CUET 2026 May 18 Shift 1 Chemistry

Question Paper (Memory-Based) with Solutions

Conducted by National Testing Agency (NTA)

General Instructions

(i) The examination will be conducted in Computer-Based Test (CBT) mode.

(ii) Each question carries +5 marks for correct answer and -1 mark for wrong answer.

(iii) The total number of questions are 50.

(iv) Duration of the exam is 1 hour (60 minutes).

1. The Henry's law constant (K_H) values for four gases W, X, Y, and Z in water at 298 K are 4.0×10^4, 2.5×10^{-2}, 1.5×10^3, and 8.0×10^1 bar, respectively. What is the correct order of their solubility in water under the same partial pressure?

(A) $W > Y > Z > X$

(B) $X > Z > Y > W$

(C) $X > Y > Z > W$

(D) $W > Z > Y > X$

Correct Answer: (B) $X > Z > Y > W$

Solution:

Concept: According to Henry's Law, the solubility of a gas in a liquid is directly proportional to the partial pressure of that gas above the surface of the liquid. Mathematically, this relation is expressed as:

$$p = K_H \cdot x$$

Where:

- p is the partial pressure of the gas in the vapor phase.
- K_H is the Henry's law constant for the specific gas-solvent system.

- x is the mole fraction of the dissolved gas in the solution (representing its solubility).

Rearranging the fundamental equation to isolate the solubility term (x) yields:

$$x = \frac{p}{K_H}$$

This expression mathematically demonstrates that at a fixed or constant partial pressure (p), the solubility (x) of a gas is inversely proportional to its Henry's law constant (K_H). Consequently, a higher value of K_H implies a lower mole fraction of the gas in the solution phase.

Step 1: Comparing the given values of Henry's law constant (K_H) for each gas.
The specific numerical values given for the constants at 298 K are:

$$K_H(W) = 4.0 \times 10^4 \text{ bar}$$
$$K_H(X) = 2.5 \times 10^{-2} \text{ bar}$$
$$K_H(Y) = 1.5 \times 10^3 \text{ bar}$$
$$K_H(Z) = 8.0 \times 10^1 \text{ bar}$$

Arranging these numerical constants in a strictly increasing sequence based on their exponents and magnitudes gives:

$$2.5 \times 10^{-2} < 8.0 \times 10^1 < 1.5 \times 10^3 < 4.0 \times 10^4$$

$$\text{Therefore: } K_H(X) < K_H(Z) < K_H(Y) < K_H(W)$$

Step 2: Inverting the order to find the decreasing sequence of gas solubility.
Because solubility (x) shares an inverse physical relationship with K_H ($x \propto 1/K_H$), the gas with the absolute lowest constant will exhibit the highest capacity to dissolve. Inverting the inequality chain established in Step 1 establishes the final relative solubility order:

$$x_X > x_Z > x_Y > x_W$$

Hence, the correct decreasing order of solubility under identical pressure conditions is $X > Z > Y > W$.

Quick Tip: For gas solubility problems, always remember: Higher $K_H \Rightarrow$ Lower solubility at a given pressure.

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2. Which of the following organic compounds is expected to have the highest boiling point?

(A) $CH_3CH_2CH_2CH_2OH$

(B) $CH_3CH_2CH_2CHO$

(C) $CH_3CH_2CH_2CH_2CH_3$

(D) $CH_3CH_2OCH_2CH_3$

Correct Answer: (A) $CH_3CH_2CH_2CH_2OH$

Solution:

Concept: The boiling point of volatile organic molecules reflects the quantity of kinetic thermal energy needed to completely separate condensed molecules into the gas phase. This physical property is governed by the structural type and cumulative strength of intermolecular forces holding the liquid phase together. When comparing organic molecules with highly similar molecular weights, the relative hierarchy of boiling points follows the sequence of baseline intermolecular forces:

$$\text{Intermolecular Hydrogen Bonding} > \text{Dipole-Dipole Interaction} > \text{London Dispersion Forces}$$

Step 1: Identifying the active functional groups and matching their intermolecular forces.

We analyze the structural features of each molecular choice:

- **Butan-1-ol** ($CH_3CH_2CH_2CH_2OH$): Contains a strongly polarized hydroxyl ($-OH$) functional group. The presence of a hydrogen atom covalently attached to highly electronegative oxygen permits extensive intermolecular hydrogen bonding.
- **Butanal** ($CH_3CH_2CH_2CHO$): Features a polar carbonyl group ($-C=O$). This structure gives rise to fixed molecular dipoles that interact via dipole-dipole attractions, which are weaker than hydrogen bonds.
- **Ethoxyethane** ($CH_3CH_2OCH_2CH_3$): An asymmetrical ether containing a polar C-O-C framework. It exhibits mild dipole-dipole interactions but lacks any hydrogen atoms bonded to oxygen to support self-hydrogen bonding.

- **Pentane** ($CH_3CH_2CH_2CH_2CH_3$): A completely nonpolar saturated hydrocarbon with a uniform electron cloud, operating strictly via temporary London dispersion forces.

Step 2: Evaluating force magnitudes to isolate the compound with the maximum boiling point. Intermolecular hydrogen bonds are significantly stronger than basic dipole-dipole attractions or weak dispersion forces. Because Butan-1-ol possesses the capability to form a network of hydrogen bonds between its molecules, it requires a much higher temperature to overcome these cohesive forces and transition into the gas phase. Therefore, Butan-1-ol has the highest boiling point among the given options.

Quick Tip: When molecular masses are similar, alcohols will almost always outboil aldehydes, ethers, and hydrocarbons due to extensive hydrogen bonding.

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3. Why do aquatic species, such as fish, generally feel more comfortable in cold water than in warm water?

(A) The solubility of oxygen gas increases as the temperature of the water decreases.

(B) The solubility of oxygen gas decreases as the temperature of the water decreases.

(C) The Henry's law constant (K_H) for oxygen decreases as temperature increases.

(D) Warm water contains more dissolved toxic gases that harm aquatic metabolism.

Correct Answer: (A) The solubility of oxygen gas increases as the temperature of the water decreases.

Solution:

Concept: The process of dissolving gaseous solutes into liquid solvents represents a phase transition that achieves dynamic chemical equilibrium. When a gas dissolves, its individual molecules contract from a high-volume gas state into a restricted dissolved state, releasing kinetic energy. As a result, gas dissolution is universally classified as an exothermic physical process:

$$\text{Gas(g)} + \text{Liquid Solvent(l)} \rightleftharpoons \text{Dissolved Solution(aq)} + \text{Heat} \quad (\Delta H < 0)$$

We use Le Chatelier's principle to evaluate how thermal energetic changes force this equilibrium to shift.

Step 1: Applying Le Chatelier's principle to the exothermic dissolution equation under cold conditions.

Le Chatelier's principle states that if a dynamic system at equilibrium experiences a temperature change, the position of the equilibrium shifts to counteract that change. When the ambient temperature of the aqueous system decreases (as seen in cold water), the system responds by attempting to generate thermal energy. To accomplish this, the equilibrium shifts toward the exothermic forward direction (to the right).

Step 2: Connecting the equilibrium shift to the breathing comfort of aquatic species.

The forward shift drives a larger mass of gaseous oxygen molecules to dissolve into the liquid phase. Consequently, cold water retains a substantially higher concentration of dissolved oxygen (DO) than warm water. Because fish and other aquatic species rely on extracting dissolved oxygen from water via their gills for respiration, the higher concentration of available oxygen makes cold water significantly more favorable and comfortable for their survival.

Quick Tip: Gas dissolution is exothermic ($\Delta H < 0$). Therefore, gas solubility decreases with an increase in temperature.

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4. What are the starting materials used in the industrial synthesis of the pesticide DDT?

(A) Chlorobenzene and Chloroform

(B) Chlorobenzene and Chloral

(C) Benzene and Chloral

(D) Chlorobenzene and Hexachloroethane

Correct Answer: (B) Chlorobenzene and Chloral

Solution:

Concept: DDT, or dichlorodiphenyltrichloroethane, is prepared through an acid-catalyzed condensation pathway that follows an electrophilic aromatic substitution mechanism (S_EAr). The structural formula of DDT features two distinct halobenzene rings linked directly to a central chlorinated alkane backbone. To synthesize this framework, a highly reactive chlorinated carbonyl compound is required to serve as the structural core and source of the electrophile.

Step 1: Generating the electrophilic intermediate from the carbonyl precursor.

The synthesis utilizes trichloroacetaldehyde, commonly referred to as **chloral** (CCl_3CHO). In the presence of a strong dehydrating acid catalyst like concentrated sulfuric acid (H_2SO_4), the carbonyl oxygen of chloral becomes protonated. This protonation increases the electrophilic character of the carbonyl carbon, creating a highly reactive intermediate capable of attacking aromatic rings.

Step 2: Condensing the electrophile with the aromatic halide to finalize the DDT structure.

The activated intermediate undergoes successive electrophilic attacks by two separate molecules of **chlorobenzene**. The positions para to the chlorine atoms on the chlorobenzene rings act as the nucleophilic sites attacking the central carbon. As the condensation reaction proceeds, a molecule of water is eliminated (H_2O), locking the two chlorobenzene groups and the trichloroethane fragment into a single molecule:

$$2\,C_6H_5Cl + CCl_3CHO \xrightarrow{\text{conc. } H_2SO_4} (Cl\text{-}C_6H_4)_2CH\text{-}CCl_3 + H_2O$$

Thus, the industrial starting components are chlorobenzene and chloral.

Quick Tip: Remember the formula: $2 \times \text{Chlorobenzene} + 1 \times \text{Chloral} \xrightarrow{H_2SO_4} \text{DDT} + H_2O$.

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5. Which of the following statements is TRUE regarding the transition state of a bimolecular nucleophilic substitution (S_N2) reaction?

(A) The central carbon atom transitions to an sp^3 hybridization state with a tetrahedral geometry.

(B) The central carbon atom adopts an unstable pentacoordinate arrangement with approximate sp^2 hybridization.

(C) The reaction forms a stable, isolation-ready carbocation intermediate.

(D) Both the nucleophile and the leaving group carry full, non-interacting formal charges.

Correct Answer: (B) The central carbon atom adopts an unstable pentacoordinate arrangement with approximate sp^2 hybridization.

Solution:

Concept: The S_N2 pathway operates via a concerted, single-step mechanism. Unlike stepwise substitutions, it does not involve the formation of any distinct, low-energy intermediates such as carbocations. Instead, bond-making between the incoming nucleophile and the substrate occurs simultaneously with bond-breaking of the leaving group. This coordinated process passes through an unstable, high-energy transition state configuration.

Step 1: Analyzing the synchronous geometry and bond configuration of the reaction center.
During an S_N2 attack, the nucleophile approaches the substrate from the side directly opposite the leaving group (180° back-side attack) to minimize electrostatic repulsion. At the peak of the transition state, the bond to the incoming nucleophile ($Nu^{\delta-}$) is partially formed, while the bond to the departing leaving group ($LG^{\delta-}$) is partially broken. This arrangement forces the central carbon atom to coordinate temporarily with five separate groups at the same time.

Step 2: Determining the transient hybridization state and electronic geometry.
Because the partial bonds to the nucleophile and leaving group lie along a single linear axis, the central carbon uses its remaining unhybridized p-orbital to interact with them. The other three stable, non-reacting substituent bonds are pushed away and flatten out into a single perpendicular plane. This planar arrangement uses three sp^2 hybrid orbitals separated by 120° angles. This creates an unstable pentacoordinate carbon center with a trigonal bipyramidal geometry in the transition state.

Quick Tip: The S_N2 mechanism involves a single concerted transition state (pentacoordinate carbon), while S_N1 proceeds via a distinct carbocation intermediate.

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6. Ethylene glycol (ethane-1,2-diol) is widely added to car radiators as an antifreeze agent. How does its addition protect the engine in extreme climates?

(A) It raises the freezing point of water and lowers its boiling point.

(B) It lowers the freezing point of water and raises its boiling point.

(C) It lowers both the freezing point and the boiling point of water equally.

(D) It reacts chemically with the metal radiator walls to reduce thermal expansion.

Correct Answer: (B) It lowers the freezing point of water and raises its boiling point.

Solution:

Concept: When a non-volatile solute is dissolved into a volatile liquid solvent, it changes the physical behavior of the solution. The solute particles occupy space at the liquid surface, decreasing the rate of evaporation and lowering the overall vapor pressure of the solvent. This shift in vapor pressure leads directly to changes in two key colligative properties:

$$\Delta T_f = K_f \cdot m \quad \text{(Depression of Freezing Point)}$$

$$\Delta T_b = K_b \cdot m \quad \text{(Elevation of Boiling Point)}$$

Step 1: Evaluating the physical mechanism behind freezing point depression.

In pure water, molecules readily assemble into a rigid, structured crystalline lattice at 0°C. When ethylene glycol (HO-CH_2-CH_2-OH) is added, its molecules form hydrogen bonds with water, disrupting the regular intermolecular organization of the solvent. To overcome this disruption and force crystallization, thermal energy must be removed from the system. This drops the freezing point significantly below 0°C (ΔT_f), preventing the coolant from freezing and cracking the radiator block in cold climates.

Step 2: Evaluating the physical mechanism behind boiling point elevation.

Simultaneously, because the non-volatile ethylene glycol solute lowers the solution's vapor pressure, a higher temperature is required for the vapor pressure to equal the external atmospheric pressure. This elevates the boiling point of the radiator fluid significantly above 100°C (ΔT_b). Together, these two property shifts widen the liquid temperature range of the coolant, protecting the engine from both freezing in winter and boiling over in summer.

Quick Tip: Solute addition expands the liquid temperature range of a solvent by pushing T_f down and pulling T_b up.

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7. Which of the following oxidizing agents is mild enough to selectively oxidize an aldehyde to a carboxylic acid without cleaving other sensitive carbon-carbon single bonds?

(A) Tollens' reagent

(B) Concentrated H_2SO_4 at high temperatures

(C) Ozone followed by Zn / H_2O

(D) $LiAlH_4$ in dry ether

Correct Answer: (A) Tollens' reagent

Solution:

Concept: Aldehydes (R-CHO) are easily oxidized because they possess a reactive hydrogen atom directly bonded to the carbonyl carbon. This structural feature allows them to undergo oxidation under mild conditions. In contrast, ketones ($R\text{-}CO\text{-}R'$) lack this specific carbonyl hydrogen atom, meaning their oxidation requires the cleavage of strong carbon-carbon single bonds under harsh conditions. Consequently, mild laboratory oxidizing agents can selectively oxidize aldehydes while leaving ketones and other functional groups untouched.

Step 1: Analyzing the chemical behavior of Tollens' reagent as a selective oxidant.

Tollens' reagent is an aqueous alkaline solution containing the diamminesilver(I) coordination complex, formulated as $[Ag(NH_3)_2]^+$. The silver ions (Ag^+) in this complex serve as a gentle, mild electron acceptor. When mixed with an aldehyde, Tollens' reagent selectively targets and oxidizes the carbonyl carbon, transforming the aldehyde group into a carboxylate anion ($R\text{-}COO^-$):

$$R\text{-}CHO + 2[Ag(NH_3)_2]^+ + 3OH^- \rightarrow R\text{-}COO^- + 2Ag(s)\downarrow + 4NH_3 + 2H_2O$$

Step 2: Ruling out alternative aggressive or reducing reagents.

We evaluate the alternative choices to confirm selectivity:

- Hot concentrated H_2SO_4 acts as a powerful, non-selective oxidizing and dehydrating agent that causes widespread decomposition.
- Ozone (O_3) followed by a zinc workup is used to cleave carbon-carbon double bonds in alkenes rather than selectively oxidizing terminal carbonyls.
- $LiAlH_4$ is a strong reducing agent that performs the opposite transformation, converting carbonyls back into primary alcohols.

Thus, Tollens' reagent is the ideal mild oxidant for this selective transformation.

Quick Tip: Mild oxidants like Tollens' or Fehling's reagents can oxidize aldehydes, but they are not strong enough to oxidize ketones.

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8. What are the primary reagents and catalysts required to carry out the Gattermann-Koch reaction?

(A) CO, HCl, and anhydrous $AlCl_3$ / CuCl

(B) $CHCl_3$ and aqueous NaOH

(C) HCN, HCl, and anhydrous $AlCl_3$

(D) CH_3Cl and anhydrous $AlCl_3$

Correct Answer: (A) CO, HCl, and anhydrous $AlCl_3$ / CuCl

Solution:

Concept: The Gattermann-Koch reaction is a classic organic named reaction used to introduce a formyl functional group (—CHO) directly onto an aromatic ring. This transformation converts benzene or activated benzene derivatives into aromatic aldehydes. Mechanistically, it operates as a variation of a Friedel-Crafts acylation, requiring a gaseous source to generate a highly reactive, short-lived formyl cation intermediate ($[HC=O]^+$).

Step 1: Understanding the generation of the active electrophilic formyl intermediate.

Formyl chloride (HCOCl) is highly unstable and decomposes rapidly at room temperature, meaning it cannot be stored or added directly to a reaction flask. To circumvent this, the Gattermann-Koch reaction generates the necessary electrophilic species *in situ*. A gaseous mixture of carbon monoxide (CO) and hydrogen chloride (HCl) is bubbled into the reaction mixture. In the presence of a strong Lewis acid catalyst like anhydrous aluminum chloride ($AlCl_3$), these components interact to form the transient formyl electrophile.

Step 2: Evaluating the role of the co-catalyst during aromatic substitution.

Because carbon monoxide reactions can be slow under standard conditions, cuprous chloride (CuCl) is added as a vital co-catalyst. The copper(I) center binds temporarily to carbon monoxide, increasing its local concentration and facilitating its reaction with HCl and $AlCl_3$. The resulting formyl cation undergoes an electrophilic aromatic substitution attack on the benzene ring, yielding benzaldehyde:

$$C_6H_6 + CO + HCl \xrightarrow{\text{anhydrous } AlCl_3/CuCl} C_6H_5CHO + HCl$$

This confirms option (A) as the correct reagent combination.

Quick Tip: Distinction: Gattermann-Koch uses CO+HCl, whereas the standard Gattermann formylation utilizes HCN + HCl.

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9. Among the given pairs of isomeric organic compounds, which pair is correctly arranged in order of INCREASING boiling point?

(A) n-Butyl alcohol < t-Butyl alcohol

(B) t-Butyl chloride < n-Butyl chloride

(C) p-Dichlorobenzene < o-Dichlorobenzene

(D) Isopentane < Neopentane

Correct Answer: (B) t-Butyl chloride < n-Butyl chloride

Solution:

Concept: For structural isomers sharing identical molecular formulas and molecular weights, variations in boiling point are governed by molecular shape and branching. Nonpolar or weakly polar covalent molecules rely on temporary London dispersion forces, which depend directly on the total accessible molecular surface area. The relationship between molecular structure and boiling point follows a reliable trend:

$$\text{Increased Branching} \Rightarrow \text{Spherical Shape} \Rightarrow \text{Smaller Surface Area} \Rightarrow \text{Weaker Dispersion Forces} \Rightarrow \text{Lower Bo}$$

Step 1: Analyzing the structural differences between butyl chloride isomers.

We compare the straight-chain and branched isomers of butyl chloride:

- **t-Butyl chloride** ($(CH_3)_3C\text{-}Cl$): Features a highly branched, compact, and nearly spherical geometry. This spherical shape minimizes the outer surface area available for contact with neighboring molecules.

- *n*-**Butyl chloride** ($CH_3CH_2CH_2CH_2Cl$): Possesses a fully extended, linear, straight-chain hydrocarbon conformation that provides a significantly larger molecular surface area.

Step 2: Correlating surface area to the final boiling point inequality.

The larger surface area of linear *n*-butyl chloride allows neighboring molecules to align closely, maximizing the strength of intermolecular London dispersion forces. Conversely, the compact shape of *t*-butyl chloride limits molecular contact, weakening these temporary attractions. Consequently, *t*-butyl chloride boils at a significantly lower temperature (324 K) than *n*-butyl chloride (351 K). This confirms that the arrangement *t*-butyl chloride < *n*-butyl chloride correctly demonstrates a trend of increasing boiling point.

Quick Tip: As molecular branching increases ⇒ Surface area decreases ⇒ Van der Waals forces weaken ⇒ Boiling point drops.

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10. When benzaldehyde is subjected to oxidation using acidified potassium permanganate ($KMnO_4$), what organic product is formed?

(A) Benzyl alcohol

(B) Benzoic acid

(C) Benzene

(D) Acetophenone

Correct Answer: (B) Benzoic acid

Solution:

Concept: Aromatic aldehydes are highly susceptible to oxidation due to the presence of the single carbon-hydrogen bond on the formyl carbonyl group ($-CHO$). When treated with a powerful transition metal oxidant, this carbonyl C-H bond is cleaved and converted into a carbon-hydroxyl (C-OH) bond. This process transforms the aldehyde functional group into a stable carboxylic acid derivative.

Step 1: Evaluating the chemical behavior of the strong oxidant with benzaldehyde.

Potassium permanganate ($KMnO_4$) under acidified conditions (H_2SO_4) serves as an exceptionally strong, non-selective oxidizing agent. The manganese center in the permanganate anion

(MnO_4^-) is in its highest oxidation state (+7) and acts as an efficient electron acceptor. When introduced to benzaldehyde (C_6H_5CHO), the reagent readily attacks the formyl carbon atom, oxidizing the functional group to form a carboxylic acid.

Step 2: Determining the final structure of the aromatic product.

The oxidation converts the formyl group ($-CHO$) directly into a carboxylic acid group ($-COOH$) attached to the benzene ring. The aromatic core remains completely intact throughout this transformation, as the benzene ring is stabilized by resonance and resists oxidative cleavage. The resulting organic product is **benzoic acid** (C_6H_5COOH):

$$C_6H_5CHO \xrightarrow{\text{Acidified } KMnO_4} C_6H_5COOH$$

This confirms option (B) as the correct choice.

Quick Tip: Whether using mild (Tollens') or strong ($KMnO_4$) oxidizing agents, aldehydes consistently convert into their corresponding carboxylic acids.