

CUET 2026 Chemistry May 24 Shift 1

Question Paper with Solutions

Conducted by National Testing Agency (NTA)



General Instructions

- (i) The examination was 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. Water movement from soil into plant roots and subsequently into upper portion of the plant is partly due to phenomenon of

- (A) Edema
- (B) Osmosis
- (C) Reverse Osmosis
- (D) Evaporation

Correct Answer: (B) Osmosis

Solution:

Concept:

Osmosis is the spontaneous net movement of solvent molecules through a selectively permeable membrane from a region of lower solute concentration (higher solvent potential) to a region of higher solute concentration (lower solvent potential).

In biological systems, osmosis plays a fundamental role in maintaining cellular turgidity and driving fluid transport across cellular boundaries.

Step 1: Identifying the Concentration Gradient:

The soil surrounding the plant roots contains moisture with a very low concentration of dissolved inorganic minerals, functioning as a dilute solution.

In contrast, the fluid inside the root hair cells (cell sap within the central vacuole) contains a relatively higher concentration of dissolved sugars, organic acids, and inorganic salts.

This establishes a steep water potential gradient between the soil water and the internal cellular fluid of the root hairs.

Step 2: Mechanism of Water Influx Across the Root Membrane:

The plasma membrane of root epidermal cells acts as a natural semi-permeable membrane.

Because of the difference in osmotic potential, water molecules move spontaneously from the soil solution into the root epidermal cells via endosmosis.

This continuous influx builds up positive hydrostatic pressure within the root cells, commonly designated as root pressure, which assists in pushing the absorbed water upward through the xylem conduits.

Step 3: Analysis of Incorrect Options:

Edema represents an abnormal accumulation of fluid within animal body tissues resulting in localized swelling, which is completely irrelevant to plant physiology.

Reverse osmosis is an artificial non-spontaneous process where an external pressure exceeding the osmotic pressure is applied to force solvent from high to low concentration.

Evaporation contributes to the transpiration pull at the leaf surfaces, but the primary phenomenon driving water entry and cellular movement in the roots is osmosis.

Final Answer:

Hence, the movement of water from soil into plant roots is partly due to osmosis, which corresponds to option (B).

Quick Tip: Remember that the initial absorption of water by root hairs is driven by osmosis, while the high-altitude ascent in tall trees is supplemented by transpiration pull.

2. Which of the following compound is used as paint remover?

- (A) Methylene chloride
- (B) Iodoform
- (C) Chloroform
- (D) 2,4-dinitrophenylhydrazine

Correct Answer: (A) Methylene chloride

Solution:

Concept:

Polyhalogen compounds are organic molecules that contain more than one halogen atom per molecule.

Many polyhalogen derivatives of methane and ethane possess unique solvency properties, moderate boiling points, and volatility, making them industrially valuable as solvents, degreasers, propellants, and strippers.

Step 1: Chemical Nature of Methylene Chloride:

Methylene chloride is the common name for dichloromethane, having the chemical formula CH_2Cl_2 .

It is a colorless, volatile chlorinated hydrocarbon liquid with a moderately sweet aroma and high dissolving power for synthetic resins, varnishes, and polymers.

Step 2: Industrial Application as a Paint Remover:

Due to its high chemical stability, non-flammability under standard conditions, and ability to penetrate and swell cross-linked paint films, methylene chloride is extensively utilized as the primary active solvent in commercial paint strippers and paint removers.

It rapidly breaks the adhesion between the paint film and the underlying substrate, allowing old coatings to be scraped away easily.

It is also utilized as a process solvent in the pharmaceutical industry and as an aerosol propellant.

Step 3: Evaluating Alternative Reagents:

Iodoform (CHI_3) was historically employed as an antiseptic because of the gradual liberation

of elemental iodine, not as an industrial solvent.

Chloroform (CHCl_3) was historically an anesthetic and is currently used in the synthesis of R-22 refrigerant.

2,4-Dinitrophenylhydrazine is an analytical reagent (Brady's reagent) utilized solely for detecting carbonyl functionalities in aldehydes and ketones.

Final Answer:

Therefore, the compound used commercially as a paint remover is methylene chloride, corresponding to option (A).

Quick Tip: Standard NCERT Industrial Uses:

CH_2Cl_2 : Paint remover, metal degreasing solvent.

CHCl_3 : Freon (R-22) manufacturing.

CHI_3 : Antiseptic powder.

CCl_4 : Fire extinguisher (Pyrene) and solvent.

3. 2-Bromopentane reacts with alcoholic KOH to form major product as:

- (A) Pent-1-ene
- (B) Pent-2-ene
- (C) Pent-3-ene
- (D) Pent-1-ene and Pent-2-ene

Correct Answer: (B) Pent-2-ene

Solution:

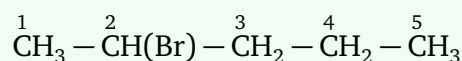
Concept:

When haloalkanes containing β -hydrogen atoms are heated with a strong base such as alcoholic potassium hydroxide (alc. KOH), they undergo a β -elimination reaction (dehydrohalogenation) to produce alkenes.

The regiochemical outcome of this elimination is governed by Zaitsev's (Saytzeff's) rule.

Step 1: Identifying the Substrate and Reaction Centers:

The chemical structure of 2-bromopentane is given by:



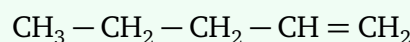
The bromine atom is bonded to the α -carbon (C2).

There are two non-equivalent adjacent carbons bearing β -hydrogens:

1. The primary β_1 -carbon at C1 containing three hydrogen atoms.
2. The secondary β_2 -carbon at C3 containing two hydrogen atoms.

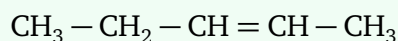
Step 2: Analysis of Competing Elimination Pathways:

Elimination of hydrogen from the C1 carbon and bromine from C2 yields pent-1-ene:



This alkene possesses only one alkyl substituent attached to the double bond (a monosubstituted alkene).

Alternatively, elimination of hydrogen from the C3 carbon and bromine from C2 yields pent-2-ene:



This alkene possesses two alkyl substituents attached to the double bond (a disubstituted alkene).

Step 3: Application of Zaitsev's Rule:

According to Zaitsev's rule, the predominant product in a dehydrohalogenation elimination is the more highly substituted alkene because it has greater hyperconjugative stabilization.

Pent-2-ene contains five hyperconjugative α -hydrogens, making it thermodynamically significantly more stable than pent-1-ene, which contains only two hyperconjugative α -hydrogens. Consequently, pent-2-ene forms as the major product (approximately 81%), whereas pent-1-ene forms as the minor product.

Final Answer:

The major product formed is pent-2-ene, which corresponds to option (B).

Quick Tip: With small bases like alc. KOH, OH^- , or OEt^- , Zaitsev's rule gives the more substituted alkene as major.

Bulky hindered bases like potassium tert-butoxide give the Hofmann (less substituted) alkene as major.

4. Which of the following salts would have the same value of the van't Hoff factor as that of $\text{Al}(\text{NO}_3)_3$ in aqueous solution?

Assume complete dissociation of electrolytes.

- (A) K_2SO_4
- (B) KCl
- (C) $\text{Al}_2(\text{SO}_4)_3$
- (D) $\text{K}_3[\text{Fe}(\text{CN})_6]$

Choose the correct answer from the options given below:

- (A) (A) and (B) only
- (B) (B) and (C) only
- (C) (D) only
- (D) (C) and (D) only

Correct Answer: (C) (D) only

Solution:**Concept:**

The van 't Hoff factor (i) accounts for the extent of dissociation or association of a solute in solution.

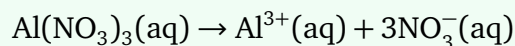
For an electrolyte that undergoes complete ionic dissociation in aqueous medium, the van 't Hoff factor equals the total number of ions produced per formula unit of the substance:

$$i = n$$

where n is the number of constituent cations and anions released into solution.

Step 1: Dissociation of Aluminum Nitrate:

Aluminum nitrate, $\text{Al}(\text{NO}_3)_3$, dissociates completely in water as follows:



The total number of ions produced per formula unit is:

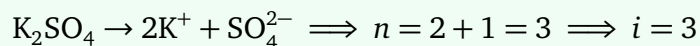
$$n = 1 \text{ (for } \text{Al}^{3+}) + 3 \text{ (for } \text{NO}_3^{-}) = 4$$

Therefore, the van 't Hoff factor for $\text{Al}(\text{NO}_3)_3$ is $i = 4$.

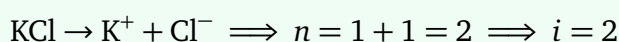
Step 2: Dissociation of the Given Salts:

Let us evaluate the dissociation behavior and calculate the value of i for each salt:

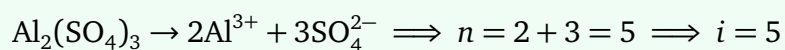
- Compound (A): K_2SO_4 dissociates as:



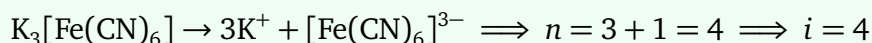
- Compound (B): KCl dissociates as:



- Compound (C): $\text{Al}_2(\text{SO}_4)_3$ dissociates as:



- Compound (D): $\text{K}_3[\text{Fe}(\text{CN})_6]$ is a coordination compound. The complex coordination sphere remains intact in solution, releasing only the ionizable counter-ions:



Step 3: Comparison and Matching:

Comparing the van 't Hoff factors shows that only salt (D), $\text{K}_3[\text{Fe}(\text{CN})_6]$, has $i = 4$, which is identical to that of $\text{Al}(\text{NO}_3)_3$.

Final Answer:

Thus, the salt with the same van 't Hoff factor is (D) only, corresponding to option (C).

Quick Tip: Always remember that ions inside the square brackets [...] of a coordination sphere do not ionize in water.

Only external counter ions dissociate along with the complex ion entity itself.

5. Which of the following statements are true for the elevation of boiling point?

(A) The boiling point of a solution is always higher than the boiling point of the pure solvent in which the solution is prepared.

(B) The boiling point of a solution is always lower than the boiling point of the pure solvent in which the solution is prepared.

(C) The elevation of boiling point is directly proportional to the molal concentration of the solute in solution.

(D) Unit of $K_b = \text{K kg mol}^{-1}$

Choose the correct answer from the options given below:

(A) (A), (B) and (D) only

(B) (B), (C) and (D) only

(C) (A), (B), (C) and (D)

(D) (A), (C) and (D) only

Correct Answer: (D) (A), (C) and (D) only

Solution:**Concept:**

The addition of a non-volatile solute to a volatile solvent lowers the escaping tendency and vapor pressure of the solvent.

Because a liquid boils when its vapor pressure equals the prevailing external atmospheric

pressure, the solution must be heated to a higher temperature than the pure solvent, leading to elevation of boiling point (ΔT_b).

Step 1: Evaluation of Statements Regarding Boiling Point Comparison:

Because non-volatile solute particles occupy part of the liquid surface, the equilibrium vapor pressure of the solution is lower than that of the pure liquid at all temperatures.

Consequently, a higher temperature is required for the solution to reach atmospheric pressure, meaning:

$$T_b > T_b^\circ$$

where T_b is the boiling point of the solution and T_b° is that of the pure solvent.

Hence, statement (A) is correct, while statement (B) is incorrect.

Step 2: Proportionality to Solute Concentration:

For dilute solutions, thermodynamic derivation shows that the elevation in boiling point is directly proportional to the molality (m) of the dissolved solute:

$$\Delta T_b \propto m \implies \Delta T_b = K_b \cdot m$$

where K_b is the molal elevation constant or ebullioscopic constant.

Hence, statement (C) is correct.

Step 3: Verification of the Unit of K_b :

From the relation $K_b = \frac{\Delta T_b}{m}$, we express the units as:

$$\text{Unit of } K_b = \frac{\text{K}}{\text{mol kg}^{-1}} = \text{K kg mol}^{-1}$$

Hence, statement (D) is correct.

Final Answer:

The true statements are (A), (C), and (D), which corresponds to option (D).

Quick Tip: Both the ebullioscopic constant (K_b) and cryoscopic constant (K_f) have the exact same unit: K kg mol^{-1} (or K m^{-1}).

Solute addition increases boiling point ($\Delta T_b > 0$) but lowers freezing point ($\Delta T_f < 0$).

6. Match List-I with List-II

List-I	List-II
(A) Osmotic pressure	(I) Formation of bubbles of nitrogen in the blood
(B) Anoxia	(II) Pressure applied on the solution side that just stops the flow of solvent
(C) Bends	(III) Impermeable to impurities
(D) Cellulose acetate	(IV) Low blood oxygen causes climbers to become weak

Choose the correct answer from the options given below:

- (A) (A) - (I), (B) - (II), (C) - (III), (D) - (IV)
(B) (A) - (II), (B) - (I), (C) - (IV), (D) - (III)
(C) (A) - (II), (B) - (IV), (C) - (I), (D) - (III)
(D) (A) - (III), (B) - (IV), (C) - (I), (D) - (II)

Correct Answer: (C) (A) - (II), (B) - (IV), (C) - (I), (D) - (III)

Solution:

Concept:

Colligative properties and solubility phenomena governed by Henry's law have extensive real-world physiological and industrial applications, ranging from cellular transport and underwater diving to mountain sickness and water purification.

Step 1: Matching Osmotic Pressure:

Osmotic pressure is experimentally defined as the minimum excess pressure applied to the solution chamber to completely halt the spontaneous inflow of solvent molecules across a semi-permeable membrane.

Therefore, entry (A) matches with item (II).

Step 2: Matching Anoxia and Altitude Physiology:

At elevated altitudes, the atmospheric pressure and partial pressure of oxygen are significantly lower than at sea level.

According to Henry's law, this leads to a lower concentration of dissolved oxygen in the blood and brain of climbers, producing cognitive impairment and physical weakness, a condition called anoxia.

Therefore, entry (B) matches with item (IV).

Step 3: Matching Bends in Scuba Diving:

When deep-sea divers dive underwater, increased hydrostatic pressure increases the solubility of atmospheric gases in their blood.

Upon rapid ascent, the pressure abruptly drops, causing dissolved nitrogen gas to come out of solution rapidly as gas bubbles that obstruct microcapillaries, causing a painful condition known as bends.

Therefore, entry (C) matches with item (I).

Step 4: Matching Cellulose Acetate:

Cellulose acetate is a semipermeable synthetic membrane employed in the reverse osmosis desalination of seawater.

It allows small water molecules to pass freely while being impermeable to ionic impurities, salts, and hydrated solutes.

Therefore, entry (D) matches with item (III).

Final Answer:

The resulting matched sequence is (A)-(II), (B)-(IV), (C)-(I), (D)-(III), corresponding to option (C).

Quick Tip: Henry's Law applications:

- Deep-sea divers breathe helium-diluted air to prevent bends.
- High altitude climbers experience anoxia due to low pO_2 .

Reverse osmosis utilizes cellulose acetate membranes.

7. Match List-I with List-II

List-I	List-II
Type of solution	Example
(A) Ideal solution	(I) 95% by volume of ethanol
(B) Positive deviation from Raoult's law	(II) Bromoethane and chloroethane
(C) Negative deviation from Raoult's law	(III) Ethanol and acetone
(D) Azeotrope	(IV) Phenol and aniline

Choose the correct answer from the options given below:

- (A) (A) - (II), (B) - (IV), (C) - (III), (D) - (I)
(B) (A) - (II), (B) - (III), (C) - (IV), (D) - (I)
(C) (A) - (I), (B) - (III), (C) - (II), (D) - (IV)
(D) (A) - (III), (B) - (IV), (C) - (I), (D) - (II)

Correct Answer: (B) (A) - (II), (B) - (III), (C) - (IV), (D) - (I)

Solution:

Concept:

Binary liquid mixtures are categorized by their vapor pressure behavior relative to Raoult's law, which depends on the relative magnitudes of adhesive (A-B) versus cohesive (A-A and B-B) intermolecular interactions.

Step 1: Identifying the Ideal Solution:

An ideal solution forms when intermolecular interactions between unlike components are nearly identical to those between like molecules ($A-B \approx A-A \approx B-B$), resulting in $\Delta H_{\text{mix}} = 0$ and $\Delta V_{\text{mix}} = 0$.

Bromoethane ($\text{C}_2\text{H}_5\text{Br}$) and chloroethane ($\text{C}_2\text{H}_5\text{Cl}$) have similar molecular sizes and polarities, forming a nearly ideal solution.

Therefore, (A) corresponds to (II).

Step 2: Identifying Positive Deviation from Raoult's Law:

Positive deviation occurs when A-B attractive interactions are weaker than A-A or B-B interactions, increasing the tendency of molecules to escape into the vapor phase.

Pure ethanol molecules are associated via hydrogen bonding. When acetone is added, its molecules sit between ethanol molecules and partially break their hydrogen bonds, increasing total vapor pressure.

Therefore, (B) corresponds to (III).

Step 3: Identifying Negative Deviation from Raoult's Law:

Negative deviation occurs when A-B interactions are stronger than A-A and B-B interactions, lowering total vapor pressure.

In a mixture of phenol and aniline, intermolecular hydrogen bonding between the phenolic hydrogen and the lone pair of the aniline nitrogen is stronger than the individual interactions in pure liquids.

Therefore, (C) corresponds to (IV).

Step 4: Identifying the Azeotropic Mixture:

An azeotrope is a liquid mixture of fixed composition that boils at a constant temperature without any change in liquid and vapor composition.

A mixture containing 95% ethanol and 5% water by volume forms a minimum boiling azeotrope that cannot be separated by fractional distillation.

Therefore, (D) corresponds to (I).

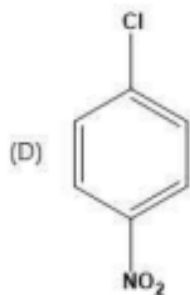
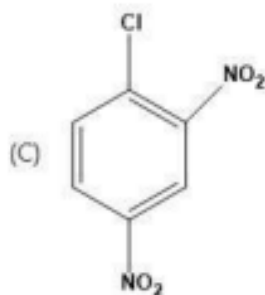
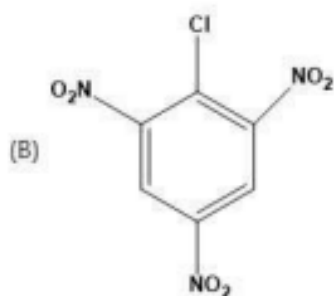
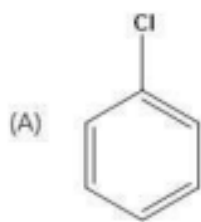
Final Answer:

The matching combination is (A)-(II), (B)-(III), (C)-(IV), (D)-(I), which corresponds to option (B).

Quick Tip: Remember key pairs:

- Ideal: Chloroethane + Bromoethane, Benzene + Toluene.
- Positive deviation: Ethanol + Acetone, CS_2 + Acetone.
- Negative deviation: Phenol + Aniline, Chloroform + Acetone.
- Azeotrope: 95% Ethanol + 5% Water.

8. Arrange the following compounds in increasing order towards nucleophilic substitution reaction.



Choose the correct answer from the options given below:

(A) (A), (B), (C), (D)

(B) (A), (D), (C), (B)

(C) (D), (B), (C), (A)

(D) (B), (A), (C), (D)

Correct Answer: (B) (A), (D), (C), (B)

Solution:

Concept:

Aryl halides are typically unreactive towards nucleophilic aromatic substitution (S_NAr) due to resonance stabilization of the C—Cl bond, sp^2 hybridization of the aromatic carbon, and electronic repulsion from the π -cloud.

However, the presence of strong electron-withdrawing groups ($-NO_2$) at the *ortho* and *para* positions relative to the halogen greatly accelerates substitution by stabilizing the anionic Meisenheimer intermediate through $-M$ and $-I$ effects.

Step 1: Assessing Reactivity of Chlorobenzene:

In chlorobenzene (A), there are no electron-withdrawing substituents on the ring.

The lone pairs on the chlorine atom are delocalized into the aromatic ring, giving the C—Cl bond partial double bond character.

Consequently, chlorobenzene requires severe conditions (623 K, 300 atm) to undergo nucleophilic attack and is the least reactive among the group.

Step 2: Assessing the Effect of Successive Nitro Groups:

In 4-nitrochlorobenzene (D), one $-NO_2$ group is positioned at the *para* position.

During nucleophilic attack, the negative charge delocalizes onto the electronegative oxygen atoms of the *para*-nitro group, facilitating the reaction at a milder temperature (443 K).

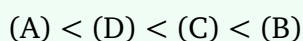
In 2,4-dinitrochlorobenzene (C), two $-NO_2$ groups are present at the *ortho* and *para* positions, providing additional resonance stabilization to the carbanion intermediate and allowing the reaction to proceed smoothly at 368 K.

In 2,4,6-trinitrochlorobenzene (B), three $-NO_2$ groups occupy both *ortho* positions and the *para* position.

This configuration heavily delocalizes the negative charge, making the compound extremely reactive such that substitution occurs simply upon warming with warm water.

Step 3: Ordering by Increasing Reactivity:

Comparing the four compounds, the reactivity towards nucleophiles increases directly with the number of *ortho*- and *para*-nitro substituents:



Final Answer:

The increasing order of reactivity is (A), (D), (C), (B), corresponding to option (B).

Quick Tip: Each additional $-\text{NO}_2$ group at an *ortho* or *para* position significantly stabilizes the Meisenheimer complex, increasing $\text{S}_{\text{N}}\text{Ar}$ reactivity:

Chlorobenzene (623 K) $\rightarrow$ 4-nitro (443 K) $\rightarrow$ 2,4-dinitro (368 K) $\rightarrow$ 2,4,6-trinitro (warm H_2O).

9. Chloroform oxidizes in the presence of light to

- (A) Phosgene
- (B) Carbon tetrachloride
- (C) Freons
- (D) Methylene chloride

Correct Answer: (A) Phosgene

Solution:**Concept:**

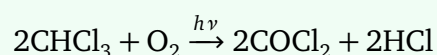
Trihalomethanes are susceptible to radical-induced photo-oxidation upon prolonged exposure to atmospheric air and light.

For chloroform, this photo-oxidation generates a toxic, suffocating gas that poses significant safety and handling concerns.

Step 1: Mechanism of Photo-Oxidation:

When chloroform (CHCl_3) is exposed to atmospheric oxygen in the presence of light, it undergoes homolytic cleavage and auto-oxidation via a free-radical chain reaction.

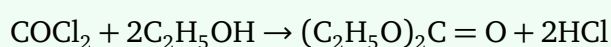
The balanced chemical equation representing this transformation is:



The principal oxidation product obtained is carbonyl chloride, commonly known as phosgene (COCl_2).

Step 2: Chemical Properties of Phosgene and Precautions:

Phosgene is a toxic gas that can cause severe pulmonary edema and respiratory failure. Because of this hazard, chloroform used for medicinal or laboratory applications is stored in completely filled, dark amber-colored bottles to exclude air and prevent light penetration. Additionally, approximately 1% ethanol is added to react with any phosgene formed, converting it into harmless diethyl carbonate:



Step 3: Verification of Options:

The direct oxidation product is carbonyl chloride (phosgene).

Compounds such as carbon tetrachloride (CCl_4), freons (CF_2Cl_2), and methylene chloride (CH_2Cl_2) are produced through alternative synthetic pathways and not by the oxidation of chloroform.

Final Answer:

Thus, chloroform oxidizes in the presence of light to form phosgene, which corresponds to option (A).

Quick Tip: $\text{Chloroform} + \text{O}_2 + \text{sunlight} \rightarrow \text{Phosgene} (\text{COCl}_2) + \text{HCl}$.

Amber bottles keep light out, and adding 1% ethanol converts any phosgene into harmless diethyl carbonate.

10. The constant 'k' in a rate law expression of a reaction is

- (A) is dependent on the concentration of reactants.
- (B) is dimensionless.
- (C) dependent on temperature.
- (D) called the Arrhenius constant.

Correct Answer: (C) dependent on temperature.

Solution:

Concept:

The rate constant (k), also called the specific reaction rate, is the proportionality constant in the rate law equation that relates the rate of a chemical reaction to the molar concentrations of the reactants.

It serves as an intrinsic quantitative measure of the inherent speed of a chemical reaction under fixed experimental conditions.

Step 1: Independence from Reactant Concentration:

In a general rate expression:

$$\text{Rate} = k[A]^x[B]^y$$

When $[A] = [B] = 1 \text{ mol L}^{-1}$, the rate of the reaction equals k .

The value of k is a characteristic property of a given reaction and does not change with varying concentrations of reactants.

Hence, statement (A) is incorrect.

Step 2: Dependence on Reaction Order for Units:

The dimensions of k depend on the overall order n of the reaction:

$$\text{Units of } k = (\text{mol L}^{-1})^{1-n} \text{ s}^{-1}$$

It is dimensionless only when $n = 1$ (where units reduce to s^{-1}), but not in general. Thus, statement (B) is incorrect.

Step 3: Dependence on Temperature via the Arrhenius Law:

The temperature dependence of the rate constant is described by the Arrhenius equation:

$$k = Ae^{-E_a/RT}$$

As temperature increases, the fraction of colliding molecules with kinetic energy exceeding the activation energy E_a increases exponentially, causing k to increase.

Generally, for every 10°C increase in temperature, the rate constant approximately doubles or triples.

Thus, k is strongly dependent on temperature. Hence, statement (C) is correct.

The pre-exponential factor A is the Arrhenius constant, not k , making statement (D) incorrect.

Final Answer:

The constant k is dependent on temperature, which corresponds to option (C).

Quick Tip: The rate constant k changes only with:

1. Temperature (exponential increase via Arrhenius equation).
2. Presence of a catalyst (lowers E_a).

It is completely independent of the concentrations of reactants and products.

11. Match List-I with List -II

List-I	List-II
(Chemical Reactions)	(Characteristic Feature)
(A) Substitution nucleophilic unimolecular	(I) Anti- Markovnikov's product
(B) Electrophilic addition of HX to unsymmetrical alkene	(II) Inversion
(C) Substitution nucleophilic bimolecular	(III) Racemization
(D) Hydroboration oxidation	(IV) Markovnikov's product

Choose the correct answer from the options given below:

- (A) (A) - (II), (B) - (I), (C) - (III), (D) - (IV)
(B) (A) - (II), (B) - (I), (C) - (IV), (D) - (III)
(C) (A) - (III), (B) - (IV), (C) - (II), (D) - (I)
(D) (A) - (III), (B) - (IV), (C) - (I), (D) - (II)

Correct Answer: (C) (A) - (III), (B) - (IV), (C) - (II), (D) - (I)

Solution:

Concept:

Organic transformations show distinct stereochemical and regiochemical outcomes depending on the reaction mechanism, whether proceeding via planar carbocations, concerted backside displacement, or cyclic addition intermediates.

Step 1: Mechanism of Unimolecular Nucleophilic Substitution (S_N1):

The rate-determining step in an S_N1 process is the departure of the leaving group to form a planar, sp^2 -hybridized carbocation.

The incoming nucleophile can attack this planar intermediate from either face with equal probability.

For an optically active substrate, this attack leads to an equimolar mixture of enantiomers, resulting in racemization.

Therefore, (A) matches with (III).

Step 2: Electrophilic Addition of HX to Alkenes:

In the electrophilic addition of hydrogen halides to unsymmetrical alkenes, the electrophilic proton attaches to the carbon atom that already bears the greater number of hydrogen atoms. This pathway proceeds via the more stable carbocation intermediate, yielding the Markovnikov product.

Therefore, (B) matches with (IV).

Step 3: Mechanism of Bimolecular Nucleophilic Substitution (S_N2):

An S_N2 reaction proceeds via a single concerted step in which the nucleophile attacks from the side opposite to the leaving group.

This backside attack turns the tetrahedral geometry inside out, leading to complete inversion of configuration (Walden inversion).

Therefore, (C) matches with (II).

Step 4: Hydroboration-Oxidation of Alkenes:

Hydroboration-oxidation involves the concerted syn-addition of borane (BH_3) across a carbon-carbon double bond, followed by alkaline peroxide oxidation.

Boron bonds to the less hindered, less substituted carbon atom, which upon oxidation produces

an alcohol with anti-Markovnikov regiochemistry.

Therefore, (D) matches with (I).

Final Answer:

The correct matching is (A)-(III), (B)-(IV), (C)-(II), (D)-(I), which corresponds to option (C).

Quick Tip: Key mechanism relationships:

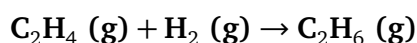
$S_N1 \rightarrow$ Planar carbocation $\rightarrow$ Racemization.

$S_N2 \rightarrow$ Backside displacement $\rightarrow$ Walden Inversion.

HX addition $\rightarrow$ Carbocation stability $\rightarrow$ Markovnikov.

Hydroboration-oxidation $\rightarrow$ Anti-Markovnikov addition of H_2O .

12. Hydrogenation of ethene represented by,



is an example of

- (A) Second order reaction.
- (B) First order reaction.
- (C) Zero-order reaction.
- (D) Third Order reaction.

Correct Answer: (B) First order reaction.

Solution:

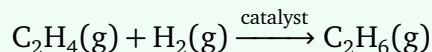
Concept:

The order of a reaction is an experimentally determined quantity reflecting the sum of the powers to which the reactant concentrations are raised in the empirical rate law.

It cannot be deduced solely from the stoichiometric coefficients of the balanced chemical equation.

Step 1: Chemical Equation and Experimental Conditions:

The catalytic hydrogenation of ethene is represented by:



This reaction takes place heterogeneously on the surface of finely divided transition metal catalysts such as platinum, palladium, or Raney nickel.

Step 2: Experimental Rate Law Formulation:

Under typical laboratory and industrial hydrogenation conditions, molecular hydrogen gas is present in large excess, or the catalyst surface is predominantly covered with adsorbed hydrogen atoms.

Consequently, the rate of the reaction depends only on the concentration of ethene in the gas phase.

Experimental kinetic investigations show that the rate law is:

$$\text{Rate} = k[\text{C}_2\text{H}_4]^1$$

Because the exponent of the concentration of ethene is 1, the reaction follows first-order kinetics.

This is explicitly highlighted as a standard example of a first-order reaction in the NCERT Chemical Kinetics curriculum alongside radioactive decay processes.

Step 3: Verification of Other Orders:

Although two molecules appear in the stoichiometry, the reaction does not exhibit second-order kinetics because hydrogen is maintained in excess.

Zero-order behavior typically applies to decompositions on fully saturated surfaces at high pressure (such as NH_3 on Pt), which is not the case here.

Final Answer:

The hydrogenation of ethene is an example of a first order reaction, corresponding to option (B).

Quick Tip: Standard NCERT reaction order examples:

- First order: Hydrogenation of ethene, thermal decomposition of N_2O_5 , radioactive disintegrations.
- Zero order: Decomposition of NH_3 on hot Pt, decomposition of HI on gold at high pressure.

13. Species that are formed in one step of reaction mechanism and used up in another step are called

- (A) catalysts
- (B) inhibitors
- (C) intermediates
- (D) promoters

Correct Answer: (C) intermediates

Solution:

Concept:

Most chemical reactions take place through a sequence of elementary steps rather than in a single step.

The sequence of elementary reactions that leads from reactants to products is defined as the reaction mechanism, which often involves short-lived, transient chemical species.

Step 1: Definition of a Reaction Intermediate:

A reaction intermediate is a chemical species produced during an early elementary step of the mechanism that is subsequently consumed in a later elementary step.

Intermediates possess real physical existence and represent local energy minima on the potential energy diagram of the reaction coordinate.

Because they are consumed in later steps, their net stoichiometry cancels out, and they do not appear in the overall balanced equation for the reaction.

Step 2: Comparison with Other Reaction Components:

A catalyst is introduced with the starting reactants to provide an alternative pathway with a

lower activation energy; it is consumed in an initial step and regenerated in a later step.

An inhibitor is a substance that interacts with reactants, catalysts, or intermediates to decrease the reaction rate.

A promoter is a substance that does not have catalytic activity on its own, but enhances the activity of a catalyst when present.

Step 3: Characterizing Intermediates:

Examples of reaction intermediates include free radicals, carbocations, carbanions, and carbenes.

Because they are generated during the reaction and subsequently used up, they match the description in the question.

Final Answer:

Such species are called intermediates, which corresponds to option (C).

Quick Tip: Remember the difference:

- Catalyst: Added initially, consumed early, regenerated at the end.
- Intermediate: Not added initially, produced in an early step, consumed in a subsequent step.

14. Choose the Incorrect statement from the following:

- (A) Two series of f-block; lanthanoids and actinoids collectively consists of twenty eight elements.
- (B) All the lanthanoids are hard metals
- (C) Actinoid contraction is greater from element to element than lanthanoid contraction
- (D) Actinoids show a greater range of oxidation states than lanthanoids

Correct Answer: (B) All the lanthanoids are hard metals

Solution:

Concept:

The f-block elements consist of two series, the lanthanoids ($4f$) and actinoids ($5f$), defined by the progressive filling of inner f-subshells.

Their physical and chemical properties exhibit systematic trends across each series governed by shielding effects, metallic bonding, and valence electron availability.

Step 1: Evaluation of Total f-Block Elements:

The lanthanoid series consists of 14 elements (from cerium, $Z = 58$, to lutetium, $Z = 71$) characterized by the progressive filling of the $4f$ orbitals.

The actinoid series consists of 14 elements (from thorium, $Z = 90$, to lawrencium, $Z = 103$) characterized by the progressive filling of the $5f$ orbitals.

Together, these two series comprise $14 + 14 = 28$ elements.

Hence, statement (A) is correct.

Step 2: Physical Hardness of Lanthanoids:

According to NCERT: "The lanthanoids are silvery white soft metals and tarnish rapidly in air. Their hardness increases with increasing atomic number, samarium being steel hard."

The earlier lanthanoids (such as lanthanum, cerium, and praseodymium) are soft and can be cut with a knife.

Therefore, the statement that *all* the lanthanoids are hard metals is incorrect.

Hence, statement (B) is false.

Step 3: Comparing Actinoid and Lanthanoid Contractions:

The $5f$ orbitals are more diffuse and extend further in space than $4f$ orbitals, providing poorer shielding against nuclear charge.

Consequently, the effective nuclear charge increases more rapidly across the actinoid series, leading to an actinoid contraction that is greater from element to element than the lanthanoid contraction.

Hence, statement (C) is correct.

Step 4: Oxidation State Ranges:

In actinoids, the $5f$, $6d$, and $7s$ energy levels are close in energy, allowing valence electrons from all three subshells to participate in bonding and yielding oxidation states up to +7.

In contrast, lanthanoids predominantly show the +3 oxidation state, with only a few showing +2 and +4.

Hence, statement (D) is correct.

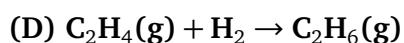
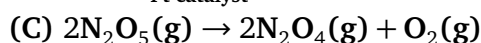
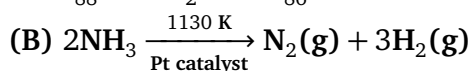
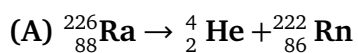
Final Answer:

The incorrect statement is (B).

Quick Tip: Lanthanoids are silvery-white soft metals whose hardness increases with atomic number across the series.

Samarium is unusually hard (steel-hard), but earlier members like cerium are soft.

15. Among the following, which are examples of first-order reactions?



Choose the correct answer from the options given below:

(A) (A), (B) and (D) only

(B) (A) and (C) only

(C) (B), (C) and (D) only

(D) (A), (C) and (D) only

Correct Answer: (D) (A), (C) and (D) only

Solution:

Concept:

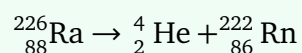
A first-order reaction has a rate that is directly proportional to the first power of the reactant concentration:

$$\text{Rate} = k[R]^1$$

Many common chemical transformations and all natural nuclear decay processes obey first-order kinetics.

Step 1: Assessing Radioactive Decay (Reaction A):

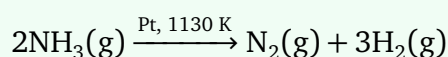
The disintegration of radium into radon and an alpha particle:



is a nuclear decay process. All natural and artificial radioactive decays obey first-order kinetics. Hence, (A) is a first-order reaction.

Step 2: Assessing Ammonia Decomposition (Reaction B):

The decomposition of ammonia on a hot platinum catalyst at 1130 K and elevated pressure is a classic example of a zero-order reaction:



Under high pressure, the metal catalyst surface is completely saturated with adsorbed ammonia molecules, so varying the concentration of NH_3 does not affect the rate.

Hence, (B) is zero-order and not first-order.

Step 3: Assessing Decomposition of N_2O_5 (Reaction C):

The thermal decomposition of dinitrogen pentoxide in the gas phase proceeds with the rate law:

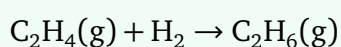
$$\text{Rate} = k[\text{N}_2\text{O}_5]$$

This is a standard example of a first-order chemical reaction in the NCERT syllabus.

Hence, (C) is a first-order reaction.

Step 4: Assessing Hydrogenation of Ethene (Reaction D):

The catalytic hydrogenation of ethene to ethane:



follows first-order kinetics with $\text{Rate} = k[\text{C}_2\text{H}_4]$.

Hence, (D) is a first-order reaction.

Final Answer:

The first-order reactions are (A), (C), and (D), which corresponds to option (D).

Quick Tip: Examples to remember for CUET:

- First Order: All radioactive decays, decomposition of N_2O_5 , decomposition of SO_2Cl_2 , hydrogenation of ethene.
- Zero Order: Decomposition of NH_3 on Pt at high pressure, decomposition of HI on Au.

16. Arrange the following rate expressions (of hypothetical reactions) in the increasing arrangement of their order of reaction:

Assume the concentrations of A and B in all the rate expressions is same.

(A) $\text{Rate} = k[\text{A}]^{1/2}[\text{B}]^{3/2}$

(B) $\text{Rate} = k[\text{A}]^{1/2}[\text{B}]^{1/2}$

(C) $\text{Rate} = k[\text{A}]^{3/2}[\text{B}]^{-1}$

(D) $\text{Rate} = k[\text{A}]^2[\text{B}]^1$

Choose the correct answer from the options given below:

(A) (A), (B), (C), (D)

(B) (C), (B), (A), (D)

(C) (B), (A), (D), (C)

(D) (C), (B), (D), (A)

Correct Answer: (B) (C), (B), (A), (D)

Solution:**Concept:**

The overall order of a chemical reaction is defined as the sum of the powers of the concentration terms of the reactants appearing in the empirical rate law expression:

$$\text{If Rate} = k[A]^x[B]^y, \quad \text{Overall Order (n)} = x + y$$

The order of a reaction can be positive, negative, zero, or fractional.

Step 1: Calculating Order for Reaction (A):

For the rate expression:

$$\text{Rate} = k[A]^{1/2}[B]^{3/2}$$

The overall order n_A is:

$$n_A = \frac{1}{2} + \frac{3}{2} = \frac{4}{2} = 2$$

Step 2: Calculating Order for Reaction (B):

For the rate expression:

$$\text{Rate} = k[A]^{1/2}[B]^{1/2}$$

The overall order n_B is:

$$n_B = \frac{1}{2} + \frac{1}{2} = 1$$

Step 3: Calculating Order for Reaction (C):

For the rate expression:

$$\text{Rate} = k[A]^{3/2}[B]^{-1}$$

The overall order n_C is:

$$n_C = \frac{3}{2} + (-1) = \frac{3}{2} - 1 = \frac{1}{2} = 0.5$$

Step 4: Calculating Order for Reaction (D):

For the rate expression:

$$\text{Rate} = k[A]^2[B]^1$$

The overall order n_D is:

$$n_D = 2 + 1 = 3$$

Step 5: Arranging in Increasing Order:

Comparing the calculated values:

$$n_C(0.5) < n_B(1) < n_A(2) < n_D(3)$$

Therefore, the increasing order of overall reaction order is:

$$(C) < (B) < (A) < (D)$$

Final Answer:

The correct increasing arrangement is (C), (B), (A), (D), corresponding to option (B).

Quick Tip: When finding the overall reaction order, simply add the powers algebraically:

$$x + y = n.$$

Remember to include negative signs when present in the exponent.

17. The electronic configuration of Co^{3+} metal ion is.....

- (A) $3d^5 4s^1$
- (B) $3d^6 4s^0$
- (C) $3d^4 4s^2$
- (D) $3d^3 4s^2 4p^1$

Correct Answer: (B) $3d^6 4s^0$

Solution:

Concept:

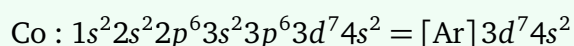
The electronic configuration of transition elements follows the Aufbau principle and Hund's rule.

During cation formation in transition metals, electrons are removed first from the outermost s -orbital (highest principal quantum number n) before removing electrons from the inner $(n - 1)d$ subshell.

Step 1: Ground-State Configuration of Neutral Cobalt:

Cobalt (Co) has atomic number $Z = 27$.

Using the noble gas core of argon ($Z = 18$), the ground-state electronic configuration of a neutral cobalt atom is:



Step 2: Ionization to the Trivalent State (Co^{3+}):

To form the Co^{3+} ion, three valence electrons must be removed from the neutral atom.

The $4s$ electrons are at a higher principal quantum level ($n = 4$) than the $3d$ electrons ($n = 3$).

Consequently, the two electrons occupying the $4s$ orbital are removed first:



The third electron is then removed from the $3d$ subshell:



Step 3: Verification with Options:

The configuration obtained for Co^{3+} is $3d^6 4s^0$, which matches option (B).

Final Answer:

The electronic configuration of Co^{3+} is $3d^6 4s^0$, corresponding to option (B).

Quick Tip: For all transition metal ions (M^{2+} , M^{3+}), always remove $4s$ electrons before $3d$ electrons.

Neutral Co = $3d^7 4s^2$.

Loss of 3 electrons: 2 from $4s$ and 1 from $3d \rightarrow 3d^6 4s^0$.

18. When Manganese (II) reacts with peroxodisulphate, the respective products obtained are:

- (A) MnO_4^{2-} only
(B) MnO_4^- and SO_4^{2-}
(C) MnO_2 and $\text{S}_2\text{O}_4^{2-}$
(D) MnO_4^{2-} and SO_4^{2-}

Correct Answer: (B) MnO_4^- and SO_4^{2-}

Solution:

Concept:

Peroxodisulphate (persulphate, $\text{S}_2\text{O}_8^{2-}$) is a very strong oxidizing agent in aqueous solution with a standard reduction potential of $E^\circ = +2.01 \text{ V}$.

It oxidizes lower oxidation states of transition metals to their highest stable oxidation states.

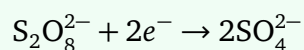
Step 1: Oxidation of Manganese(II):

In the presence of peroxodisulphate (typically catalyzed by silver ions, Ag^+), manganese(II) salts (Mn^{2+}) are oxidized to the intense purple permanganate ion (MnO_4^-), where manganese is in its highest oxidation state of +7.

Step 2: Reduction of Peroxodisulphate:

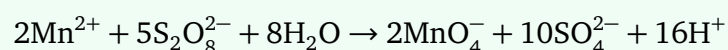
The peroxodisulphate ion contains an unstable peroxo linkage ($-\text{O}-\text{O}-$) in which the oxygen atoms have an oxidation state of -1 .

During the redox process, the peroxo bond is reduced, converting the persulphate ion into two sulphate ions (SO_4^{2-}), where oxygen is in the normal -2 oxidation state:



Step 3: Overall Stoichiometric Reaction:

Combining the oxidation and reduction half-reactions yields the overall balanced equation:



The products formed from this reaction are MnO_4^- (permanganate ion) and SO_4^{2-} (sulphate ion).

Final Answer:

The respective products obtained are MnO_4^- and SO_4^{2-} , which corresponds to option (B).

Quick Tip: Peroxodisulphate ($\text{S}_2\text{O}_8^{2-}$) is an exceptionally strong oxidant that oxidizes Mn^{2+} directly to permanganate (MnO_4^-), not stopping at MnO_4^{2-} or MnO_2 .

19. The most stable oxidation state of titanium is

- (A) Ti^{3+}
- (B) Ti^{2+}
- (C) Ti^{4+}
- (D) Ti^{5+}

Correct Answer: (C) Ti^{4+}

Solution:**Concept:**

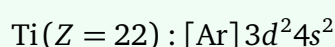
The relative stability of transition metal oxidation states is closely related to the electronic configuration of the resulting cation.

Configurations with completely empty (d^0), half-filled (d^5), or fully filled (d^{10}) subshells possess extra stability.

Step 1: Electronic Configuration of Titanium:

Titanium is the second element of the 3d-transition series, with atomic number $Z = 22$.

Its ground-state electronic configuration is:



It has four valence electrons available for chemical bonding.

Step 2: Assessing Available Oxidation States:

Titanium commonly displays +2, +3, and +4 oxidation states:

- In Ti^{2+} , the configuration is $[\text{Ar}] 3d^2$. These ions are strong reducing agents and easily oxidize to higher states.
- In Ti^{3+} , the configuration is $[\text{Ar}] 3d^1$. These ions are reducing and tend to undergo oxidation to the +4 state.
- In Ti^{4+} , all four valence electrons (two from 4s and two from 3d) are removed:



In the +4 state, titanium acquires the stable noble gas electronic configuration of argon ([Ar]).

Step 3: Feasibility of the +5 State:

The +5 oxidation state does not exist under standard chemical conditions because removing a fifth electron requires breaking into the filled core of the noble gas argon shell, which requires very high ionization energy.

Hence, Ti^{4+} is the most stable and predominant oxidation state of titanium.

Final Answer:

The most stable oxidation state of titanium is Ti^{4+} , corresponding to option (C).

Quick Tip: Remember the most stable states of early 3d metals:

Sc^{3+} (d^0), Ti^{4+} (d^0), and V^{5+} (d^0) are the most stable because they achieve the inert argon configuration.

20. Potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) is a strong oxidizing agent. Select the correct statements from the following:

- (A) It is used for preparation of many azo compounds.
- (B) With the decreasing pH of the solution, dichromates changes into chromates.
- (C) In acidified solution equivalent weight of dichromate is $M/5$
- (D) The bond angle between Cr-O-Cr is 126° .

Choose the correct answer from the options given below:

- (A) (A), (B) and (D) only
(B) (A), (C) and (D) only
(C) (A) and (D) only
(D) (B), (C) and (D) only

Correct Answer: (C) (A) and (D) only

Solution:

Concept:

Potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) is an important industrial reagent and laboratory standard in volumetric titrations.

Its properties include pH-dependent equilibria between chromate and dichromate, an n -factor of 6 in acid, and a bridged tetrahedral structure with a characteristic bond angle.

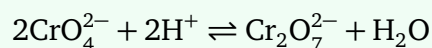
Step 1: Evaluation of Statement (A):

Potassium dichromate is widely utilized as an oxidizing agent in organic chemistry, specifically in the dye industry for preparing azo dyes and intermediates.

Hence, statement (A) is correct.

Step 2: Evaluation of Statement (B):

In aqueous solution, chromate (CrO_4^{2-} , yellow) and dichromate ($\text{Cr}_2\text{O}_7^{2-}$, orange) exist in a pH-dependent equilibrium:



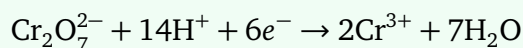
When the pH decreases (acidic medium, high $[\text{H}^+]$), Le Chatelier's principle shifts the equilibrium to the right, converting chromates into dichromates.

Conversely, increasing pH (alkaline conditions) shifts the equilibrium to the left, converting dichromate into chromate.

Statement (B) states that decreasing pH converts dichromate to chromate, which is incorrect.

Step 3: Evaluation of Statement (C):

In acidic solution, the reduction half-reaction of dichromate is:



Because each mole of dichromate accepts 6 electrons, the n -factor is 6.

The equivalent weight is therefore:

$$\text{Equivalent Weight} = \frac{\text{Molar Mass}}{6} = \frac{M}{6}$$

Statement (C) claims the equivalent weight is $M/5$, which is incorrect (this value applies to KMnO_4 in acid).

Step 4: Evaluation of Statement (D):

The dichromate ion consists of two tetrahedral CrO_4 units sharing a central bridging oxygen atom.

The $\text{Cr} - \text{O} - \text{Cr}$ bond angle in the dichromate ion is 126° .

Hence, statement (D) is correct.

Final Answer:

The correct statements are (A) and (D) only, corresponding to option (C).

Quick Tip: Key dichromate details:

- $\text{Cr} - \text{O} - \text{Cr}$ bridging angle = 126° .
- $\text{Cr}_2\text{O}_7^{2-}$ in acid has $n = 6 \implies \text{Eq. Wt.} = M/6$.
- Lower pH (acidic) favors orange $\text{Cr}_2\text{O}_7^{2-}$; higher pH (basic) favors yellow CrO_4^{2-} .

21. Which of the following is the correct IUPAC name for the $[\text{Pt}(\text{NH}_3)_2\text{Cl}(\text{NO}_2)]$ coordination compound?

- (A) Diamminechloridonitrito-N-platinum(II)
- (B) Diamminechloridonitrido-N-platinum(III)
- (C) Diamminechloridonitrito-N-platinate(II)
- (D) Diamminechloridenitrido-N-platinum(II)

Correct Answer: (A) Diamminechloridonitrito-N-platinum(II)

Solution:

Concept:

Coordination complexes are systematically named according to IUPAC nomenclature:

1. Ligands are listed alphabetically before the central metal.
2. Neutral ligands retain their name (with exceptions like NH_3 = ammine), while anionic ligands end in '-o' or '-ido'.
3. Ambidentate ligands include the coordinating donor atom.
4. The oxidation state of the metal is indicated in Roman numerals in parentheses.
5. For neutral or cationic coordination spheres, the metal keeps its common name. The suffix '-ate' is used only for anionic complexes.

Step 1: Determining the Oxidation State of the Metal:

Let the oxidation state of the platinum atom be x .

The charges of the coordinated ligands are:

- Ammine (NH_3): neutral ligand, charge = 0
- Chlorido (Cl^-): monoanionic ligand, charge = -1
- Nitrito-N (NO_2^-): monoanionic ligand, charge = -1

The overall complex molecule is neutral, so:

$$x + 2(0) + (-1) + (-1) = 0 \implies x - 2 = 0 \implies x = +2$$

Thus, platinum is in the +2 oxidation state, written as (II).

Step 2: Alphabetical Ordering of Ligands:

- Two NH_3 ligands: 'diammine' (alphabetized under 'a')
- One Cl^- ligand: 'chlorido' (alphabetized under 'c')
- One NO_2^- coordinated through nitrogen: 'nitrito-N' (alphabetized under 'n')

Thus, the correct alphabetical sequence is: diamminechloridonitrito-N.

Step 3: Constructing the Full Name:

Because the coordination sphere is neutral, the metal is named as 'platinum', followed by its oxidation state (II).

Combining the components gives:



Final Answer:

The correct IUPAC name is Diamminechloridonitrito-N-platinum(II), corresponding to option (A).

Quick Tip: Common IUPAC traps:

- NH_3 is spelled 'ammine' (with double 'm').
- Use 'platinate' only when the complex carries a net negative charge. For neutral or cationic complexes, use 'platinum'.

22. Which one of the following compounds does not show geometrical isomerism?

- (A) MnO_4^-
- (B) $[\text{Fe}(\text{NH}_3)_2(\text{CN})_4]^-$
- (C) $[\text{CrCl}_2(\text{ox})_2]^{3-}$
- (D) $[\text{CoCl}_2(\text{en})_2]$

Correct Answer: (A) MnO_4^-

Solution:

Concept:

Geometrical isomerism (cis-trans isomerism) occurs in coordination compounds when ligands can be arranged in spatially distinct positions around the central metal atom.

Tetrahedral complexes (ML_4) do not show geometrical isomerism because all four ligand positions are mutually adjacent, with identical bond angles of 109.5° .

Step 1: Geometry and Symmetry of MnO_4^- :

The permanganate ion (MnO_4^-) features manganese in the +7 oxidation state surrounded by four identical oxide (O^{2-}) ligands in a regular tetrahedral geometry (d^3s hybridization).

Because all four vertices of a tetrahedron are equidistant and adjacent to each other, no cis or trans arrangements can exist.

Furthermore, all four ligands are identical.

Therefore, MnO_4^- cannot exhibit geometrical isomerism.

Step 2: Assessing $[\text{Fe}(\text{NH}_3)_2(\text{CN})_4]^-$:

This is a six-coordinate octahedral complex of the general formula $[\text{Ma}_2\text{b}_4]$.

It exhibits geometrical isomerism:

- cis-isomer: the two NH_3 ligands occupy adjacent positions at 90° .
- trans-isomer: the two NH_3 ligands occupy opposite positions at 180° .

Step 3: Assessing $[\text{CrCl}_2(\text{ox})_2]^{3-}$ and $[\text{CoCl}_2(\text{en})_2]$:

Both are octahedral complexes of the general formula $[\text{Ma}_2(\text{AA})_2]$, where ox^{2-} and en are symmetrical bidentate chelating ligands.

Both complexes exist as cis and trans geometrical isomers, depending on whether the two monodentate chloro ligands are adjacent or opposite to each other.

Final Answer:

Hence, MnO_4^- does not show geometrical isomerism, which corresponds to option (A).

Quick Tip: Tetrahedral complexes ($\text{CN} = 4$) NEVER show geometrical isomerism because all four positions are equivalent and adjacent to one another.

23. Which of the following hybridisation is correct for $[\text{FeF}_6]^{3-}$?

- (A) sp^3d^2 with 1 unpaired electrons
- (B) sp^3d^2 with 5 unpaired electrons
- (C) d^2sp^3 with 1 unpaired electrons
- (D) d^2sp^3 with 5 unpaired electrons

Correct Answer: (B) sp^3d^2 with 5 unpaired electrons

Solution:

Concept:

According to Valence Bond Theory (VBT) and Crystal Field Theory (CFT), the hybridization and magnetic properties of an octahedral complex depend on the oxidation state of the metal and the field strength of the ligands.

Weak field ligands produce small crystal field splitting ($\Delta_o < P$), resulting in high-spin complexes where electrons remain unpaired and outer d -orbitals ($4d$) are utilized for hybridization.

Step 1: Determining the Oxidation State of Iron:

Let the oxidation state of iron be x .

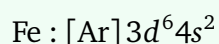
Fluoride is a monoanionic ligand (F^- , charge = -1):

$$x + 6(-1) = -3 \implies x = +3$$

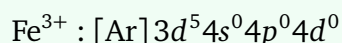
The iron atom is in the $+3$ oxidation state.

Step 2: Electronic Configuration of Fe^{3+} :

Neutral iron ($Z = 26$) has the ground-state configuration:



Removing two $4s$ electrons and one $3d$ electron gives:

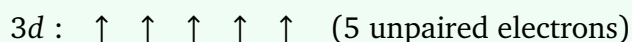


Step 3: Determining Hybridization and Unpaired Electrons:

The fluoride ion (F^-) is a weak field ligand positioned low in the spectrochemical series.

Because Δ_o is less than the pairing energy P , the crystal field is too weak to force the pairing of $3d$ electrons.

Therefore, all five electrons remain unpaired, occupying the five $3d$ orbitals singly:



To accommodate six lone pairs donated by the six fluoride ligands, the Fe^{3+} ion uses:

- One empty $4s$ orbital,
- Three empty $4p$ orbitals,
- Two empty outer $4d$ orbitals.

These six atomic orbitals hybridize to form six equivalent sp^3d^2 hybrid orbitals, forming an outer-orbital, high-spin octahedral complex with 5 unpaired electrons.

Final Answer:

The complex has sp^3d^2 hybridization with 5 unpaired electrons, which corresponds to option (B).

Quick Tip: Comparing Fe^{3+} ($3d^5$):

- With weak field ligand F^- : no pairing $\rightarrow sp^3d^2$ (outer orbital) with 5 unpaired electrons.
- With strong field ligand CN^- : pairing occurs $\rightarrow d^2sp^3$ (inner orbital) with 1 unpaired electron.

24. Match List-I with List-II

List-I	List-II
(A) ion or molecule having two different donor atoms and either of the two ligates in the complex	(I) central atom or ion
(B) In a coordination entity, the atom/ion to which a fixed number of ions/groups are bound in a definite geometrical arrangement	(II) Chelate ligand
(C) ion or molecule using its two or more donor atoms simultaneously to bind a single metal ion	(III) Ambidentate ligand
(D) ion or molecule bound to the central atom/ion through two donor atoms	(IV) Didentate ligand

Choose the correct answer from the options given below:

- (A) (A) - (II), (B) - (I), (C) - (III), (D) - (IV)
- (B) (A) - (II), (B) - (III), (C) - (I), (D) - (IV)
- (C) (A) - (III), (B) - (II), (C) - (I), (D) - (IV)

(D) (A) - (III), (B) - (I), (C) - (II), (D) - (IV)

Correct Answer: (D) (A) - (III), (B) - (I), (C) - (II), (D) - (IV)

Solution:

Concept:

The terminology of coordination chemistry is defined by standard IUPAC conventions that describe the central metal, types of ligands based on denticity, and the modes of coordination.

Step 1: Matching Ambidentate Ligands:

An ambidentate ligand is a monodentate species that possesses two different potential donor atoms, but coordinates through only one donor atom at a time to the central metal.

Examples include NO_2^- (which can bind through N or O) and SCN^- (which can bind through S or N).

Therefore, (A) matches with (III).

Step 2: Matching Central Atom or Ion:

In a coordination entity, the metal atom or cation to which a fixed number of neutral molecules or anions are bound in a definite geometrical arrangement is defined as the central atom or ion.

Therefore, (B) matches with (I).

Step 3: Matching Chelate Ligands:

When a di- or polydentate ligand uses two or more of its donor atoms simultaneously to bind to the same central metal ion, it forms a cyclic ring structure known as a chelate ring, and the ligand is called a chelate ligand.

Therefore, (C) matches with (II).

Step 4: Matching Didentate Ligands:

A ligand that coordinates to the central metal atom or ion through two donor atoms is termed a didentate (or bidentate) ligand, such as ethane-1,2-diamine or the oxalate ion.

Therefore, (D) matches with (IV).

Final Answer:

The resulting matched sequence is (A)-(III), (B)-(I), (C)-(II), (D)-(IV), which corresponds to option (D).

Quick Tip: Key definitions:

- Ambidentate: has two donor atoms, but binds via only ONE atom at a time.
- Didentate: binds through two donor atoms.
- Chelate: binds through two or more donor atoms simultaneously to form a ring.

25. In nucleophilic addition reaction of HCN to ethanal, the hybridisation of the carbonyl carbon in the final product is

- (A) sp^3
- (B) sp^2
- (C) sp^2d
- (D) spd^2

Correct Answer: (A) sp^3

Solution:**Concept:**

Nucleophilic addition is the characteristic reaction of aldehydes and ketones.

During this reaction, the planar sp^2 -hybridized carbonyl carbon is attacked by an incoming nucleophile, converting it into a tetrahedral sp^3 -hybridized carbon in the resulting addition product.

Step 1: Carbonyl Carbon in Starting Ethanal:

The chemical structure of ethanal is $\text{CH}_3 - \text{CH} = \text{O}$.

The carbonyl carbon is bonded to:

- One hydrogen atom by a σ -bond,

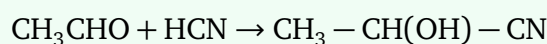
- One methyl group by a σ -bond,
- One carbonyl oxygen atom by a double bond (one σ -bond and one π -bond).

With three σ -bonds and no lone pairs, the steric number is 3, corresponding to sp^2 hybridization with trigonal planar geometry.

Step 2: Addition of Hydrogen Cyanide:

The addition of HCN to ethanal proceeds via base catalysis:

1. The cyanide nucleophile ($:CN^-$) attacks the electrophilic carbonyl carbon.
2. The $C=O$ π -bond cleaves, transferring the electron pair to oxygen to form an alkoxide intermediate.
3. Subsequent proton transfer yields ethanal cyanohydrin (2-hydroxypropanenitrile):



Step 3: Determining Hybridization in the Final Product:

In ethanal cyanohydrin, the former carbonyl carbon atom is bonded to four distinct groups:

- A single σ -bond to $-H$,
- A single σ -bond to $-OH$,
- A single σ -bond to $-CH_3$,
- A single σ -bond to $-CN$.

With four single σ -bonds and zero lone pairs, the steric number of this carbon atom is 4.

Therefore, the hybridization of this carbon atom changes from sp^2 in ethanal to sp^3 (tetrahedral geometry) in the final product.

Final Answer:

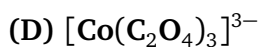
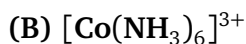
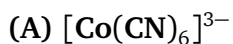
The hybridization of the carbonyl carbon in the final product is sp^3 , corresponding to option (A).

Quick Tip: In nucleophilic addition reactions of aldehydes and ketones:

- Starting carbonyl carbon: sp^2 (planar, 120°).
- Final product carbon: sp^3 (tetrahedral, 109.5°).

26. Arrange the following complex ions in increasing order of their wavelength of light ab-

sorbed:



Choose the correct answer from the options given below:

(A) (A), (B), (D), (C)

(B) (A), (D), (B), (C)

(C) (D), (B), (A), (C)

(D) (C), (D), (B), (A)

Correct Answer: (A) (A), (B), (D), (C)

Solution:

Concept:

In octahedral coordination complexes of a transition metal ion, the absorption of light corresponds to the promotion of an electron from the lower t_{2g} energy level to the higher e_g level (a $d-d$ transition).

The energy of the absorbed photon (Δ_o) is inversely related to its wavelength (λ) via the Planck-Einstein relation:

$$\Delta_o = \frac{hc}{\lambda} \implies \lambda \propto \frac{1}{\Delta_o}$$

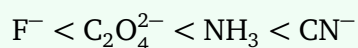
Therefore, a ligand that generates a stronger crystal field causes a larger crystal field splitting energy (Δ_o) and leads to the absorption of light at a shorter wavelength.

Step 1: Ranking Ligand Field Strengths via the Spectrochemical Series:

All four complexes involve the identical central metal ion, Co^{3+} ($3d^6$).

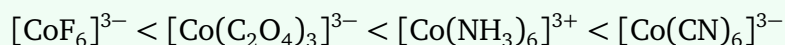
Hence, the magnitude of Δ_o depends exclusively on the field strength of the coordinated ligands.

According to the spectrochemical series, the crystal field strength of the ligands increases in the order:

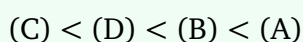


Step 2: Determining the Order of Crystal Field Splitting Energy (Δ_o):

Because Δ_o increases with ligand field strength, the complexes arrange in order of increasing Δ_o as:



In terms of the given labels, this sequence is:



Step 3: Calculating the Relative Wavelengths of Absorbed Light:

Since absorbed wavelength is inversely proportional to Δ_o ($\lambda = hc/\Delta_o$), the complex with the highest Δ_o absorbs at the shortest wavelength, and the complex with the lowest Δ_o absorbs at the longest wavelength.

Inverting the Δ_o sequence gives the increasing order of absorbed wavelength:

$$\lambda_{(A)} < \lambda_{(B)} < \lambda_{(D)} < \lambda_{(C)}$$

Thus, the increasing order of wavelength of light absorbed is (A), (B), (D), (C).

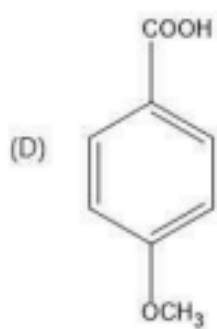
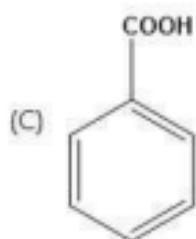
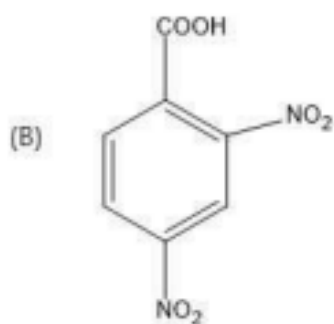
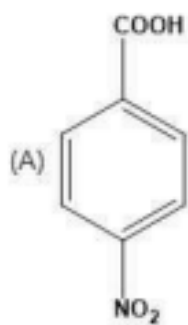
Final Answer:

The correct increasing order is (A), (B), (D), (C), which corresponds to option (A).

Quick Tip: Remember: Stronger ligand field $\rightarrow$ Larger $\Delta_o \rightarrow$ Shorter absorbed wavelength (λ).

Spectrochemical series order: Halides < Oxygen donors < Nitrogen donors < Carbon donors.

27. The correct increasing order of acidity of the following molecules is



Choose the correct answer from the options given below:

- (A) (A), (B), (C), (D)
- (B) (D), (C), (A), (B)
- (C) (B), (A), (D), (C)
- (D) (C), (B), (D), (A)

Correct Answer: (B) (D), (C), (A), (B)

Solution:

Concept:

The acidity of substituted benzoic acids depends on the stability of the carboxylate anion formed after deprotonation.

Electron-withdrawing groups ($-\text{NO}_2$) stabilize the negative charge on the carboxylate group through $-I$ and $-M$ effects, thereby increasing the acidity.

Electron-donating groups ($-\text{OCH}_3$) destabilize the conjugate base through $+M$ electron donation into the ring, thereby decreasing the acidity.

Step 1: Effect of Electron-Donating Methoxy Group in Compound (D):

In 4-methoxybenzoic acid (D), the methoxy group ($-\text{OCH}_3$) at the *para*-position acts as a strong resonance electron-donating group ($+M > -I$).

It pumps electron density into the benzene ring and intensifies the negative charge on the carboxylate anion, destabilizing it.

Therefore, 4-methoxybenzoic acid is less acidic than unsubstituted benzoic acid (C).

Step 2: Reference Acidity of Benzoic Acid (C):

Benzoic acid (C) lacks any substituents on the phenyl ring.

It is more acidic than 4-methoxybenzoic acid (D), but less acidic than derivatives bearing electron-withdrawing nitro groups.

Step 3: Effect of Nitro Groups in Compounds (A) and (B):

In 4-nitrobenzoic acid (A), the nitro group at the *para*-position exerts both powerful $-M$ and $-I$ electron-withdrawing effects, significantly stabilizing the carboxylate anion and increasing acidity.

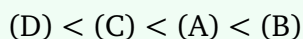
In 3,5-dinitrobenzoic acid (B), two nitro groups are present at both *meta*-positions.

Although the mesomeric effect does not operate at *meta*-positions, two strongly electronegative NO_2 groups exert a combined inductive electron-withdrawing effect ($-I$), resulting in a stronger overall acidifying effect than a single *para*-nitro group (pK_a of 3,5-dinitrobenzoic acid ≈ 2.82 vs pK_a of 4-nitrobenzoic acid ≈ 3.44).

Thus, compound (B) is the strongest acid in the series.

Step 4: Compiling the Increasing Acidity Order:

Arranging the compounds from weakest acid to strongest acid gives:



Final Answer:

The correct increasing order of acidity is (D), (C), (A), (B), corresponding to option (B).

Quick Tip: Acidity of aromatic acids:

$-M, -I$ groups (e.g., $-\text{NO}_2$) $\rightarrow$ Increase acidity.

$+M$ groups (e.g., $-\text{OCH}_3, -\text{OH}$) $\rightarrow$ Decrease acidity.

Order: 4-methoxybenzoic acid < benzoic acid < 4-nitrobenzoic acid < 3,5-dinitrobenzoic acid.

28. Conversion of carboxylic acid to hydrocarbon is carried out using

- (A) KMnO_4
- (B) LiAlH_4 and ether
- (C) NaOH and CaO
- (D) B_2H_6 (Diborane)

Correct Answer: (C) NaOH and CaO

Solution:

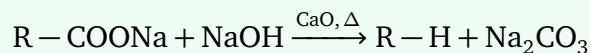
Concept:

Carboxylic acids lose carbon dioxide to form hydrocarbons containing one fewer carbon atom through decarboxylation.

This chemical transformation is carried out using soda lime, which is a dry mixture of sodium hydroxide (NaOH) and calcium oxide (CaO).

Step 1: Mechanism of Soda-Lime Decarboxylation:

When the sodium salt of a carboxylic acid is heated strongly with soda lime (NaOH : CaO in a 3 : 1 mass ratio), it undergoes decarboxylation to produce an alkane:



In this reaction, the carboxyl group is removed as sodium carbonate, yielding a hydrocarbon containing one less carbon atom than the parent carboxylic acid.

Calcium oxide (CaO) serves as a porous, hygroscopic support that keeps the reaction mixture dry and raises the fusion temperature, preventing the glass vessel from melting.

Step 2: Evaluating Alternative Reagents:

- KMnO_4 is a powerful oxidizing agent that oxidizes alkyl benzenes, alcohols, and aldehydes to carboxylic acids, rather than converting carboxylic acids to hydrocarbons.
- LiAlH_4 in dry ether reduces carboxylic acids to primary alcohols ($\text{R} - \text{CH}_2\text{OH}$), not hydrocarbons.
- B_2H_6 (diborane) selectively reduces carboxylic acids to primary alcohols and does not cleave the carbon chain to form hydrocarbons.

Final Answer:

The reagent used to convert a carboxylic acid to a hydrocarbon is NaOH and CaO, which corresponds to option (C).

Quick Tip: To convert R-COOH into R-H (step-down alkane), always use soda lime ($\text{NaOH} + \text{CaO}$). Do not confuse this with Kolbe's electrolytic decarboxylation, which produces a dimerized alkane (R-R).

29. Sodium benzoate finds applications in

- (A) Perfumes
- (B) Nylon 6,6
- (C) Soaps and detergents

(D) Food preservatives

Correct Answer: (D) Food preservatives

Solution:

Concept:

Chemical substances added to food items to prevent spoilage caused by microbial growth (such as fungi, bacteria, and yeasts) or undesirable chemical alterations are called food preservatives.

Step 1: Chemical Structure and Properties of Sodium Benzoate:

Sodium benzoate is the sodium salt of benzoic acid, having the molecular formula $\text{C}_6\text{H}_5\text{COONa}$. It is a white, odorless crystalline powder that dissolves readily in water, unlike benzoic acid itself, which is sparingly soluble.

Step 2: Mechanism of Action as a Food Preservative:

In acidic food matrices (such as carbonated soft drinks, fruit juices, jams, and pickles), sodium benzoate converts to lipophilic undissociated benzoic acid.

Benzoic acid readily diffuses across microbial cell membranes, lowering the intracellular pH and inhibiting phosphofructokinase and cellular metabolism, thereby inhibiting the proliferation of molds, yeasts, and bacteria.

Because it is metabolized in the human liver by conjugation with glycine to form non-toxic hippuric acid, which is excreted in urine, it is safe for human consumption within regulatory limits.

Step 3: Verification of Other Options:

- Perfumes primarily use fragrant volatile esters and essential oils, not sodium benzoate.
- Nylon 6,6 is synthesized by condensation copolymerization of adipic acid and hexamethylenediamine.
- Soaps are sodium or potassium salts of higher fatty acids (such as stearic, palmitic, and oleic acids).

Final Answer:

Sodium benzoate is used as a food preservative, corresponding to option (D).

Quick Tip: Standard NCERT food preservatives:

- Sodium benzoate ($\text{C}_6\text{H}_5\text{COONa}$) is the most widely used chemical food preservative.
- Salts of sorbic acid and propanoic acid are also commonly used.

30. Iodoform reaction with sodium hypiodite is used for detection of .

- (A) CH_3CO group
(B) CH_3CO and $\text{CH}_3\text{CH}(\text{OH})$ groups
(C) CH_3O group
(D) $(\text{CH}_3)_3\text{CO}$ group

Correct Answer: (B) CH_3CO and $\text{CH}_3\text{CH}(\text{OH})$ groups

Solution:

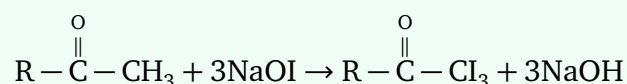
Concept:

The haloform reaction is a qualitative analytical reaction used to detect methyl ketones and secondary alcohols containing a methyl group bonded to a carbinol carbon.

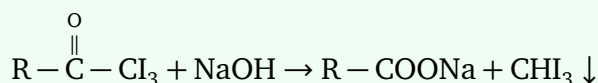
When treated with sodium hypoiodite (NaOI , generated in situ from $\text{I}_2 + \text{NaOH}$), these compounds produce a bright yellow precipitate of iodoform (CHI_3).

Step 1: Reaction of Methyl Carbonyl Compounds ($\text{CH}_3\text{CO}-$):

Any aldehyde or ketone containing the $\text{CH}_3\text{C}=\text{O}$ group possesses α -hydrogens that undergo successive base-catalyzed halogenation to form a triiodomethyl carbonyl intermediate:



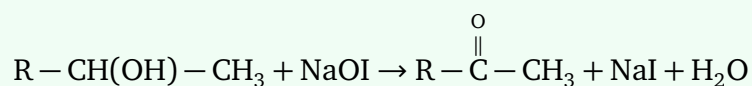
Nucleophilic attack by hydroxide ion cleaves the carbon-carbon bond, yielding a carboxylate salt and a characteristic yellow precipitate of iodoform:



Step 2: Reaction of Alcohols Containing $\text{CH}_3\text{CH}(\text{OH})-$:

Sodium hypoiodite acts as an oxidizing agent as well as a halogenating agent.

Compounds containing the $\text{CH}_3-\text{CH}(\text{OH})-$ group are first oxidized in situ by hypoiodite to the corresponding methyl carbonyl compound:



The generated methyl ketone then undergoes the iodoform reaction as shown above to produce yellow CHI_3 .

Step 3: Evaluating Excluded Groups:

Methoxy groups ($\text{CH}_3\text{O}-$) and tertiary alkoxy groups ($(\text{CH}_3)_3\text{CO}-$) cannot be oxidized to methyl carbonyl units and fail the iodoform test completely.

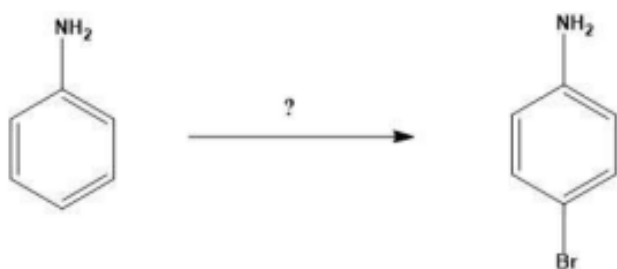
Final Answer:

Thus, the iodoform test detects both CH_3CO and $\text{CH}_3\text{CH}(\text{OH})$ groups, corresponding to option (B).

Quick Tip: Iodoform test ($\text{I}_2 + \text{NaOH}$) gives a positive yellow precipitate of CHI_3 (mp 119°C) with:

1. $\text{CH}_3-\text{C}=\text{O}$ (e.g., acetaldehyde, all methyl ketones).
2. $\text{CH}_3-\text{CH}(\text{OH})-$ (e.g., ethanol, secondary alcohols with a methyl group).

31. The first step in conversion of aniline to 4-bromoaniline involves



- (A) Acetylation of amino group
- (B) Formation of diazonium salt in the presence of NaNO_2 and HCl .
- (C) Reaction with Bromine water at room temperature.
- (D) Reaction with Bromine in the presence of NaOH .

Correct Answer: (A) Acetylation of amino group

Solution:

Concept:

The amino group ($-\text{NH}_2$) in aniline is a very strong activating and *ortho/para*-directing group in electrophilic aromatic substitution due to resonance donation of its unshared electron pair into the benzene ring.

To achieve controlled monobromination and avoid polybromination, the activating power of the amino group must first be reduced by protecting it via acetylation.

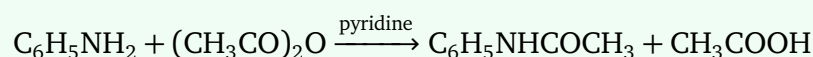
Step 1: The Problem of Direct Bromination:

When aniline is treated directly with bromine water at room temperature, the amino group activates the ring so strongly that electrophilic bromination occurs instantaneously at all available *ortho*- and *para*-positions.

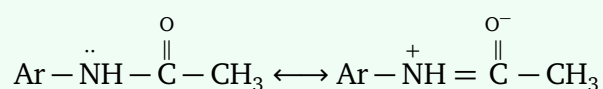
This produces 2,4,6-tribromoaniline as a white precipitate, making selective synthesis of 4-bromoaniline impossible by direct halogenation.

Step 2: Protection via Acetylation:

To moderate the activating effect, the first step is the acetylation of the amino group by treating aniline with acetic anhydride in pyridine:



In the resulting acetanilide, the nitrogen lone pair is delocalized onto the carbonyl oxygen of the acetyl group:



This delocalization reduces the availability of the nitrogen lone pair to the aromatic ring, lowering its activating power.

Step 3: Subsequent Monobromination and Deprotection:

The protected acetanilide then undergoes electrophilic bromination with Br_2 in acetic acid to give 4-bromoacetanilide as the major product due to steric hindrance at the *ortho*-position.

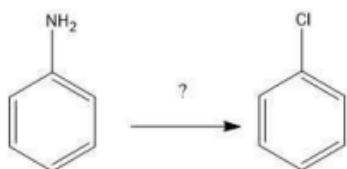
Subsequent acid or alkaline hydrolysis removes the acetyl group to deliver 4-bromoaniline selectively.

Final Answer:

The first step is the acetylation of the amino group, corresponding to option (A).

Quick Tip: To obtain mono-substituted derivatives of aniline (such as 4-bromoaniline or 4-nitroaniline), ALWAYS protect the $-\text{NH}_2$ group first by acetylation to form acetanilide!

32. Which of the following reagents will bring out the following transformation ?



Choose the correct answer from the options given below:

- (A) (A) and (C) only
- (B) (A), (B) and (D) only
- (C) (A), (B), (C) and (D)
- (D) (B), (C) and (D) only

Correct Answer: (A) (A) and (C) only

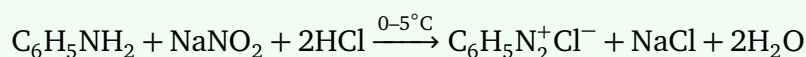
Solution:

Concept:

The primary route for converting aniline into aryl halides involves converting aniline into a benzenediazonium salt (diazotization) followed by displacement of the diazonium group by a chloride nucleophile using copper-based reagents.

Step 1: The Diazotization Requirement:

In the initial step, primary aromatic amines must be treated with nitrous acid (HNO_2), generated in situ from sodium nitrite and hydrochloric acid ($\text{NaNO}_2 + \text{HCl}$) at low temperature (273–278 K):

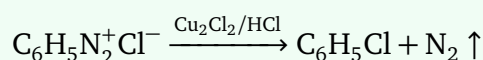


This reaction requires an acidic medium.

Using $\text{NaNO}_2/\text{NaOH}$ (as in options B and D) provides basic conditions that fail to produce nitrous acid, preventing diazonium salt formation.

Step 2: Sandmeyer Reaction via Reagent (C):

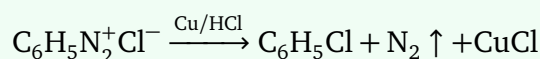
When the freshly prepared benzenediazonium chloride solution is treated with cuprous chloride dissolved in hydrochloric acid ($\text{Cu}_2\text{Cl}_2/\text{HCl}$), chlorobenzene is formed:



This process is known as the Sandmeyer reaction. Hence, set (C) carries out the transformation.

Step 3: Gattermann Reaction via Reagent (A):

Alternatively, treating the benzenediazonium salt with copper powder in the presence of hydrochloric acid (Cu/HCl) also produces chlorobenzene:



This variation is known as the Gattermann reaction. Hence, set (A) also successfully carries out the transformation.

Final Answer:

The transformation can be accomplished using (A) and (C) only, corresponding to option (A).

Quick Tip: Aniline to Chlorobenzene:

1. $\text{NaNO}_2 + \text{HCl} \xrightarrow{0-5^\circ\text{C}} \text{Ar-N}_2^+\text{Cl}^-$ (Diazotization).
2. Followed by either Sandmeyer ($\text{Cu}_2\text{Cl}_2/\text{HCl}$) or Gattermann (Cu/HCl).

33. Amongst the following, the strongest base in the aqueous medium is :

- (A) CH_3NH_2
- (B) NCCH_2NH_2
- (C) $(\text{CH}_3)_2\text{NH}$
- (D) $\text{C}_6\text{H}_5\text{NHCH}_3$

Correct Answer: (C) $(\text{CH}_3)_2\text{NH}$

Solution:**Concept:**

The basicity of amines in aqueous solution is determined by the availability of the nitrogen unshared electron pair to accept a proton and the stability of the resulting substituted ammonium cation.

In water, three competing factors determine the stability of the conjugate acid:

1. Inductive effect (+I of alkyl groups),
2. Solvation effect (stabilization of cation through hydrogen bonding with water),
3. Steric hindrance to protonation and solvation.

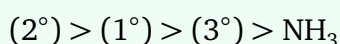
Step 1: Comparing Aliphatic vs Aromatic and Substituted Amines:

- N-Methylaniline ($\text{C}_6\text{H}_5\text{NHCH}_3$, compound D) is an aromatic amine where the nitrogen lone pair is delocalized into the benzene ring via resonance, substantially lowering its basicity compared to aliphatic amines.

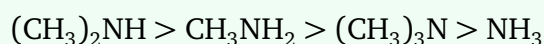
- Aminoacetonitrile (NCCH_2NH_2 , compound B) contains a strong electron-withdrawing cyano group ($-I$ effect) that withdraws electron density from the nitrogen atom, drastically reducing its basicity.

Step 2: Analysis of Aqueous Basicity in Methyl-Substituted Amines:

For methyl-substituted aliphatic amines in aqueous medium, the combined interplay of inductive, steric, and hydration effects gives the basicity order:



Specifically:



In dimethylamine ($(\text{CH}_3)_2\text{NH}$), two electron-releasing methyl groups supply electron density via $+I$ induction while leaving room for effective hydration of the protonated cation through two hydrogen bonds.

This balance of induction and hydration makes dimethylamine more basic in water than methylamine (CH_3NH_2).

Step 3: Verification with pK_b Values:

The experimental pK_b values confirm this order:

- $(\text{CH}_3)_2\text{NH}$: $pK_b = 3.27$ (strongest base)
- CH_3NH_2 : $pK_b = 3.38$
- $\text{C}_6\text{H}_5\text{NHCH}_3$: $pK_b = 9.30$

Final Answer:

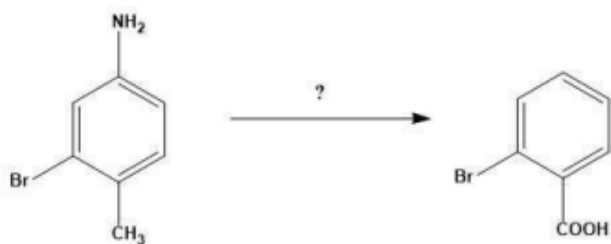
The strongest base in aqueous medium is $(\text{CH}_3)_2\text{NH}$, corresponding to option (C).

Quick Tip: Basicity order of aliphatic amines in aqueous solution:

- Methyl group: $2^\circ > 1^\circ > 3^\circ > \text{NH}_3$ (Code: 213).
- Ethyl group: $2^\circ > 3^\circ > 1^\circ > \text{NH}_3$ (Code: 231).

In both cases, the secondary (2°) amine is the strongest base!

34. Select the correct set of reagents required for conversion of the following chemical reactions



- (A) (i). NaNO_2/HCl , 273–278 K (ii). $\text{H}_3\text{PO}_4, \text{H}_2\text{O}$ (iii). KMnO_4 and KOH
 (B) (i). NaNO_2/HCl (ii). H_3PO_4 (iii). $\text{NaOH}/\text{H}_2\text{O}$
 (C) (i). $\text{HNO}_3/\text{H}_2\text{SO}_4$ (ii). H_3PO_4 (iii). KMnO_4 and KOH
 (D) (i). NaNO_2/HCl (ii). Sn/HCl (iii). KMnO_4 and KOH

Correct Answer: (A) (i). NaNO_2/HCl , 273–278 K (ii). $\text{H}_3\text{PO}_4, \text{H}_2\text{O}$ (iii). KMnO_4 and KOH

Solution:

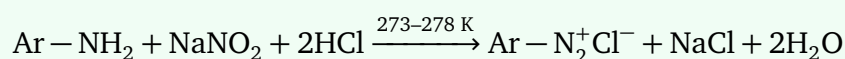
Concept:

Transforming 2-bromo-4-methylaniline into 2-bromobenzoic acid requires two key synthetic modifications:

1. Deamination: complete removal of the aromatic primary amino group ($-\text{NH}_2 \rightarrow -\text{H}$),
2. Side-chain oxidation: vigorous oxidation of the methyl group to a carboxylic acid group ($-\text{CH}_3 \rightarrow -\text{COOH}$).

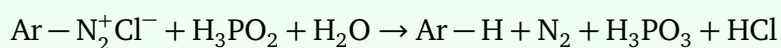
Step 1: Diazotization of the Amino Group:

Treating 2-bromo-4-methylaniline with sodium nitrite in aqueous hydrochloric acid at 273–278 K quantitatively converts the primary aromatic amino group into a diazonium salt:



Step 2: Reductive Deamination Using Hypophosphorous Acid:

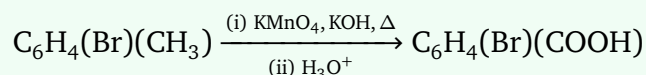
The diazonium intermediate is treated with hypophosphorous acid (H_3PO_4) in water, reducing the diazonium group to a hydrogen atom and evolving nitrogen gas:



This removes the functional group at position 4 relative to methyl, isolating 2-bromotoluene.

Step 3: Oxidation of Alkyl Side Chain:

Heating 2-bromotoluene with alkaline potassium permanganate (KMnO_4 and KOH) followed by acidic workup oxidizes the methyl group to a carboxylic acid:



This sequence yields 2-bromobenzoic acid.

Final Answer:

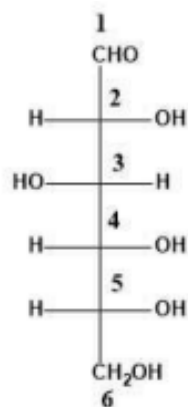
The correct reagent sequence is (i). NaNO_2/HCl , 273–278 K, (ii). $\text{H}_3\text{PO}_4, \text{H}_2\text{O}$, (iii). KMnO_4 and KOH , corresponding to option (A).

Quick Tip: To remove an $-\text{NH}_2$ group from a benzene ring:

1. NaNO_2/HCl at $0-5^\circ\text{C} \rightarrow$ Diazonium salt.
2. $\text{H}_3\text{PO}_2/\text{H}_2\text{O}$ or $\text{CH}_3\text{CH}_2\text{OH} \rightarrow$ Reduction to $-\text{H}$.

To oxidize alkyl side chains to $-\text{COOH}$: Alkaline KMnO_4 .

35. $-\text{OH}$ group at which carbon center of glucose form a pyranose ring structure?



(A) C6

- (B) C4
(C) C3
(D) C5

Correct Answer: (D) C5

Solution:

Concept:

In aqueous solution, open-chain D-(+)-glucose undergoes intramolecular cyclization between a hydroxyl group and the aldehyde carbon at C1 to form a six-membered cyclic hemiacetal known as a pyranose ring.

Step 1: Numbering the Open-Chain Glucose Skeleton:

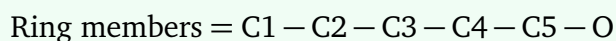
In the Fischer projection of D-glucose:

- C1 is the terminal aldehyde carbon ($-\text{CH}=\text{O}$),
- C2, C3, C4, and C5 are chiral secondary alcohol carbons carrying $-\text{OH}$ groups,
- C6 is the primary alcohol carbon ($-\text{CH}_2\text{OH}$).

Step 2: Thermodynamic Stability of Ring Sizes:

Six-membered rings are thermodynamically favored because they minimize angle and torsional strain.

Nucleophilic attack of the hydroxyl oxygen at C5 onto the planar aldehyde carbonyl at C1 forms a six-membered ring containing five carbon atoms and one oxygen atom:



This six-membered heterocyclic ring is named a pyranose ring due to its structural resemblance to pyran.

Step 3: Verification of Other Hydroxyl Groups:

- Attack by the $-\text{OH}$ group at C4 would form a five-membered furanose ring, which is less stable and less prevalent in aldohexoses than the pyranose form.
- The $-\text{OH}$ group at C6 is outside the ring and remains as an exocyclic $-\text{CH}_2\text{OH}$ substituent on the C5 carbon.

Therefore, the pyranose ring of glucose is formed specifically by the hydroxyl group at C5.

Final Answer:

The -OH group involved in forming the pyranose ring is at C5, corresponding to option (D).

Quick Tip: Remember ring formation in carbohydrates:

- Glucose pyranose ring: C1 aldehyde + C5 hydroxyl → 6-membered ring.
- Fructose furanose ring: C2 ketone + C5 hydroxyl → 5-membered ring.

36. Gabriel phthalimide synthesis of amines produces

- (A) tertiary amines.
- (B) secondary amines.
- (C) primary amines.
- (D) aromatic secondary amines.

Correct Answer: (C) primary amines.

Solution:

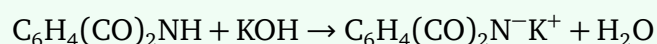
Concept:

The Gabriel phthalimide synthesis is a selective laboratory method used for preparing pure primary aliphatic amines without contamination by secondary or tertiary amines.

Step 1: Generation of the Phthalimide Anion:

Phthalimide is treated with ethanolic potassium hydroxide (KOH).

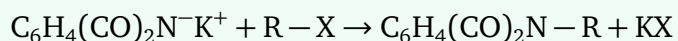
The acidic imide hydrogen between the two carbonyl groups is deprotonated, yielding potassium phthalimide, which serves as a nucleophile:



Step 2: Nucleophilic Alkylation via S_N2 Pathway:

Potassium phthalimide is heated with a primary alkyl halide (R – X).

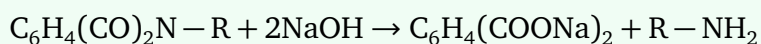
The phthalimide anion attacks the alkyl halide via an S_N2 mechanism, displacing the halide ion to produce N-alkylphthalimide:



Because N-alkylphthalimide lacks acidic protons on the nitrogen, further alkylation cannot take place, preventing the formation of secondary or tertiary amines.

Step 3: Hydrolysis or Hydrazinolysis to Free Primary Amine:

Alkaline hydrolysis of N-alkylphthalimide with aqueous sodium hydroxide yields phthalate salt and liberates the pure primary aliphatic amine:



Aromatic primary amines cannot be prepared by this method because aryl halides do not undergo nucleophilic substitution with the phthalimide anion under standard conditions.

Final Answer:

Gabriel phthalimide synthesis selectively produces primary amines, corresponding to option (C).

Quick Tip: Gabriel synthesis highlights:

- Exclusively produces: Pure primary aliphatic amines (1°).
- Cannot prepare: Aniline or aromatic amines (aryl halides do not undergo S_N2).

37. Peptide bond in proteins is structurally represented as

- (A) -CO-NH-
- (B) -COO-NH-
- (C) -C-O-C-
- (D) -C-O-CO-

Correct Answer: (A) -CO-NH-

Solution:

Concept:

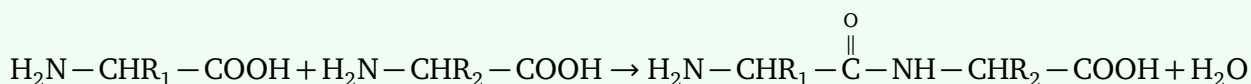
Proteins are linear polymers of α -amino acids connected by peptide bonds.

A peptide bond is a covalent amide linkage formed by a condensation reaction between adjacent amino acid residues.

Step 1: Condensation of Amino Acid Residues:

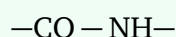
When two α -amino acid molecules react, the carboxylic acid group ($-\text{COOH}$) of one amino acid condenses with the amino group ($-\text{NH}_2$) of the neighboring amino acid.

This condensation eliminates a molecule of water:

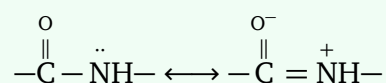


Step 2: Structural Characteristics of the Peptide Linkage:

The resulting amide bond connecting the two amino acid units is represented as:



Resonance between the carbonyl group and the nitrogen atom gives the peptide bond partial double bond character:



This partial double bond character makes the peptide bond planar, rigid, and resistant to rotation, which is important for the folding of protein secondary structures.

Step 3: Verification of Other Options:

- Option (B), $-\text{COO}-\text{NH}-$, represents a nonexistent or unstable carbamate-like linkage.
- Option (C), $-\text{C}-\text{O}-\text{C}-$, represents an ether or glycosidic bond.
- Option (D), $-\text{C}-\text{O}-\text{CO}-$, represents an acid anhydride linkage.

Final Answer:

The peptide bond in proteins is represented as -CO-NH- , corresponding to option (A).

Quick Tip: Key linkages in biomolecules:

- Proteins: Peptide linkage (-CO - NH-).
- Carbohydrates: Glycosidic linkage (-C - O - C-).
- Nucleic acids: Phosphodiester linkage.

38. Fibrous protein is characterized by the presence of hydrogen and disulfide bonds. Examples of fibrous protein are

- (A) Keratin
- (B) Myosin
- (C) Insulin
- (D) Albumins

Choose the correct answer from the options given below:

- (A) (A), (B) and (D) only
- (B) (A) and (B) only
- (C) (A), (B), (C) and (D)
- (D) (C) and (D) only

Correct Answer: (B) (A) and (B) only

Solution:**Concept:**

Proteins are classified into fibrous and globular proteins based on their molecular shape and solubility.

- Fibrous proteins have polypeptide chains running parallel along an axis, held together by hydrogen and disulfide bonds to form fiber-like structures that are typically insoluble in water.
- Globular proteins fold their polypeptide chains into spherical shapes, making them soluble in

aqueous solutions.

Step 1: Identifying Fibrous Proteins:

- Keratin (A): Keratin is an insoluble structural fibrous protein found in hair, wool, nails, horns, and feathers.

Its polypeptide chains are arranged in α -helices or β -sheets held together by hydrogen bonds and extensive disulfide cross-linkages between cysteine residues.

- Myosin (B): Myosin is a fibrous muscle protein that functions alongside actin in muscle contraction.

Its long, fibrous tail domains form coiled-coil rods that are insoluble in water.

Hence, (A) and (B) are fibrous proteins.

Step 2: Identifying Globular Proteins:

- Insulin (C): Insulin is a globular peptide hormone composed of two polypeptide chains folded into a compact, spherical structure that is soluble in water.

- Albumins (D): Albumins (such as ovalbumin in egg white and serum albumin in blood) are globular proteins with spherical conformations that dissolve in water and dilute salt solutions.

Hence, (C) and (D) are globular proteins, not fibrous proteins.

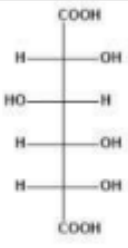
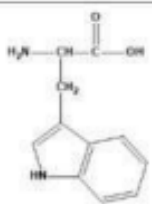
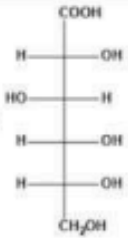
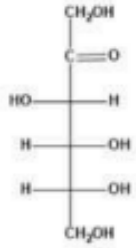
Final Answer:

The examples of fibrous proteins are (A) and (B) only, corresponding to option (B).

Quick Tip: Protein classifications to remember:

- Fibrous (Insoluble, rod-like): Keratin (hair, nails), Myosin (muscles), Collagen.
- Globular (Soluble, spherical): Insulin, Albumin, Hemoglobin.

39. Match List-I with List-II

List-I	List-II
(Name of the Compounds)	(Chemical Structures)
(A) Gluconic acid	(I) 
(B) Fructose	(II) 
(C) Tryptophan	(III) 
(D) Saccharic acid	(IV) 

Choose the correct answer from the options given below:

- (A) (A) - (I), (B) - (II), (C) - (III), (D) - (IV)
 (B) (A) - (II), (B) - (I), (C) - (III), (D) - (IV)
 (C) (A) - (III), (B) - (II), (C) - (IV), (D) - (I)
 (D) (A) - (III), (B) - (IV), (C) - (II), (D) - (I)

Correct Answer: (D) (A) - (III), (B) - (IV), (C) - (II), (D) - (I)

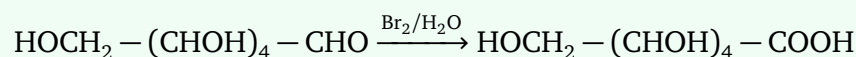
Solution:

Concept:

Carbohydrates and amino acids have characteristic functional group compositions and oxidation states that can be recognized by their chemical structures and Fischer projection formulas.

Step 1: Identifying Gluconic Acid (A):

Gluconic acid is a monocarboxylic aldonic acid formed by mild oxidation of the aldehyde group of D-glucose using bromine water:



Structure (III) shows a six-carbon chain containing one terminal carboxyl group ($-\text{COOH}$) at C1 and a primary alcohol group ($-\text{CH}_2\text{OH}$) at C6.

Therefore, (A) matches with (III).

Step 2: Identifying Fructose (B):

D-Fructose is a ketohexose with the structure $\text{HOCH}_2 - \text{CO} - (\text{CHOH})_3 - \text{CH}_2\text{OH}$.

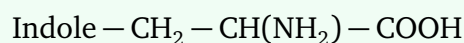
Structure (IV) depicts a six-carbon ketose chain with a ketone carbonyl group at C2 and primary alcohol groups at both ends (C1 and C6).

Therefore, (B) matches with (IV).

Step 3: Identifying Tryptophan (C):

Tryptophan is an essential α -amino acid containing an aromatic indole heterocyclic side chain attached to the β -carbon of alanine.

Structure (II) shows an amino acid containing an indole bicyclic system:



Therefore, (C) matches with (II).

Step 4: Identifying Saccharic Acid (D):

Saccharic acid (glucaric acid) is a dicarboxylic aldonic acid formed by strong oxidation of both the C1 aldehyde and C6 primary alcohol groups of D-glucose with concentrated nitric acid:



Structure (I) shows a six-carbon chain terminated by two carboxylic acid groups ($-\text{COOH}$) at positions C1 and C6.

Therefore, (D) matches with (I).

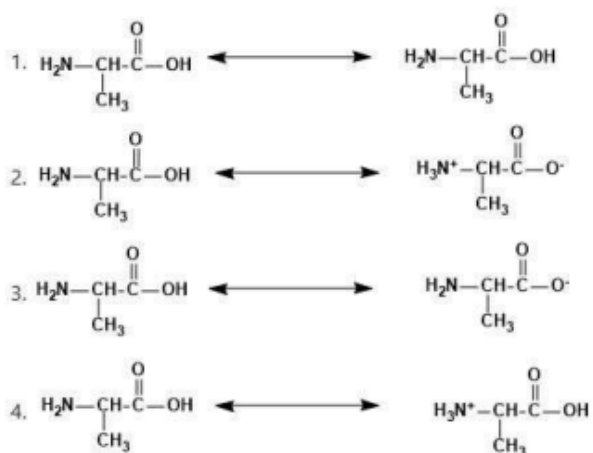
Final Answer:

The correct matching sequence is (A)-(III), (B)-(IV), (C)-(II), (D)-(I), corresponding to option (D).

Quick Tip: Glucose oxidation summary:

- Mild oxidation ($\text{Br}_2/\text{H}_2\text{O}$): Only C1 is oxidized $\rightarrow$ Gluconic acid (monocarboxylic).
- Strong oxidation (HNO_3): Both C1 and C6 are oxidized $\rightarrow$ Saccharic acid (dicarboxylic).

40. Which of the following gives the correct representation of zwitter ion of the given amino acid ?



- (A) Structure 1
(B) Structure 2
(C) Structure 3
(D) Structure 4

Correct Answer: (B) Structure 2

Solution:

Concept:

Amino acids are dipolar molecules containing both an acidic carboxyl group ($-\text{COOH}$) and a basic amino group ($-\text{NH}_2$).

In neutral aqueous solution, an internal acid-base proton transfer occurs from the carboxyl group to the amino group, generating a dipolar ion known as a zwitterion.

Step 1: Identifying the Substrate Amino Acid:

The amino acid shown is alanine:

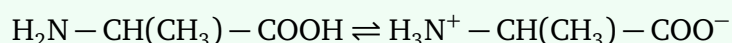


It consists of a central α -carbon bonded to a methyl side chain, a hydrogen atom, an amino group, and a carboxyl group.

Step 2: Intramolecular Proton Transfer Mechanism:

The carboxyl group has a low pK_a (≈ 2.3) and acts as a proton donor, while the basic amino group has a higher pK_a (≈ 9.7) and acts as a proton acceptor.

The acidic proton of the $-\text{COOH}$ group transfers to the lone pair of the $-\text{NH}_2$ group:



Step 3: Characterizing the Zwitterion Structure:

In the resulting zwitterion:

- The amino group carries a positive charge: $-\text{NH}_3^+$,
- The carboxylate group carries a negative charge: $-\text{COO}^-$.

The molecule contains equal numbers of positive and negative charges, making it electrically neutral overall.

- Form (A) represents the un-ionized covalent structure.
- Form (C) represents the anionic form predominant in strongly alkaline medium.
- Form (D) represents the cationic form predominant in strongly acidic medium.
- Form (B) correctly represents the dipolar zwitterion.

Final Answer:

The correct representation of the zwitterion is $\text{H}_3\text{N}^+ - \text{CH}(\text{CH}_3) - \text{COO}^-$, corresponding to option (B).

Quick Tip: A zwitterion must simultaneously possess:

- A protonated ammonium group ($-\text{NH}_3^+$).
- A deprotonated carboxylate group ($-\text{COO}^-$).

Its net molecular electrical charge is zero at the isoelectric point.

Comprehension: (Questions 41 to 45)

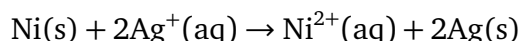
Electrochemical cells

We can construct innumerable number of galvanic cells on the pattern of Daniell cell by taking combinations of different half-cells. Each half-cell consists of a metallic electrode dipped into an electrolyte. The two half-cells are connected by a metallic wire through a voltmeter and a switch externally. The electrolytes of the two half-cells are connected internally through a salt bridge. Sometimes, both the electrodes dip in the same electrolyte solution and in such cases we do not require a salt bridge.

For the cell

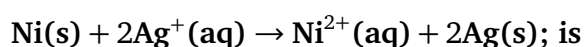


The cell reaction is:



Nernst equation relates the emf of the cell with standard emf and the concentration of reduced and oxidized species.

41. The Nernst equation for the given reaction



$$(A) E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{RT}{2F} \ln \frac{[\text{Ni}^{2+}]}{[\text{Ag}^+]^2}$$

- (B) $E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{RT}{2F} \ln \frac{[\text{Ni}^{2+}]}{[\text{Ag}^+]}$
- (C) $E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{RT}{F} \ln \frac{[\text{Ni}^{2+}]}{[\text{Ag}^+]}$
- (D) $E_{\text{cell}} = E_{\text{cell}}^{\circ} + \frac{RT}{F} \ln \frac{[\text{Ni}^{2+}]}{[\text{Ag}^+]}$

Correct Answer: (A) $E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{RT}{2F} \ln \frac{[\text{Ni}^{2+}]}{[\text{Ag}^+]^2}$

Solution:

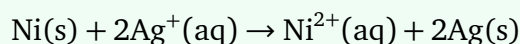
Concept:

The Nernst equation expresses the electromotive force (E_{cell}) of an electrochemical cell as a function of the standard cell potential (E_{cell}°), temperature (T), the number of moles of electrons transferred (n), and the reaction quotient (Q):

$$E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{RT}{nF} \ln Q$$

Step 1: Determining the Number of Electrons Transferred (n):

The overall redox reaction is:



Splitting the reaction into its two half-cell reactions:

- Anodic oxidation: $\text{Ni(s)} \rightarrow \text{Ni}^{2+}(\text{aq}) + 2e^-$
- Cathodic reduction: $2\text{Ag}^+(\text{aq}) + 2e^- \rightarrow 2\text{Ag(s)}$

Two moles of electrons are exchanged during the overall cell process.

Therefore, $n = 2$.

Step 2: Formulating the Reaction Quotient (Q):

In writing the expression for the reaction quotient Q , pure solids have unit activity ($a_{\text{Ni(s)}} = 1$ and $a_{\text{Ag(s)}} = 1$).

Taking stoichiometric coefficients into account:

$$Q = \frac{[\text{Ni}^{2+}]}{[\text{Ag}^+]^2}$$

Step 3: Assembling the Nernst Equation:

Substituting $n = 2$ and the expression for Q into the general Nernst equation gives:

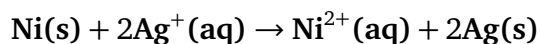
$$E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{RT}{2F} \ln \frac{[\text{Ni}^{2+}]}{[\text{Ag}^+]^2}$$

Final Answer:

The correct Nernst equation corresponds to option (A).

Quick Tip: Remember to square the concentration of Ag^+ in the denominator of Q because its stoichiometric coefficient in the balanced cell reaction is 2!

42. The standard electrode potential for the cell



is 0.80 V. The standard Gibbs energy for the reaction is:

- (A) $-154.379 \text{ kJ mol}^{-1}$
- (B) $154.379 \text{ kJ mol}^{-1}$
- (C) $212.2 \text{ kJ mol}^{-1}$
- (D) $-212.2 \text{ kJ mol}^{-1}$

Correct Answer: (A) $-154.379 \text{ kJ mol}^{-1}$

Solution:

Concept:

The maximum electrical work obtainable from an electrochemical cell under standard conditions is equal to the decrease in standard Gibbs free energy:

$$\Delta G^{\circ} = -nFE_{\text{cell}}^{\circ}$$

where n is the number of moles of electrons transferred, F is the Faraday constant ($1 \text{ F} \approx 96487 \text{ C mol}^{-1}$), and E_{cell}° is the standard electromotive force.

Step 1: Identifying Given Parameters:

- Number of electrons transferred: $n = 2$
- Standard Faraday constant: $F = 96487 \text{ C mol}^{-1}$
- Standard cell potential: $E_{\text{cell}}^{\circ} = 0.80 \text{ V}$

Step 2: Calculating ΔG° :

Substitute the values into the thermodynamic relation:

$$\Delta G^{\circ} = -(2) \times (96487 \text{ C mol}^{-1}) \times (0.80 \text{ V})$$

Recalling that $1 \text{ C} \cdot \text{V} = 1 \text{ J}$:

$$\Delta G^{\circ} = -154379.2 \text{ J mol}^{-1}$$

Step 3: Converting to Kilojoules per Mole:

Convert the calculated value to kJ mol^{-1} :

$$\Delta G^{\circ} = \frac{-154379.2}{1000} \text{ kJ mol}^{-1} = -154.379 \text{ kJ mol}^{-1}$$

Because E_{cell}° is positive ($+0.80 \text{ V}$), the standard Gibbs free energy change ΔG° must be negative, reflecting a spontaneous process.

Final Answer:

The standard Gibbs energy for the reaction is $-154.379 \text{ kJ mol}^{-1}$, corresponding to option (A).

Quick Tip: Sign check in electrochemistry:

If $E_{\text{cell}}^{\circ} > 0$, then $\Delta G^{\circ} < 0$ (spontaneous reaction).

This allows you to eliminate positive answer choices immediately.

43. The relationship between the equilibrium constant of the reaction and the standard electrode potential of the cell in which that reaction takes place is given by

(A) $E_{\text{cell}}^{\circ} = \frac{RT}{2.303 \times nF} \log K_c$

- (B) $E_{\text{cell}}^{\circ} = \frac{2.303RT}{nF} \log K_c$
 (C) $E_{\text{cell}}^{\circ} = \frac{2.303RT}{nF} \ln K_c$
 (D) $E_{\text{cell}}^{\circ} = 2.303RT \ln K_c$

Correct Answer: (B) $E_{\text{cell}}^{\circ} = \frac{2.303RT}{nF} \log K_c$

Solution:

Concept:

At dynamic chemical equilibrium, the cell electromotive force reaches zero ($E_{\text{cell}} = 0$) and the reaction quotient becomes equal to the equilibrium constant ($Q = K_c$).

Substituting these boundary conditions into the Nernst equation provides the thermodynamic link between standard potential and the equilibrium constant.

Step 1: Applying Equilibrium Conditions to the Nernst Equation:

The general Nernst equation is:

$$E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{RT}{nF} \ln Q$$

Setting $E_{\text{cell}} = 0$ and $Q = K_c$:

$$0 = E_{\text{cell}}^{\circ} - \frac{RT}{nF} \ln K_c$$

Rearranging gives:

$$E_{\text{cell}}^{\circ} = \frac{RT}{nF} \ln K_c$$

Step 2: Converting Natural Logarithm to Base-10 Logarithm:

Using the identity relating natural and common logarithms:

$$\ln K_c = 2.303 \log_{10} K_c$$

Substituting this into the expression gives:

$$E_{\text{cell}}^{\circ} = \frac{2.303RT}{nF} \log K_c$$

Step 3: Analyzing the Given Choices:

- Option (B) correctly includes the factor 2.303 alongside the common logarithm $\log K_c$.
- Option (C) incorrectly combines 2.303 with the natural logarithm $\ln K_c$.
- Option (A) has the 2.303 factor in the denominator.
- Option (D) omits the nF term entirely.

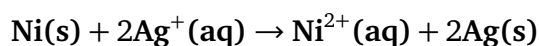
Final Answer:

The correct relationship is $E_{\text{cell}}^{\circ} = \frac{2.303RT}{nF} \log K_c$, corresponding to option (B).

Quick Tip: At 298 K, substituting numerical values into this equation gives the useful form:

$$E_{\text{cell}}^{\circ} = \frac{0.0591}{n} \log K_c$$

44. In the given cell,



which of the given species is the reducing agent?

- (A) $\text{Ni}^{2+}(\text{aq})$
- (B) Ni(s)
- (C) $\text{Ag}^+(\text{aq})$
- (D) Ag(s)

Correct Answer: (B) Ni(s)

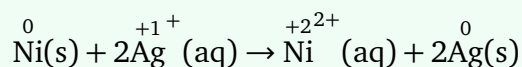
Solution:**Concept:**

In a redox reaction:

- The species that loses electrons undergoes oxidation and acts as the reducing agent (reductant).
- The species that gains electrons undergoes reduction and acts as the oxidizing agent (oxidant).

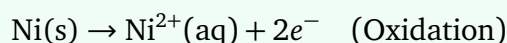
Step 1: Tracking Oxidation States:

Let us evaluate the changes in oxidation number for all elements in the cell reaction:



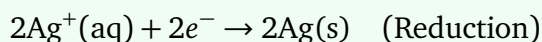
1. Nickel: The oxidation state of solid nickel increases from 0 in Ni(s) to +2 in Ni²⁺(aq).

This increase in oxidation number indicates that nickel loses two electrons:



2. Silver: The oxidation state of silver decreases from +1 in Ag⁺(aq) to 0 in Ag(s).

This decrease in oxidation number indicates that silver ions gain electrons:

**Step 2: Identifying the Reducing Agent:**

Because Ni(s) is oxidized by losing electrons to Ag⁺, it causes the reduction of silver ions.

Therefore, metallic nickel, Ni(s), serves as the reducing agent.

Ag⁺(aq) is the oxidizing agent, while Ni²⁺(aq) and Ag(s) are reaction products.

Final Answer:

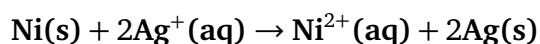
The reducing agent is Ni(s), which corresponds to option (B).

Quick Tip: Remember:

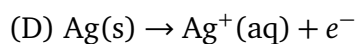
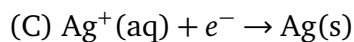
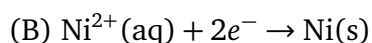
- Reducing agent = Reactant that undergoes oxidation (loses e⁻).
- Oxidizing agent = Reactant that undergoes reduction (gains e⁻).

Products cannot be the agents for the forward reaction!

45. Which of the following is the anodic half cell reaction?



(A) $\text{Ni}(\text{s}) \rightarrow \text{Ni}^{2+}(\text{aq}) + 2e^-$



Correct Answer: (A) $\text{Ni}(\text{s}) \rightarrow \text{Ni}^{2+}(\text{aq}) + 2e^{-}$

Solution:

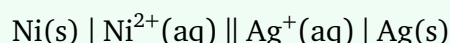
Concept:

In all electrochemical and galvanic cells, the electrode at which oxidation (loss of electrons) occurs is designated as the anode.

The electrode at which reduction (gain of electrons) occurs is designated as the cathode.

Step 1: Analyzing Cell Notation and Half-Reactions:

The cell notation given in the comprehension is:

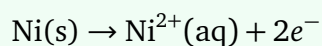


By IUPAC convention:

- The half-cell written on the left-hand side is the anode.
- The half-cell written on the right-hand side is the cathode.

Step 2: Formulating the Oxidation Reaction at the Anode:

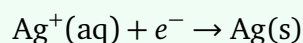
At the nickel electrode (anode), metallic nickel loses two electrons to enter the solution as hydrated nickel(II) cations:



This is the anodic half-cell reaction.

Step 3: Formulating the Reduction Reaction at the Cathode:

At the silver electrode (cathode), silver ions in solution accept electrons from the electrode to deposit as metallic silver:



This represents the cathodic half-cell reaction.

Final Answer:

The anodic half-cell reaction is $\text{Ni(s)} \rightarrow \text{Ni}^{2+}(\text{aq}) + 2e^{-}$, which corresponds to option (A).

Quick Tip: Standard mnemonic:

- Anode = Oxidation (An Ox).
- Cathode = Reduction (Red Cat).

In galvanic cells, the anode is written on the left.

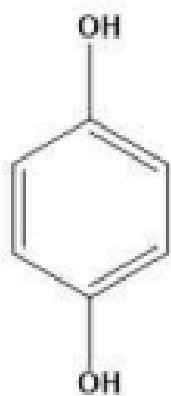
Comprehension: (Questions 46 to 50)

Alcohols, Phenols and Ethers

Alcohols and phenols are formed when a hydrogen atom in a hydrocarbon, aliphatic and aromatic respectively, is replaced by -OH group. These classes of compounds find wide applications in industry as well as in day-to-day life. For instance, have you ever noticed that ordinary spirit used for polishing wooden furniture is chiefly a compound containing hydroxyl group, ethanol. The sugar we eat, the cotton used for fabrics, the paper we use for writing, are all made up of compounds containing -OH groups. The common name of an alcohol is derived from the common name of the alkyl group and adding the word alcohol to it. For example, CH_3OH is methyl alcohol. The simplest hydroxy derivative of benzene is phenol. It is its common name and also an accepted IUPAC name. As structure of phenol involves a benzene ring, in its substituted compounds the terms ortho (1,2-disubstituted), meta (1,3-disubstituted) and para (1,4-disubstituted) are often used in the common names.

In ethers, the four electron pairs, i.e., the two bond pairs and two lone pairs of electrons on oxygen are arranged approximately in a tetrahedral arrangement. The bond angle is slightly greater than the tetrahedral angle due to the repulsive interaction between the two bulky (-R) groups.

46. What is the common name for the following structure given below?



- (A) Resorcinol
- (B) Catechol
- (C) Hydroquinone
- (D) m-cresol

Correct Answer: (C) Hydroquinone

Solution:

Concept:

Benzenediols are aromatic compounds containing two hydroxyl groups attached directly to a benzene ring.

The three positional isomers of dihydroxybenzene have established common names accepted alongside systematic IUPAC nomenclature.

Step 1: Identifying the Substitution Pattern:

The structure displayed in the problem shows a benzene ring substituted with two phenolic hydroxyl groups at positions 1 and 4 relative to each other:

Benzene-1,4-diol (1,4-dihydroxybenzene)

This represents the *para*-disubstituted isomer.

Step 2: Analysis of Common Names of Benzenediols:

1. 1,2-Dihydroxybenzene (ortho isomer) is commonly called Catechol.

2. 1,3-Dihydroxybenzene (meta isomer) is commonly called Resorcinol.
3. 1,4-Dihydroxybenzene (para isomer) is commonly called Hydroquinone or Quinol.
4. m-Cresol is a monohydric phenol bearing a methyl group at the 3-position (3-methylphenol).

Step 3: Matching Structure with Common Name:

Because the two —OH groups are positioned *para* (1,4) to each other across the benzene ring, the common name of the structure is hydroquinone.

Final Answer:

The common name for the given structure is Hydroquinone, corresponding to option (C).

Quick Tip: Dihydric Phenols Nomenclature:

- 1,2-isomer = Catechol.
- 1,3-isomer = Resorcinol.
- 1,4-isomer = Hydroquinone (Quinol).

47. The catalyst involved in the production of methanol through hydrogenation of carbon monoxide is

- (A) $\text{ZnO-Cr}_2\text{O}_3$
- (B) ZnO/Pt
- (C) Anhyd. AlCl_3
- (D) Anhyd. FeCl_3

Correct Answer: (A) $\text{ZnO-Cr}_2\text{O}_3$

Solution:

Concept:

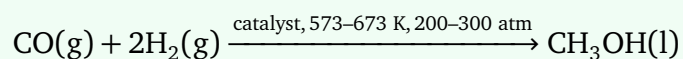
Methanol (CH_3OH), historically known as wood spirit, is industrially manufactured on a large scale by the catalytic hydrogenation of water gas (a mixture of carbon monoxide and

hydrogen).

This heterogeneous catalytic reaction requires specific mixed metal oxide catalysts operating at elevated temperatures and pressures.

Step 1: The Industrial Synthesis Reaction:

Carbon monoxide reacts with gaseous hydrogen according to the balanced chemical equation:



Step 2: Identifying the Heterogeneous Catalyst:

According to NCERT Alcohols, Phenols and Ethers:

"Methanol is produced by catalytic hydrogenation of carbon monoxide at high pressure and temperature and in the presence of $\text{ZnO} - \text{Cr}_2\text{O}_3$ catalyst."

The mixed catalyst composed of zinc oxide and chromium(III) oxide ($\text{ZnO} - \text{Cr}_2\text{O}_3$) provides active catalytic sites that selectively adsorb CO and H_2 , facilitating hydride and proton transfer to yield methanol with high selectivity.

Step 3: Evaluating Alternative Options:

- ZnO/Pt is not used commercially for this transformation.
- Anhydrous AlCl_3 is a strong Lewis acid used in Friedel-Crafts alkylation and acylation reactions.
- Anhydrous FeCl_3 is a Lewis acid catalyst used in the electrophilic halogenation of aromatic rings.

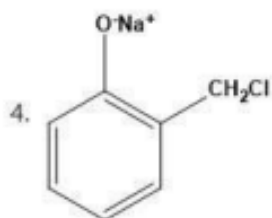
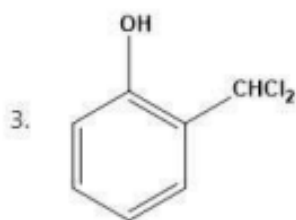
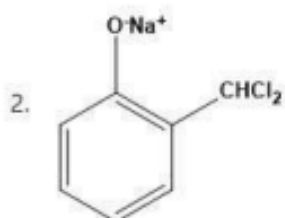
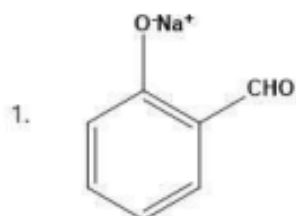
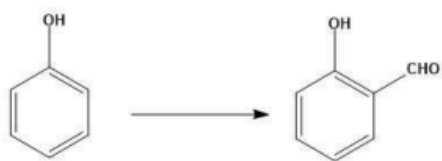
Final Answer:

The catalyst involved is $\text{ZnO-Cr}_2\text{O}_3$, corresponding to option (A).

Quick Tip: Industrial conditions for Methanol manufacture:

- Reaction: $\text{CO} + 2\text{H}_2 \rightarrow \text{CH}_3\text{OH}$.
- Catalyst: $\text{ZnO} - \text{Cr}_2\text{O}_3$.
- Conditions: 573–673 K and 200–300 atm.

48. Consider the following chemical reaction and identify the intermediate involved in the reaction.



(A) Figure 1

(B) Figure 2

(C) Figure 3

(D) Figure 4

Correct Answer: (B) Figure 2

Solution:

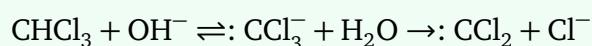
Concept:

The conversion of phenol to salicylaldehyde by heating with chloroform in the presence of aqueous sodium hydroxide is known as the Reimer-Tiemann reaction.

The reaction proceeds through an electrophilic aromatic substitution pathway involving dichlorocarbene, generating a substituted benzal chloride intermediate.

Step 1: Generation of the Electrophilic Carbene:

In the initial step, hydroxide ion abstracts an acidic proton from chloroform (CHCl_3), which subsequently loses a chloride ion by α -elimination to form neutral dichlorocarbene ($:\text{CCl}_2$):

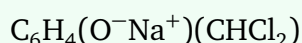


Dichlorocarbene has a sextet of valence electrons, making it an electrophile.

Step 2: Electrophilic Attack on Sodium Phenoxide:

Simultaneously, sodium hydroxide deprotonates phenol to generate the nucleophilic phenoxide ion ($\text{C}_6\text{H}_5\text{O}^-\text{Na}^+$).

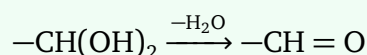
The phenoxide ion attacks the electrophilic dichlorocarbene primarily at the electron-rich *ortho*-position, generating an intermediate carrying a dichloromethyl group:



This species is sodium 2-(dichloromethyl)phenoxide (intermediate B).

Step 3: Hydrolysis to the Aldehyde:

In the subsequent step, the two chlorine atoms of the $-\text{CHCl}_2$ group are nucleophilically displaced by hydroxide ions to form an unstable gem-diol:



Subsequent acidification yields salicylaldehyde.

Thus, the isolated intermediate before hydrolysis is the sodium phenoxide bearing an *ortho*- CHCl_2 group.

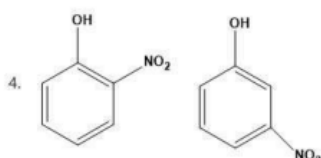
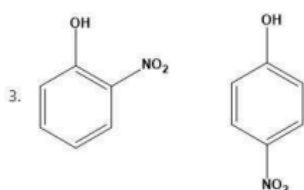
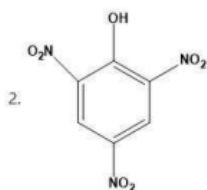
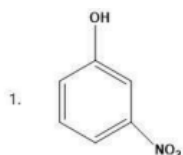
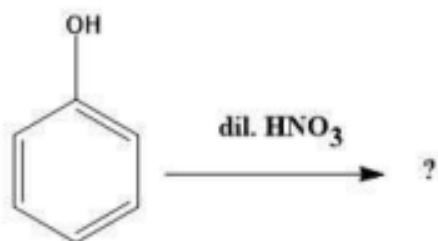
Final Answer:

The intermediate involved in the reaction is the *ortho*-dichloromethyl phenoxide intermediate, corresponding to option (B).

Quick Tip: Reimer-Tiemann intermediate checkpoints:

- Reactive intermediate/electrophile = Dichlorocarbene (:CCl_2).
- Isolable reaction intermediate = Benzal chloride type: $\text{Ar}(\text{O}^-\text{Na}^+)(\text{CHCl}_2)$.

49. Consider the following chemical reaction and identify the final product(s)



(A) Figure 1

- (B) Figure 2
(C) Figure 3
(D) Figure 4

Correct Answer: (C) Figure 3

Solution:

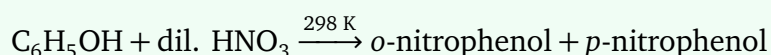
Concept:

The hydroxyl group ($-\text{OH}$) attached directly to a benzene ring activates the ring strongly towards electrophilic aromatic substitution through $+M$ resonance, directing incoming electrophiles to the *ortho*- and *para*-positions.

Step 1: Reaction Conditions with Dilute Nitric Acid:

When phenol is treated with dilute nitric acid (dil. HNO_3) at low temperature (298 K), the mild nitrating conditions prevent destructive over-oxidation of the activated phenolic ring.

The electrophilic nitronium ion (NO_2^+) attacks the activated *ortho*- and *para*-positions, yielding a mixture of two mononitrophenols:



Step 2: Analysis of the Products Formed:

- *ortho*-Nitrophenol (2-nitrophenol) contains an intramolecular hydrogen bond between the phenolic $-\text{OH}$ and the adjacent nitro group, making it steam-volatile.

- *para*-Nitrophenol (4-nitrophenol) forms intermolecular hydrogen bonds with surrounding molecules, resulting in higher boiling points and lower volatility.

These two structural isomers are separated in the laboratory by steam distillation.

Step 3: Comparison with Concentrated Nitric Acid:

If concentrated nitric acid in the presence of concentrated sulfuric acid were used, phenol would undergo extensive nitration at all available *ortho*- and *para*-positions to produce 2,4,6-trinitrophenol (picric acid).

Because dilute nitric acid is specified, only mononitration occurs, yielding a mixture of *ortho*- and *para*-nitrophenols.

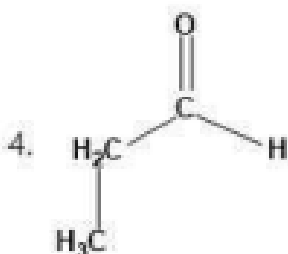
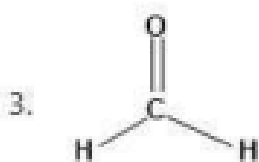
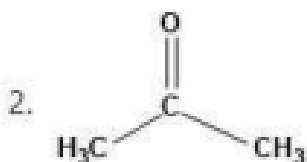
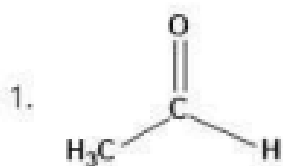
Final Answer:

The reaction yields a mixture of *ortho*-nitrophenol and *para*-nitrophenol, which corresponds to option (C).

Quick Tip: Nitration of Phenol:

- With dilute HNO_3 at 298 K $\rightarrow$ *ortho*-nitrophenol + *para*-nitrophenol (separable by steam distillation).
- With concentrated $\text{HNO}_3 \rightarrow$ 2,4,6-trinitrophenol (picric acid).

50. The final product for the following reaction is



(A) Figure 1

- (B) Figure 2
(C) Figure 3
(D) Figure 4

Correct Answer: (A) Figure 1

Solution:

Concept:

Passing alcohol vapors over heated copper metal at 573 K is an industrial and laboratory method for the selective catalytic dehydrogenation of primary and secondary alcohols.

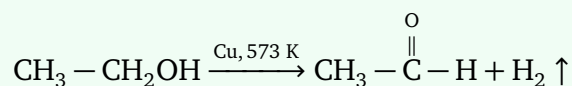
This oxidation method avoids the use of strong aqueous oxidizing agents and prevents over-oxidation to carboxylic acids.

Step 1: Mechanism of Catalytic Dehydrogenation:

Ethanol ($\text{CH}_3\text{CH}_2\text{OH}$) is a primary (1°) alcohol.

When ethanol vapors are passed over finely divided metallic copper heated to 573 K (300°C), it undergoes dehydrogenation (loss of one molecule of hydrogen gas, H_2).

The two hydrogen atoms—one from the hydroxyl group and one from the α -carbon—are removed:



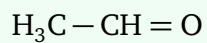
The product is ethanal (acetaldehyde).

Step 2: Behavior of Other Classes of Alcohols over Heated Copper:

- Secondary (2°) alcohols undergo dehydrogenation to produce ketones (e.g., propan-2-ol forms acetone).
 - Tertiary (3°) alcohols lack an α -hydrogen atom; instead of dehydrogenating, they undergo dehydration in the presence of heated copper at 573 K to yield alkenes.
- Since ethanol is a primary alcohol, it dehydrogenates cleanly to yield ethanal.

Step 3: Matching Product Structure:

Option (A) displays the structural formula of ethanal:



Final Answer:

The final product is ethanal, corresponding to option (A).

Quick Tip: Behavior of alcohols over Cu at 573 K:

- 1° alcohol → Aldehyde (e.g., Ethanol → Ethanal).
- 2° alcohol → Ketone (e.g., Isopropanol → Acetone).
- 3° alcohol → Alkene (via dehydration, e.g., tert-butanol → 2-methylpropene).