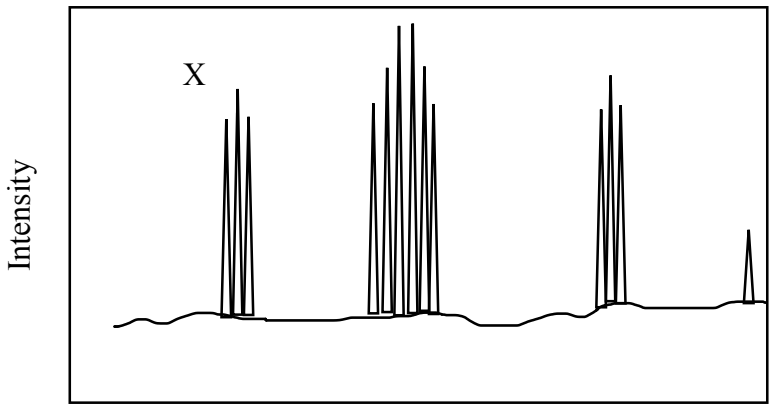
i. Identify the conjugate base pair of NH_4^+. **[$\frac{1}{2}$]**

ii. Which reaction has a faster rate of reversible reaction? Why? **[1]**

iii. If H_2O is added to both the reactions, which reaction will resist change in pH? **[$\frac{1}{2}$]**

c) Use a chemical equation to propose an experiment to make an organic compound that can be used in the manufacture of perfumes. Write the IUPAC names of all the organic compounds. **[2]**

d) The spectrum given below corresponds to halo alkane. Study the spectrum and answer the questions that follow:



i. Identify the compound and write its structural formula. $[\frac{1}{2}]$

ii. Peak X in the spectrum is the result of how many neighboring protons? $[\frac{1}{2}]$

iii. What is a chemical shift? **[1]**

iv. How does the presence of halogen affect chemical shift? **[1]**

e) An artificial transmutation in a nuclear reaction is meant for the production of new elements with atomic numbers higher than the parent elements. Do you agree with the statement? Justify with the help of a nuclear reaction. **[2]**

Question 4

a) The basic information of a few isotopes is given in the table. Study the table and answer the questions that follow:

Isotopes	X	Y	Z
Mass number	3	32	23
Atomic number	1	16	12

i. Identify the isotope that can decay β-rays. $[\frac{1}{2}]$

ii. Write the balanced nuclear reaction for beta decay. $[\frac{1}{2}]$

iii. Which isotope leads to the formation of a stable halogen when it undergoes (α, p) reaction? Support your answer with an equation. **[1]**

b) The osmotic pressures of glucose solutions A and B are 2.6 atm and 2.9 atm respectively at 298 K. If solutions A and B are separated by a semi-permeable membrane, by how much should the concentration of solution A be increased to prevent osmosis? **[2]**

[R = 0.0821 L atm K^{-1} mol^{-1}]

c) Materials are classified into conductor, semi-conductor and insulator. With reference to the properties of materials, name household items and explain their uses applying the knowledge of thermodynamics. **[2]**

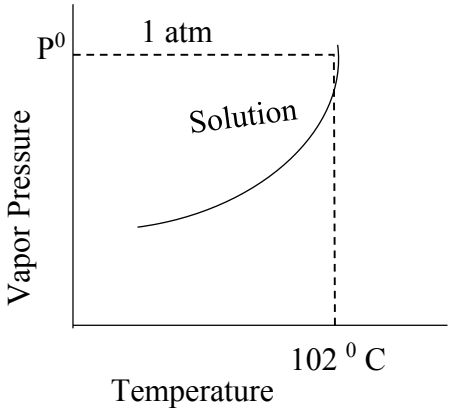
d) Benzoic acid is a stronger acid than acetic acid despite having the same functional group. Comment on the nature of CH_3 and C_6H_5 group that results in the difference in the acidic strength of the two compounds. **[2]**

e) Design an experiment to conduct a chemical analysis of a sample of cold drinks available in the market. Include the procedure and the results of the chemical analysis in your design. **[2]**

Question 5

a) How is aniline prepared from nitrobenzene? Write the chemical equation. **[1]**

b) The graph below shows the boiling point of an aqueous solution of a certain non-volatile solute. Study the graph and answer the questions that follow:

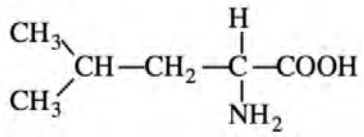


i. What is the molality of the solution? (K_b of pure water is 0.52^0C Kg mol^{-1}). **[1]**

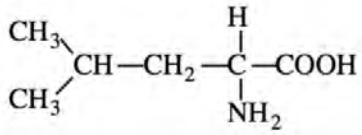
ii. Redraw the graph given above and plot a curve when additional solute is added to the same solution. **[1]**

iii. Write any **TWO** applications of this property of the solution in our day-to-day lives. **[1]**

c) Leucine is one of the essential amino acids. It is involved in the regulation of cellular processes such as protein synthesis, tissue regeneration and metabolism. The structure of leucine is given below:



i. Mark the chiral C-atom on the given structure. **[$\frac{1}{2}$]**

ii. Draw its structure at isoelectric point. **[$\frac{1}{2}$]**

iii. Draw the optical isomers of the amino acid. **[1]**

d) The following information outlines the experimental procedure for Cannizzaro reaction. Correct the experimental conditions wherever necessary and rewrite in the space provided. **[2]**

Step 1: One mole of acetaldehyde is heated with sodium hydroxide in a round bottom flask

Step 2: Acetaldehyde first undergoes oxidation to form ethyl alcohol

Step 3: The alcohol formed will undergo reduction to form acetic acid

e) The voltage generated by a car battery depends on electrochemical cells. Six same electrochemical cells are stacked in series to produce a voltage of 12 V. Use the list given below to construct an electrochemical cell which can power a car. In your design, mention how will you prevent overheating. **[2]**

Electrode	Standard reduction (V)
Sn^{2+}|Sn	-0.14
Li^{+}|Li	-3.04
Co^{2+}|Co	-0.28
Mg^{2+}|Mg	-2.38
Mn^{2+}|Mn	-1.05

Question 6

a) What is Kwashiorkor? How can you prevent it? **[1]**

b) Pema and Dorji conducted an experiment to calculate the heat of neutralization by mixing 100 g each of HCl and NaOH solution in a calorimeter. They found out that the temperature of the acid-base mixture solution was 10 ^{0}C higher than the individual solution. Pema concluded that the heat of neutralization is equal to 10 J whereas Dorji got a different value. (Specific heat of H_2O = 4.184 J K^{-1} g^{-1})

i. Show the calculation done by Dorji. **[1]**

ii. Whose conclusion was wrong? Why? **[1]**

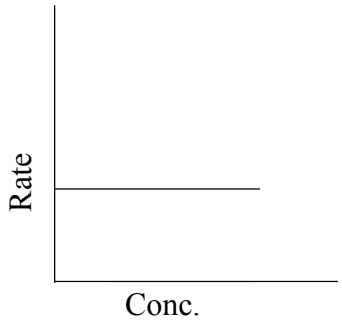
c) Sonam used Fehling's solution test and the Iodoform test to identify compounds X and Y. Compound X gave a positive test to both the tests while compound Y gave a positive test to only Fehling's solution.

i. Write the structural formulas of X and Y. **[1]**

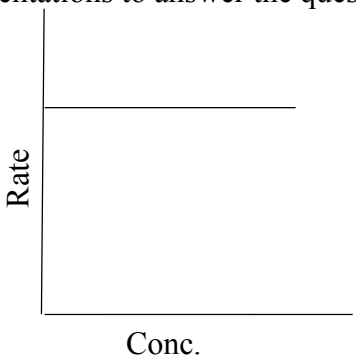
ii. Draw the structure of the product when compound Y reacts with HCN? **[1]**

d) Use the following graphical representations to answer the questions that follow.

a)



b)



i. What is the order of the reaction represented by the graphs? **[1]**

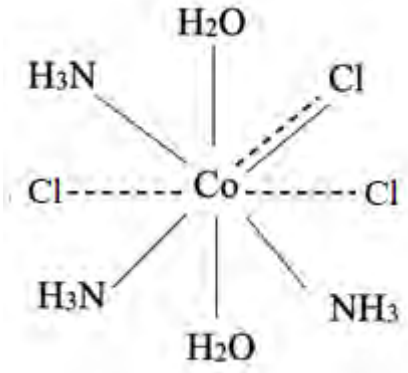
ii. Give **TWO** reasons for the difference in the graph lines. **[1]**

e) The concentration of an acid solution changes but the nature of acid remains the same upon addition of water. Do you agree with the statement? Justify with a suitable example. **[3]**

Question 7

a) Write the mechanism for the reaction of acetyl chloride with excess ammonia. **[2]**

b) The structure of two coordination compounds are shown below:

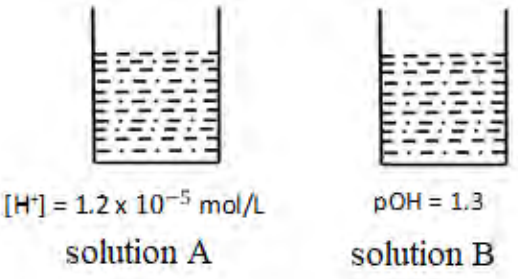


i. Write the IUPAC names of the compounds. **[1]**

ii. In the above structure, the association of one of the chlorine atoms with the central metal ion is shown by two different lines. What does this indicate? **[1]**

c) For a reaction aA + bB → Products, the order of reaction is (a + b). Do you agree with the statement? Give reason for your claim. **[2]**

d) Solutions that act as nutritive mediums for the growth of plants are acidic in nature. You are studying to find out a suitable solution for potted plants that grow well at pH range 4 – 6.



i. Calculate the pH of the solutions and infer which solution is best suited for your plants. **[$1\frac{1}{2}$]**

ii. If equal molars of solutions A and B are taken, which solution would have a high degree of dissociation? **[$\frac{1}{2}$]**

e) A primary amine is more basic than a tertiary amine but less basic than the secondary amine. Discuss the statement. **[2]**

Question 8

a) For the reaction A → 2B, the following data were obtained.

Expt.	**Initial concentration of A (M)**	**Initial reaction rate (mol $L^{-1}\ min^{-1}$)**
1	0.1	9.0×10^{-3}
2	0.3	8.1×10^{-2}
3	0.3	1.6×10^{-1}

i. Calculate the order of the reaction. **[1]**

ii. Plot a graph of rate vs concentration for the order of reaction. **[1]**

b) A group of students prepared equal volumes of two solutions, each of which contain the same amount of different solutes. However, the freezing point of the solutions is different despite having the same amount of solute. Study the statement and give any **TWO** reasons for the cause of difference in their freezing points. **[2]**

c) Benzaldehyde is the simplest representative of aromatic aldehydes. Answer the questions related to benzaldehyde.

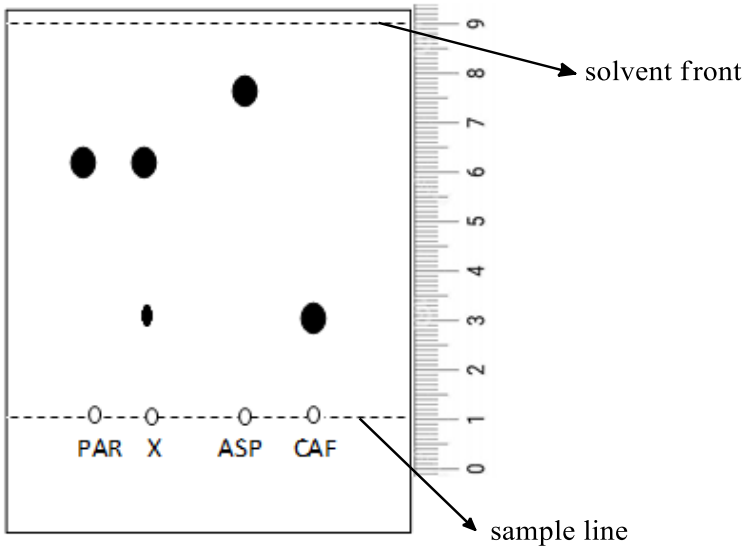
i. Complete the following chemical equation: $[\frac{1}{2}]$

…… + $2CrO_2Cl_2$ → C_6H_5CHO + $2CrCl_2(OH)_2$

ii. What will happen if benzaldehyde is treated with $NaBH_4$? Support your answer with a chemical equation. $[1\frac{1}{2}]$

d) The boiling point of carboxylic acids and aldehydes can be compared based on the size of alkyl group. Do you agree with the statement? Justify. **[2]**

e) A medical student analyzed four samples on a single TLC plate. The samples were caffeine (CAF), acetaminophen (PAR), Aspirin (ASP) and the commercial pain relief medicine (X). With reference to the chromatogram below, answer the questions that follow.



i. What is the R_f of medicine 'X'? **[$\frac{1}{2}$]**

ii. Which compounds are present in medicine 'X'? $[\frac{1}{2}]$

iii. Would you recommend this commercial pain relief medicine 'X' to others? Why? **[1]**

Question 9

a) Explain how mass spectrometry is employed for the determination of molecular mass and identification of unknown molecules. **[2]**

b) Biological processes, both in plants and animals involve coordination compounds. Explain the vital role of any **TWO** coordination compounds in biological processes. **[2]**

c) Primary amines can be produced using two different methods. One method is Hoffman degradation and the other method is the reduction. Mention **TWO** differences between the two methods. **[2]**

Hoffman degradation	**Reduction**	

d) Electrochemical cells are used to power home appliances, automobiles and for medical diagnosis. What are some of the ways by which we can improve the use of electrochemical cells to reduce the impacts on our health and the environment? **[2]**

e) A teacher asked students to evaluate the spontaneity of a reaction that has a negative value of ΔH. Group A said the reaction is spontaneous while Group B said that the reaction is non-spontaneous. Which group do you support? Justify your answer with an example. **[2]**
