CBSE EXAMINATION PAPER-2025

CHEMISTRY

(Solved)

Time allowed : 3 hours Maximum Marks : 71

General Instructions :

Read the following instructions carefully and follow them :

i. This question paper contains **39 questions.** All questions are **compulsory.**
ii. This question paper is divided into **5 sections.**
iii. **Section A** – questions number **1 to 13** are multiple choice questions Each question carries **1 marks.**
iv. **Section B** – questions number **14 to 18** are very short answer Each question carries **2 marks.**
v. **Section C** – questions number **19 to 24** are short answer Each question carries **3 marks.**
vi. **Section D** – questions number **25 to 33** are case based questions
vii. **Section E** – questions number **34 to 39** are long answer Each question carries **5 marks.**
viii. There is no overall choice given in the question paper. However, an internal choice has been provided in few questions.
ix. Use of calculator is NOT allowed.

Section A

Question 1.

In case of association, abnormal molar mass of solute will

[1 Marks]

(A) increase

(B) decrease

(C) remain same

(D) first increase and then decrease

Explanation: The correct answer is 'increase'. In the context provided, when solutes associate in solution, they form larger particle aggregates, leading to a smaller number of moles of dissolved particles compared to what would be expected. This results in a calculated colligative property that suggests a higher molar mass than the actual molar mass of the solute, known as abnormal molar mass.

Question 2.

The magnetic moment is associated with its spin angular momentum and orbital angular momentum . Spin only magnetic moment value of Cr^{3+} ion (Atomic no. : Cr=24) is_____ .

[1 Marks]

(A) 3.47 B.M.

(B) 2.87 B.M.

(C) 3.87 B.M.

(D) 3.57 B.M.

Explanation:

The correct answer is 3.87 B.M. because chromium (Cr^{3+}) has an electronic configuration of [Ar] $3d^3$. This results in three unpaired electrons. Using the formula $\mu = \sqrt{n(n+2)}$, where n is the number of unpaired electrons, we get $\mu = \sqrt{3(3+2)} = \sqrt{15}$, which approximates to 3.87 B.M. This aligns with the calculated and observed magnetic moment for Cr^{3+} ions, confirming 3.87 B.M. as the correct answer.

Question 3.

Acidified $KMnO_4$ oxidises sulphite to

[1 Marks]

(A) SO^{2-}_4

(B) $SO_2(g)$

(C) $S_2O^{2-}_8$

(D) $S_2O^{2-}{}_3$

Explanation: The correct option is SO_4^{2-} (sulfate). The reaction from the provided context shows that when sulphite (SO_3^{2-}) is oxidised by acidified permanganate ($KMnO_4$), it forms sulfate (SO_4^{2-}). This is confirmed by the equation: $5SO_3^{2-} + 2MnO_4^- + 6H^+ \rightarrow 2Mn^{2+} + 3H_2O + 5SO_4^{2-}$, indicating the conversion of sulphite to sulphate.

Question 4.

The correct IUPAC name of $[Pt(NH_3)_2Cl_2]^{2+}$ is

[1 Marks]

(A) Diamminedichloridoplatinum (O)

(B) Diamminedichloridoplatinum (IV)

(C) Diamminedichloridoplatinate (II)

(D) Diamminedichloridoplatinate (IV)

Explanation: The correct answer is 'Diamminedichloridoplatinum (IV)'. In this complex, 'ammine' (from NH_3) is indicated as 'di' because there are two NH_3 ligands, and 'chloro' (for Cl) is indicated as 'di' as well, since there are two chloride ligands. The oxidation state of platinum in this cation is +4, which is indicated by (IV) in the name.

Question 5.

Arrange the following compounds in increasing order of their boiling points:

[1 Marks]

(A) (ii) < (i) < (iii)

(B) (iii) < (ii) < (i)

(C) (iii) < (i) < (ii)

(D) (i) < (ii) < (iii)

Explanation: The correct order is (iii) < (ii) < (i). According to the context, I and II have the same molecular formula but different boiling points, which means the boiling points can vary based on structural isomerism. Compounds with a straight-chain structure (I) generally have higher boiling points compared to branched isomers (II and III) due to better packing and stronger van der Waals forces. Therefore, compound III has the lowest boiling point, followed by compound II, and then compound I with the highest boiling point.

Question 6.

Alkyl halides undergoing nucleophilic bimolecular substitution reaction involve

[1 Marks]

(A) formation of racemic mixture

(B) inversion of configuration

(C) formation of carbocation

(D) retention of configuration

Explanation: The correct answer is 'inversion of configuration' because nucleophilic bimolecular substitution (SN2) reactions involve the attack of a nucleophile at the carbon center from the opposite side of the leaving group, leading to a flip in the stereochemistry at that carbon center. This is characteristic of SN2 reactions when primary alkyl halides are involved, as indicated in the context.

Question 7.

Which is the correct order of acid strength from the following?

[1 Marks]

(A) $C_6H_5OH>ROH>H_2O$

(B) $H_2O>C_6H_5OH>ROH$

(C) $C_6H_5OH >H_2O >ROH$

(D) $ROH>C_6H_5OH>H_2O$

Explanation: The correct answer is $C_6H_5OH > H_2O > ROH$. This order reflects the acid strength based on the stability of the resulting ions after proton dissociation; phenol (C_6H_5OH) is a stronger acid than water (H_2O), which in turn is stronger than alcohols (ROH) due to differences in electronegativity and bond polarity.

Question 8.

The acid formed when propyl magnesium bromide is treated with CO_2 followed by acid hydrolysis is

[1 Marks]

(A) CH_3COOH

(B) C_3H_7COOH

(C) C_3H_7OH

(D) C_2H_5COOH

Explanation: The correct answer is C_3H_7COOH. When propyl magnesium bromide (a Grignard reagent) reacts with carbon dioxide, it forms a carboxylic acid after acid hydrolysis. The structure C_3H_7COOH corresponds to propanoic acid, which is produced from the reaction of the Grignard reagent with CO_2 and subsequent acidification.

Question 9.

The best reagent for converting propanamide into propanamine is

–––––––––––––––––.

[1 Marks]

(A) excess H_2

(B) iodine in the presence of red phosphorus

(C) Br_2 in aqueous NaOH

(D) $LiAlH_4$ in ether

Explanation: The correct option is $LiAlH_4$ in ether. Lithium aluminum hydride ($LiAlH_4$) is a strong reducing agent that can effectively convert amides, such as propanamide, into amines, specifically propanamine, by reducing the carbonyl group to an amine. The other options do not provide the necessary reduction for this transformation.

Question 10.

Which of the following statements is not true about glucose?

[1 Marks]

(A) On heating with HI it forms n-hexane.

(B) It does not give Schiff's test.

(C) It exists in furanose form.

(D) It is an aldohexose.

Explanation:

The statement 'It does not give Schiff's test' is not true about glucose. According to the context, despite having the aldehyde group, glucose does not give Schiff’s test, indicating it behaves differently because it does not possess a free -CHO group due to its cyclic structure.

Question 11.

An unripe mango placed in a concentrated salt solution to prepare pickle, shrivels because_____________.

[1 Marks]

(A) it gains water due to reverse osmosis

(B) it loses water due to osmosis

(C) it loses water due to reverse osmosis

(D) it gains water due to osmosis

Explanation: The correct option is 'it loses water due to osmosis'. In a concentrated salt solution, the external environment (the salt solution) is hypertonic compared to the inside of the mango. Water moves out of the mango into the salt solution through the process of osmosis, leading to the mango shriveling.

Question 12.

Assertion (A): $[Cr(H_2O)_6]Cl_2$ and $[Fe(H_2O)_6]Cl_2$ are examples of homoleptic complexes.

Reason (R) : All the ligands attached to the metal are the same.

[1 Marks]

(A) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(B) Assertion (A) is false, but Reason (R) is true

(C) Assertion (A) is true, but Reason (R) is false.

(D) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

Explanation:

Both Assertion (A) and Reason (R) are true, and Reason (R) is the correct explanation of the Assertion (A). Homoleptic complexes are defined as those in which a metal is bound to only one kind of donor group, which applies to both $[Cr(H_2O)_6]Cl_2$ and $[Fe(H_2O)_6]Cl_2$, as they both have ligands (water) that are the same.

Question 13.

Assertion (A) :	The boiling points of alkyl halides decrease in the order : RI > RBr > RCl > RF.
Reason (R) :	The boiling points of alkyl chlorides, bromides and iodides are considerably higher than that of the hydrocarbon of comparable molecular mass.

[1 Marks]

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(B) Assertion (A) is false, but Reason (R) is true

(C) Assertion (A) is true, but Reason (R) is false.

(D) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

Explanation:

Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A). The order of boiling points is influenced by molecular weight and polarity, with RI having the highest boiling point due to its larger atomic size and ability to form stronger dipole-dipole interactions compared to RBr, RCl, and RF. However, the reason provided discusses the boiling points of alkyl halides in relation to hydrocarbons rather than directly explaining the order of boiling points among the alkyl halides.

Section B

Question 14. Define Azeotrope. What type of Azeotrope is formed by negative deviation from Raoult's law? Give an example.

[2 Marks]

Answer: An azeotrope is a mixture of two or more liquids that exhibits constant boiling behavior due to specific composition. When a solution shows a negative deviation from Raoult's law, it forms a maximum boiling azeotrope. In this case, the intermolecular forces between the components A and B are stronger than those among A-A or B-B. An example is a mixture of nitric acid and water, which contains 68% nitric acid and boils at 393.5 K.

Question 15.

Complete and balance the following chemical equations:

(a)$2MnO_4^-(aq) + 10I^-(aq) + 16H^+(aq) \rightarrow$

(b) $Cr_2O^{2-}{}_7(aq) + 6Fe^{2+}(aq) + 14H^+(aq) \rightarrow$

[2 Marks]

Answer: The balanced equation for (a) is $2MnO_4^-(aq) + 10I^-(aq) + 16H^+(aq) \rightarrow 2Mn^{2+}(aq) + 8H_2O(l) + 5I_2(g)$. For (b), the balanced equation is $Cr_2O_7^{2-}(aq) + 6Fe^{2+}(aq) + 14H^+(aq) \rightarrow 6Fe^{3+}(aq) + 2Cr^{3+}(aq) + 7H_2O(l)$.

Question 16.

Write the reactions involved when D-glucose is treated with following reagents:

(a) HCN

(b) Br_2 water

[2 Marks]

Answer: When D-glucose is treated with HCN, it forms cyanohydrin through the nucleophilic addition of HCN to the carbonyl group, resulting in a compound with a -CN group. In the reaction with Br_2 water, glucose is oxidized to gluconic acid, confirming the presence of an aldehyde group. Both reactions highlight the reactivity of the carbonyl group found in glucose.

Question 17.

Give reasons :

(a) Cooking is faster in pressure cooker than in an open pan.

(b) on mixing liquid X and Y , volume of the resulting solution decreases . what type of deviation from raoult's law is shown by the resulting solution ? what change in temperature would you observe after mixing liquids X and Y?

[2 Marks]

Answer: Cooking is faster in a pressure cooker due to the increase in pressure, which raises the boiling point of water and allows food to cook at a higher temperature, thus speeding up the cooking process. When liquids X and Y are mixed and the total volume decreases, this indicates a negative deviation from Raoult's law, meaning the interactions between the different molecules (X and Y) are stronger than those within each individual liquid. The temperature of the mixture may drop due to energy being absorbed in forming these interactions.

Question 18.

Would you expect benzaldehyde to be more reactive or less reactive in nucleophilic addition reactions than propanal ? Justify your answer.

[2 Marks]

Answer: Benzaldehyde is less reactive than propanal in nucleophilic addition reactions. This is due to the presence of the aromatic ring in benzaldehyde, which stabilizes the carbonyl group through resonance. The resonance structures delocalize the positive charge, reducing the electrophilicity of the carbonyl carbon. On the other hand, propanal, which lacks such resonance stabilization, has a more reactive carbonyl group. Therefore, nucleophiles will more readily attack propanal compared to benzaldehyde.

Section C

Question 19.

A solution of glucose (molar mass =180 g mol^{-1}) in water has a boiling point of 100.20 °C. Calculate the freezing point of the same solution. Molal constants for water Kf and Kb are 1.86 K kg mol^{-1}and 0.512 K kg mol^{-1} respectively.

[3 Marks]

Answer: To find the freezing point of the glucose solution, we first determine the molality of the solution. The boiling point elevation (\u0394Tb) is the difference between the boiling point of the solution (100.20 °C) and the boiling point of pure water (100 °C), which is 0.20 °C. Using the formula \u0394Tb = Kb * m, we rearrange for molality (m). Here, \u0394Tb = 0.20 °C and Kb = 0.512 K kg mol^{-1}. Thus, m = \u0394Tb / Kb = 0.20 °C / 0.512 K kg mol^{-1} = 0.3906 mol/kg. To find the freezing point depression (\u0394Tf), we use \u0394Tf = Kf * m. Substituting Kf = 1.86 K kg mol^{-1}, we have \u0394Tf = 1.86 K kg mol^{-1} * 0.3906 mol/kg = 0.726 K. Since the freezing point of pure water is 0 °C, the freezing point of the solution will be 0 °C - 0.726 K = -0.726 °C.

Question 20.

A certain reaction is 50% complete in 20 minutes at 300 K and the same reaction is 50% complete in 5 minutes at 350 K. Calculate the activation energy if it is a first order reaction.

[R=8.314 J K^{-1} mol^{-1}; log 4 =0.602]

[3 Marks]

Answer: To calculate the activation energy (Ea) for a first-order reaction, we can use the Arrhenius equation: k = Ae^(-Ea/RT). Given the reaction times and temperatures, we first determine the rate constants k1 and k2 from the half-life equations. The half-life (t1/2) for a first-order reaction is given by t1/2 = 0.693/k. At 300 K, k1 = 0.03465 s^{-1} and at 350 K, k2 = 0.1386 s^{-1}. Using the two rate constants and the Arrhenius equation, we can derive Ea. Rearranging gives us: ln(k2/k1) = (Ea/R)(1/T1 - 1/T2). Substituting R and temperatures allows us to solve for Ea, resulting in 55.18 kJ/mol. Thus, the activation energy is 55.18 kJ/mol.

Question 21.

The elements of 3d transition series are given as :

Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn

Answer the following :

(a) Copper has exceptionally positive $E^{\circ}_{m2+/m}$ value, why ?

(b) Which element is a strong reducing agent in +2 oxidation state and why ?

(c) Zn^{2+} salts are colourless. Why ?

[3 Marks]

Answer: (a) Copper has an exceptionally positive $E^{\circ}_{m2+/m}$ value because the fully filled $3d^{10}$ configuration of Cu^{+} and Cu metal is very stable, so Cu^{2+} tends to get reduced easily to Cu metal making its reduction potential more positive.
(b) Manganese in +2 oxidation state (Mn^{2+}) is a strong reducing agent because the half-filled d^5 configuration of Mn^{2+} is stable, and it easily loses electrons to form higher oxidation states like +3, +4, +7, thereby acting as a strong reducing agent.
(c) Zn^{2+} salts are colourless because Zn^{2+} has a completely filled d^{10} electronic configuration, so there are no d-d electron transitions that can absorb visible light, resulting in colourless compounds.

Question 22.

How do you convert :

(a) Chlorobenzene to biphenyl

(b) Propene to I-Iodopropane

(c) 2-bromobutane to but-2-ene.

[3 Marks]

Answer: (a) Chlorobenzene to biphenyl: Chlorobenzene undergoes Wurtz reaction using sodium metal in dry ether to form biphenyl. This involves coupling of two chlorobenzene molecules by sodium.
(b) Propene to I-Iodopropane: Propene reacts with hydrogen iodide (HI) in the presence of

an acid catalyst. The HI adds across the double bond following Markovnikov's rule, giving I-Iodopropane with the iodine atom attached to the more substituted carbon.
(c) 2-bromobutane to but-2-ene: 2-bromobutane undergoes dehydrohalogenation when treated with a strong base like alcoholic KOH. This elimination reaction removes HBr and forms a double bond, resulting in but-2-ene.

Question 23.

(a) Arrange the following compounds in increasing order of their boiling point :

$(CH_3)_2NH$, $CH_3CH_2NH_2$, CH_3CH_20H.

(b) Give plausible explanation for each of the following :

(i) Aromatic primary amines cannot be prepared by Gabriel Phthalimide synthesis.

(iI) Amides are less basic than amines.

[3 Marks]

Answer: (a) Arrangement of compounds in increasing order of boiling points:
$(CH_3)_2NH$ (Dimethylamine) < $CH_3CH_2NH_2$ (Ethylamine) < CH_3CH_2OH (Ethanol).
Explanation:
Boiling point depends on intermolecular forces. Ethanol has hydrogen bonding due to -OH group, so it has the highest boiling point. Ethylamine also exhibits hydrogen bonding but less strong than ethanol, so it comes next. Dimethylamine has weaker hydrogen bonding because of steric hindrance and less polarity, so it has the lowest boiling point.

(b) Explanation:
(i) Aromatic primary amines cannot be prepared by Gabriel Phthalimide synthesis because the nucleophilic substitution reaction required in this method is hindered by the resonance stabilization of the aromatic amine group, making the reaction ineffective for aromatic amines.
(ii) Amides are less basic than amines because in amides the lone pair of electrons on nitrogen is delocalized over the oxygen atom through resonance, reducing the availability of the lone pair to accept protons, whereas in amines the lone pair is localized and more available for protonation, making amines more basic.

Question 24.

(a) What is the difference between native protein and denatured protein ?

(b) Which one of the following is a disaccharide ? Glucose, Lactose, Amylose, Fructose

(c) Which vitamin is responsible for the coagulation of blood ?

[3 Marks]

Answer: (a) A native protein is a protein that is found in its natural, functional three-dimensional structure in a biological system, retaining its biological activity. A denatured protein has lost its natural structure due to factors like heat, pH changes, or chemicals, resulting in loss of its biological activity.
(b) Lactose is the disaccharide among the options given. It consists of two monosaccharides, β-D-galactose and β-D-glucose, linked by a β(1→4) glycosidic bond.
(c) Vitamin K is responsible for the coagulation of blood. It helps in the synthesis of proteins needed for blood clotting.

Section D

Question 25. Phenols undergo electrophilic substitution reactions readily due to the strong activating effect of OH group attached to the benzene ring. Since the OH group increases the electron density more to o- and p- positions, therefore the OH group is ortho, para-directing. Reimer-Tiemann reaction is one of the examples of aldehyde group being introduced on the aromatic ring of phenol, ortho to the hydroxyl group.

Question 26.

The following questions are case based questions. Read the passage carefully and answer the questions that follow.

The rate of a chemical reaction is expressed either in terms of decrease in the concentration of reactants or increase in the concentration of a product per unit time. Rate of the reaction depends upon the nature of reactants, concentration of reactants, temperature, presence of catalyst, surface area of the reactants and presence of light. Rate of reaction is directly related to the concentration of reactant. Rate law states that the rate of reaction depends upon the concentration terms on which the rate of reaction actually depends, as observed experimentally. The sum of powers of the concentration of the reactants in the Rate law expression is called order of reaction while the number of reacting species taking part in an elementary reaction which must collide simultaneously in order to bring about a chemical reaction is called molecularity of the reaction.

Question 27.

The following questions are case based questions. Read the passage carefully and answer the questions that follow.

The rate of a chemical reaction is expressed either in terms of decrease in the concentration of reactants or increase in the concentration of a product per unit time. Rate of the reaction depends upon the nature of reactants, concentration of reactants, temperature, presence of catalyst, surface area of the reactants and presence of light. Rate of reaction is directly related to the concentration of reactant. Rate law states that the rate of reaction depends upon the concentration terms on which the rate of reaction actually depends, as observed experimentally. The sum of powers of the concentration of the reactants in the Rate law expression is called order of reaction while the number of reacting species taking part in an elementary reaction which must collide simultaneously in order to bring about a chemical reaction is called molecularity of the reaction.

Question 28.

The following questions are case based questions. Read the passage carefully and answer the questions that follow.

The rate of a chemical reaction is expressed either in terms of decrease in the concentration of reactants or increase in the concentration of a product per unit time. Rate of the reaction depends upon the nature of reactants, concentration of reactants, temperature, presence of catalyst, surface area of the reactants and presence of light. Rate of reaction is directly related to the concentration of reactant. Rate law states that the rate of reaction depends upon the concentration terms on which the rate of reaction actually depends, as observed experimentally. The sum of powers of the concentration of the reactants in the Rate law expression is called order of reaction while the number of reacting species taking part in an elementary reaction which must collide simultaneously in order to bring about a chemical reaction is called molecularity of the reaction.

Question 29.

The following questions are case based questions. Read the passage carefully and answer the questions that follow.

The rate of a chemical reaction is expressed either in terms of decrease in the concentration of reactants or increase in the concentration of a product per unit time. Rate of the reaction depends upon the nature of reactants, concentration of reactants, temperature, presence of catalyst, surface area of the reactants and presence of light. Rate of reaction is directly related to the concentration of reactant. Rate law states that the rate of reaction depends upon the concentration terms on which the rate of reaction actually depends, as observed experimentally. The sum of powers of the concentration of the reactants in the Rate law expression is called order of reaction while the number of reacting species taking part in an elementary reaction which must collide simultaneously in order to bring about a chemical reaction is called molecularity of the reaction.

Question 30.

The following questions are case based questions. Read the passage carefully and answer the questions that follow.

The rate of a chemical reaction is expressed either in terms of decrease in the concentration of reactants or increase in the concentration of a product per unit time.

Rate of the reaction depends upon the nature of reactants, concentration of reactants, temperature, presence of catalyst, surface area of the reactants and presence of light. Rate of reaction is directly related to the concentration of reactant. Rate law states that the rate of reaction depends upon the concentration terms on which the rate of reaction actually depends, as observed experimentally. The sum of powers of the concentration of the reactants in the Rate law expression is called order of reaction while the number of reacting species taking part in an elementary reaction which must collide simultaneously in order to bring about a chemical reaction is called molecularity of the reaction.

Question 31.

Question 32.

The following questions are case based questions. Read the passage carefully and answer the questions that follow.

The rate of a chemical reaction is expressed either in terms of decrease in the concentration of reactants or increase in the concentration of a product per unit time. Rate of the reaction depends upon the nature of reactants, concentration of reactants, temperature, presence of catalyst, surface area of the reactants and presence of light. Rate of reaction is directly related to the concentration of reactant. Rate law states that the rate of reaction depends upon the concentration terms on which the rate of reaction actually depends, as observed experimentally. The sum of powers of the concentration of the reactants in the Rate law expression is called order of reaction while the number of reacting species taking part in an elementary reaction which must collide simultaneously in order to bring about a chemical reaction is called molecularity of the reaction.

Answer the following questions :

> **(1)**
>
> **(i) What is a rate determining step ?**
>
> **(ii) Define complex reaction.**
>
> [2 Marks]
>
> **Answer:** (i) A rate determining step is the slowest step in a multi-step chemical reaction that controls the overall rate of the reaction. Since it has the highest energy barrier, it effectively sets the pace for the entire reaction mechanism, meaning that the rate of the overall reaction is limited by this step.\n(ii) A complex reaction is one that involves more than one elementary step, with intermediates formed during the process. In such reactions, the rate is primarily determined by the slowest step, while

the molecularity of the complex reaction may not hold significance as it does for elementary reactions. Thus, the order of the complex reaction correlates to the slowest step's molecularity and is defined by the reaction's rate law.

Key Points: Rate determining step is the slowest step in a reaction - It controls the overall rate of a multi-step reaction - Complex reaction involves multiple steps with intermediates formed

(2)

What is the effect of temperature on the rate constant of a reaction ?

[1 Marks]

Answer: The effect of temperature on the rate constant of a reaction is significant as most chemical reactions are accelerated by an increase in temperature. As the temperature rises, the kinetic energy of the reactant molecules also increases, leading to more frequent and effective collisions among the reacting species. According to the Arrhenius equation, the rate constant (k) is temperature-dependent and increases with temperature. For example, the decomposition of N2O5 demonstrates this effect, where the time taken for half of the original material to decompose decreases dramatically from 10 days at 0°C to just 12 minutes at 50°C. Therefore, raising the temperature enhances the rate constant and, consequently, the rate of reaction.

Key Points: Temperature increases kinetic energy - More frequent collisions - Arrhenius equation indicates k increases with temperature - Example: N2O5 decomposition times

(3)

The conversion of molecule X to Y follows second order kinetics. If concentration of X is increased 3 times, how will it affect the rate of formation of Y ?

[1 Marks]

Answer: In a second-order reaction, the rate of formation of the product Y is proportional to the square of the concentration of the reactant X. This means that if the concentration of X is increased three times (i.e., [X] becomes 3[X]), the new rate of reaction can be calculated as follows: Rate = k[X]^2. When [X] is increased to 3[X], the rate becomes k(3[X])^2 = k(9[X]^2) = 9 * k[X]^2. Therefore, the rate of formation of Y will increase by a factor of 9 as a result of tripling the concentration of X. Hence, if the concentration of X is increased threefold, the rate of formation of product Y will increase nine times.

> Key Points: Second order kinetics; Rate ∝ [X]^2; Tripling [X] increases rate by factor of 9

(4)

Why is molecularity applicable only for elementary reactions whereas order is applicable for elementary as well as complex reactions ?

[1 Marks]

Answer: Molecularity is a term that applies only to elementary reactions because it refers to the number of molecules participating in a single step of the reaction. Since an elementary reaction occurs in one step, its molecularity can be directly defined as the number of reactant species involved. On the other hand, the order of a reaction is a broader term that describes how the rate of that reaction depends on the concentration of reactants, and it can be determined from the rate law for both elementary and complex reactions. For complex reactions, which may consist of several elementary steps, the overall order is determined by the slowest step, making the concept of order applicable beyond just the elementary reactions. Therefore, while molecularity is restricted to simple, single-step reactions, order encompasses the rate behavior of both simple and complex reaction mechanisms.

> Key Points: Molecularity refers to single-step reactions only - Order applies to both simple and complex reactions - Order is determined by the rate-determining step in complex reactions - Molecularity is limited to whole numbers (1-3), while order can be fractional.

Question 33.

Phenols undergo electrophilic substitution reactions readily due to the strong activating effect of OH group attached to the benzene ring. Since, the OH group increases the electron density more to 0— and — positions therefore OH group is ortho, para-directing. Reimer-Tiemann reaction is one of the examples of aldehyde group being introduced on the aromatic ring of phenol, ortho to the hydroxyl group. This is a general method used for the ortho-formylation of phenols.

Answer the following questions :

(1)

Why phenol does not undergo protonation readily ?

[1 Marks]

Answer: Phenol does not undergo protonation readily due to the resonance stabilization of its hydroxyl (-OH) group. The -OH group acts as an electron-donating group, which strengthens the aromatic character of phenol. This enhanced resonance makes the benzene ring less susceptible to protonation. Additionally, when a proton is added to the hydroxyl oxygen, it would create a positively charged species that is less stable compared to the neutral phenol molecule. Thus, the strong activating effect of the -OH group not only directs electrophiles to the ortho and para positions but also inhibits protonation of the phenolic compound.

Key Points: Resonance stabilization of the -OH group; electron donation strengthens aromaticity; protonation creates a less stable positive ion.

(2)

Which is a stronger acid — phenol or cresol ? Give reason.

[1 Marks]

Answer: Cresol is a stronger acid than phenol. This is primarily because cresol has a methyl group (-CH3) attached to the aromatic ring, which provides a +I (inductive) effect, stabilizing the negative charge on the phenoxide ion formed after deprotonation. Compared to phenol, where only the -OH group is present, cresol benefits from both the +I effect of the methyl group and the resonance stability from the -OH group. Thus, cresol can donate a proton more easily than phenol, making it a stronger acid.

Key Points: Cresol has a methyl group which stabilizes the phenoxide ion; -CH3 provides +I effect; cresol donates protons more easily than phenol.

(3)

What happens when phenol reacts with

(i) Br_2/CS_2

(ii) Conc. HNO_3

[2 Marks]

Answer: When phenol reacts with Br_2 in carbon disulfide (CS_2), it undergoes electrophilic substitution leading to bromination primarily at the ortho and para positions due to the activating effect of the hydroxyl group (-OH). This results in the formation of ortho-bromophenol and para-bromophenol. On the other hand, when phenol is treated with concentrated nitric acid (Conc. HNO_3), nitration occurs, yielding a mixture of ortho-nitrophenol and para-nitrophenol as products. The presence of the -OH group enhances the reactivity of the phenol and directs the incoming electrophile (Br or NO_2) towards the ortho and para positions.

Key Points: Bromination at ortho and para positions-Formation of ortho and para-bromophenol-Nitration yields ortho and para-nitrophenol

(4)

Write the IUPAC name of the product formed in the Reimer-Tiemann reaction.

[1 Marks]

Answer: The product formed in the Reimer-Tiemann reaction when phenol is treated with chloroform in the presence of sodium hydroxide is salicylaldehyde. The structure of salicylaldehyde features a hydroxyl group (-OH) and an aldehyde group (-CHO) attached to the benzene ring, specifically at the ortho position relative to each other. Its IUPAC name reflects this as 2-hydroxybenzaldehyde.

Key Points: Reimer-Tiemann reaction introduces a –CHO group; product is salicylaldehyde; IUPAC name is 2-hydroxybenzaldehyde; –OH group is ortho-directing.

Section E

Question 34.

(a) Write the cell reaction and calculate the e.m.f. of the following cell at 298 K:

$Sn(s)|Sn^{2+}(0.004\ M)||H^+(0.02\ M)|H_2(g)(1\ Bar)|Pt(s)$

(Given: $E^o(_{sn2+}/_{sn}=-0.14$ V, $E^oH_{+}|H_{2(^{g})pt}= 0.00$ V)

(b) Account for the following observations:

(i) On the basis of E^o values, O_2 gas should be liberated at anode but it is Cl_2 gas which is liberated in the electrolysis of aqueous NaCl;

(ii) Conductivity of CH_3COOH decreases on dilution.

[5 Marks]

Answer:

To find the cell reaction and e.m.f. for the described electrochemical cell, we start with the half-cell reactions. The oxidation half-reaction occurs at the Sn electrode: $Sn(s) \rightarrow Sn^{2+}(aq) + 2\ e^-$; with a standard potential $E^o = -0.14$ V. The reduction half-reaction at the hydrogen electrode is: $2\ H^+(aq) + 2\ e^- \rightarrow H_2(g)$; with $E^o = 0.00$ V. Next, we apply the Nernst equation to calculate the e.m.f. using these concentrations: \nE(cell) = E^o(cell) - (0.0591/n) log($[Sn^{2+}]/[H^+]^2$)\nWe plug in the values (n = 2, $[Sn^{2+}] = 0.004$ M, $[H^+] = 0.02$ M) and find the logarithmic term. The standard e.m.f. of the cell, E^o(cell) = 0.00 V - (-0.14 V) = 0.14 V, gives us an overall e.m.f. considering concentration effects. During the electrolysis of aqueous NaCl, the theoretical expectation is that water (H_2O) would oxidize to produce O_2 gas due to its lower E^o value compared to Cl^- ions. However, this is not the case because of the higher overpotential for oxygen evolution compared to chlorine. Thus, Cl^- is preferentially oxidized to form Cl_2 gas. Furthermore, in the case of acetic acid (CH_3COOH), dilution causes the concentration of ionizable molecules to decrease; as a result, the degree of ionization increases but the overall conductivity declines due to reduced concentration of mobile ions (H^+ and CH_3COO^-) for conduction, leading to the observed decrease in conductivity.

Question 35.

(a) Write the anode and cathode reactions and the overall cell reaction occurring in a lead storage battery during its use.

(b) Calculate the potential for half-cell containing 0.01 M $K_2Cr_207(aq)$, 0.01 M Cr^{3+} (aq) and 1.0×10^{-4} M H^+ (aq).

The half cell reaction is

$Cr_20^{2-}{}_7(aq)+14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_20(l)$

and the standard electrode potential is given as $E^0= 1.33$ V.

[Given : log 10 = 1].

[5 Marks]

Answer: (a) Reactions in Lead Storage Battery during use:

Anode reaction (oxidation): $Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2e^-$

Cathode reaction (reduction): $PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$

Overall cell reaction: $Pb(s) + PbO_2(s) + 2H_2SO_4(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$

(b) Calculation of electrode potential:

Given half cell reaction: $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$
Standard electrode potential, $E^o = 1.33$ V
Using Nernst equation:
$E = E^o - (0.059 / n) * \log Q$
where n = 6 (number of electrons), Q = reaction quotient
$Q = [Cr^{3+}]^2 / [Cr_2O_7^{2-}] * [H^+]^{14}$
Given concentrations:
$[Cr_2O_7^{2-}] = 0.01$ M
$[Cr^{3+}] = 0.01$ M
$[H^+] = 1.0 \times 10^{-4}$ M
Calculating log Q:
$\log Q = \log([Cr^{3+}]^2 / [Cr_2O_7^{2-}] * [H^+]^{14})$
$= \log(0.01^2 / 0.01 * (1.0 \times 10^{-4})^{14})$
$= \log(0.0001 / 0.01 * 10^{-56}) = \log(0.01 * 10^{-56}) = \log 10^{-58} = -58$
Now calculate E:
$E = 1.33 - (0.059 / 6) * (-58) = 1.33 + 0.059 * 9.67 = 1.33 + 0.57 = 1.90$ V
So, the potential of the half cell under given conditions is 1.90 V.

Question 36.

Answer the following :

(a) Low spin tetrahedral complexes are not known.

(b) $c0^{2+}$ is easily oxidised to $C0^{3+}$ in the presence of a strong ligand [At. No. of co = 27]

(c) What type of isomerism is shown by the complex $[Co(NH_3)_6]\ [Cr(CN)_6]$?

(d) Why a solution$[Ni(H_2O)_6]^{2+}$ is green while a solution of $[Ni(CN)_4]^{2-}$is colourless.

(At. No. of Ni = 28)

(e) Write the IUPAC name of the following complex : $[Co(NH_3)_5(C0_3)]Cl$

[5 Marks]

Answer: (a) Low spin tetrahedral complexes are not known because the crystal field splitting energy (\u0394t) in tetrahedral geometry is small and less than pairing energy.

Strong field ligands required to pair electrons for low spin complexes cannot cause this in tetrahedral complexes.
(b) Co^{2+} is easily oxidised to Co^{3+} in the presence of strong ligands because strong field ligands increase the crystal field splitting which stabilizes the higher oxidation state (Co^{3+}) due to greater ligand field stabilization energy.
(c) The complex $[Co(NH_3)_6][Cr(CN)_6]$ shows ionisation isomerism because exchanging the anion and cation parts forms different compounds having different properties.
(d) $[Ni(H_2O)_6]^{2+}$ is green because water is a weak field ligand causing smaller crystal field splitting and d-d transitions absorb visible light. $[Ni(CN)_4]^{2-}$ is colourless because CN^- is a strong field ligand causing large crystal field splitting which leads to pairing of electrons and no d-d transitions in visible region, so no colour.
(e) The IUPAC name of $[Co(NH_3)_5(CO_3)]Cl$ is pentaamminecarbonatocobalt(III) chloride.

Question 37.

(a) What is meant by 'Chelate effect' ? Give an example.

(b) Write the hybridization and magnetic behaviour of $[Fe(CN)_6]^{4-}$ (Atomic number : Fe= 26)

(c) If $PtCl_2 \cdot 2NH_3$ does not react with $AgN0_3$, what will be its formula ?

[5 Marks]

Answer: (a) **Chelate effect** is the enhanced stability of coordination compounds formed by multidentate ligands compared to those formed by equivalent monodentate ligands. This is because multidentate ligands form ring structures with the central metal ion, increasing the complex's stability.
Example: Ethane-1,2-diamine (en) forms a chelate complex with Ni^{2+}, such as $[Ni(en)_3]^{2+}$.

(b) In $[Fe(CN)_6]^{4-}$, iron is in +2 oxidation state as CN^- is a strong field ligand causing pairing of electrons. The electronic configuration of Fe^{2+} is $3d^6$. Due to strong field CN ligands, the hybridization is d_2sp_3 which is octahedral. All the electrons are paired, so the complex is diamagnetic.

(c) $PtCl_2 \cdot 2NH_3$ does not react with $AgNO_3$, which means Cl ions are not free but coordinated to Pt. This indicates the complex formula is $[PtCl_2(NH_3)_2]$ with no counter ions. Hence, the formula of the compound is **$[PtCl_2(NH_3)_2]$**.

Question 38.

(a)Carry out the following conversions:

(i) Ethanal to But-2-enal;

(ii) Propanoic acid to ethane.

(b) An alkene A with molecular formula C_5H_{10} on ozonolysis gives a mixture of two compounds B and C. Compound B gives positive Fehling test and also reacts with iodine and NaOH solution. Compound C does not give Fehling solution test but forms iodoform. Identify the compounds A, B and C.

[5 Marks]

Answer: (a)(i) Conversion of Ethanal to But-2-enal:
Step 1: Ethanal undergoes aldol condensation in the presence of dilute NaOH. Two ethanal molecules react to form 3-hydroxybutanal.
Step 2: The 3-hydroxybutanal undergoes dehydration by heating to form But-2-enal (an alpha,beta-unsaturated aldehyde).
Overall reaction: $2\ CH_3CHO$ --(dil NaOH, heat)--> $CH_3CH=CHCHO$

(ii) Conversion of Propanoic acid to Ethane:
Step 1: Propanoic acid is converted to propanoyl chloride by treating with $SOCl_2$.
Step 2: Propanoyl chloride is converted to ethane by reaction with zinc and dilute acid (Zn / H_2SO_4) which reduces the acyl chloride to alkane, removing one carbon atom.
Another easier method is by reducing acid to alkane using Zn and heat but this method retains the carbon chain length. To reduce the acid to alkane with removal of one carbon, catalytic decarboxylation can be done using soda lime (NaOH + CaO) and heat:
CH_3CH_2COOH --(NaOH + CaO, heat)--> $C_2H_6 + CO_2 + H_2O$

(b) Identification of compounds A, B and C:
Given: A is an alkene C_5H_{10}, on ozonolysis yields compounds B and C.
Compound B gives positive Fehling test and reacts with iodine and NaOH solution indicating the presence of an aldehyde group and an alpha-hydroxy ketone or methyl ketone.
Compound C does not give Fehling test but forms iodoform test (yellow precipitate) indicating presence of methyl ketone.
Ozonolysis of alkene breaks C=C bond giving aldehyde or ketone products.
Possible A: 2-methylbut-2-ene (C_5H_{10})
Ozonolysis of 2-methylbut-2-ene yields methyl ethyl ketone (C_4H_8O) and ethanal (C_2H_4O).
Here, B is ethanal (positive Fehling and iodoform test), C is methyl ethyl ketone (positive iodoform, no Fehling).
Alternatively, A could be pent-2-ene.
Hence,
A: pent-2-ene (C_5H_{10})
B: ethanal (gives positive Fehling and iodine test)

C: propanone (gives iodoform test, no Fehling)
This fits the test data and molecular weights.

Summary:
(a)(i) Ethanal to But-2-enal by aldol condensation using dilute NaOH and heat.
(a)(ii) Propanoic acid to ethane by decarboxylation using soda lime.
(b) A: pent-2-ene; B: ethanal; C: propanone.

Question 39. An organic compound (A) (molecular formula $C_8H_{18}O_2$) was hydrolyzed with dilute sulfuric acid to get a carboxylic acid (B) and an alcohol (C). Oxidation of (C) with chromic acid produced (B). (C) on dehydration gives But-1-ene. Identify (A), (B), and (C) and write chemical equations for the reactions involved.

[5 Marks]

Answer: Answer:
(a) Identification of compounds:
Compound (A) has the molecular formula C8H18O2 and undergoes acid hydrolysis to give a carboxylic acid (B) and an alcohol (C). Given that oxidation of (C) with chromic acid produces (B), and (C) on dehydration gives But-1-ene, (C) must be Butan-1-ol (CH3CH2CH2CH2OH). The carboxylic acid (B) produced by oxidation of (C) is Butanoic acid (CH3CH2CH2COOH).
Thus, (A) is an ester formed from Butanoic acid and Butan-1-ol. The molecular formula fits Butyl butanoate (CH3CH2CH2COOCH2CH2CH2CH3).

(b) Chemical reactions involved:
1. Hydrolysis of ester (A) with dilute H2SO4:
CH3CH2CH2COOCH2CH2CH2CH3 + H2O --(H2SO4/dil)--> CH3CH2CH2COOH (B) + CH3CH2CH2CH2OH (C)

2. Oxidation of alcohol (C) with chromic acid:
CH3CH2CH2CH2OH + [O] --(CrO3/H2SO4)--> CH3CH2CH2COOH (B)

3. Dehydration of alcohol (C) gives But-1-ene:
CH3CH2CH2CH2OH --(conc H2SO4, heat)--> CH2=CHCH2CH3 + H2O

Summary:
(A) - Butyl butanoate (C8H18O2)
(B) - Butanoic acid (C4H8O2)
(C) - Butan-1-ol (C4H10O)
The reactions show hydrolysis of ester to acid and alcohol, oxidation of alcohol to acid, and dehydration of alcohol to alkene.