CUET PG 2025 Chemistry Question Paper with Solutions

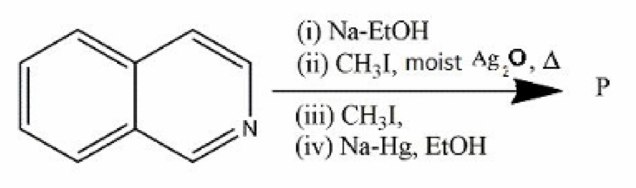
Time Allowed :1 Hour 45 Mins	**Maximum Marks :**300	**Total questions :**75

General Instructions

Read the following instructions very carefully and strictly follow them:

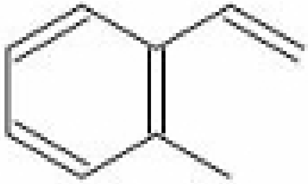
1. The examination duration is 105 minutes. Manage your time effectively to attempt all questions within this period.
2. The total marks for this examination are 300. Aim to maximize your score by strategically answering each question.
3. There are 75 mandatory questions to be attempted in the Atmospheric Science paper. Ensure that all questions are answered.
4. Questions may appear in a shuffled order. Do not assume a fixed sequence and focus on each question as you proceed.
5. The marking of answers will be displayed as you answer. Use this feature to monitor your performance and adjust your strategy as needed.
6. You may mark questions for review and edit your answers later. Make sure to allocate time for reviewing marked questions before final submission.
7. Be aware of the detailed section and sub-section guidelines provided in the exam. Understanding these will aid in effectively navigating the exam.

1. The reaction steps shown are:



The final product (P) is:

1.



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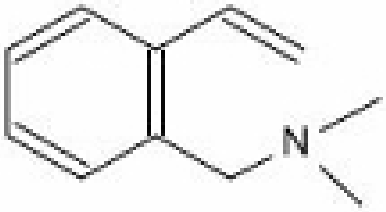

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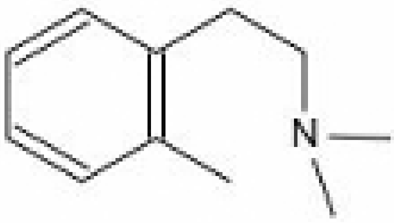

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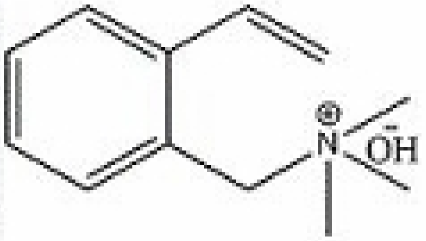

Correct Answer: (2) Quinoline

Solution:

Step 1: Elimination with Sodium Ethoxide.

When sodium ethoxide ($NaOEt$) is introduced, it acts as a strong base. Its main role is to abstract a proton adjacent to a halogen atom in the substrate. This leads to the removal of HX (dehydrohalogenation), thereby forming a double bond. As a result, a more unsaturated intermediate is generated which is highly reactive and undergoes further transformations.

Step 2: Alkylation using Methyl Iodide.

The intermediate is then treated with methyl iodide (CH_3I). Methyl iodide is an excellent alkylating agent. The lone pair of electrons on the nitrogen atom of pyridine attacks the electrophilic carbon of methyl iodide. This results in the formation of a quaternary ammonium salt (N-methyl pyridinium salt). This step makes the nitrogen more positively charged and hence facilitates subsequent rearrangements.

Step 3: Reaction with Moist Silver Oxide and Heating.

When this quaternary salt is treated with moist silver oxide (Ag_2O) followed by heating, the iodide ion is replaced with a hydroxide ion. The hydroxide ion makes the salt unstable and prone to rearrangement. On heating, the system undergoes a structural rearrangement in order to gain aromatic stability. This rearrangement shifts the system towards the fused heterocyclic ring system.

Step 4: Reduction with Sodium–Mercury Amalgam.

Finally, the intermediate product is reduced by sodium amalgam ($Na - Hg$) in ethanol. The reduction removes any extra positive charges and stabilizes the system by regenerating aromaticity. The end product obtained after this reduction step is **quinoline**, a bicyclic aromatic heterocycle containing both a benzene and pyridine ring fused together.

Final Answer:

$$\boxed{\text{Quinoline}}$$

Quick Tip

Formation of quinoline involves sequential elimination, alkylation, rearrangement, and reduction steps, with the sodium amalgam reduction being the key to restore aromaticity.

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2. Consider the following statements with respect to citral:

- (A) Geranial and Neral are geometrical isomers of citral.
- (B) It forms geranic acid on heating with potassium hydrogen sulfate.
- (C) It gives 6-methylhept-5-en-2-one on treating with potassium carbonate.
- (D) On oxidation with silver oxide it yields Laevolic acid.

Choose the correct answer from the options given below:

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

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

Solution:
Step 1: Geranial and Neral as Geometrical Isomers.
Citral exists in two geometrical forms due to restricted rotation around the double bond near the aldehyde group. The **trans-isomer** is known as **geranial**, while the **cis-isomer** is called **neral**. Since they differ only in the spatial arrangement of substituents, they are geometrical isomers. Hence, statement (A) is correct.
Step 2: Formation of Geranic Acid.
On heating citral with potassium hydrogen sulfate ($KHSO_4$), dehydration and rearrangement occur. This leads to the formation of **geranic acid**, a known transformation of citral under acidic dehydrating conditions. Thus, statement (B) is correct.
Step 3: Treatment with Potassium Carbonate.
When citral is treated with potassium carbonate (K_2CO_3), no such rearrangement to form 6-methylhept-5-en-2-one occurs. The base does not induce the claimed cleavage under these conditions. Therefore, statement (C) is incorrect.
Step 4: Oxidation with Silver Oxide.
On oxidation with silver oxide (Ag_2O), the aldehyde group in citral is oxidized. The reaction proceeds through oxidative cleavage leading to the formation of **Laevolic acid**. This confirms that statement (D) is correct.

Step 5: Evaluating the Options.

Since statements (A), (B), and (D) are correct while (C) is not, the correct option is (A).

Final Answer:

$$\boxed{\text{(A), (B) and (D) only}}$$

Quick Tip

Citral exists as two geometric isomers, and its reactivity under different reagents can lead to geranic acid or Laevolic acid, but not the claimed ketone in option (C).

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3. Which correct sequence of reactions are applied to achieve the following transformation?

$$\text{Benzoyl Chloride} \xrightarrow{H_2,\text{Pd-BaSO}_4} \xrightarrow{\text{dil. NaOH}} \text{Cinnamaldehyde}$$

Choose the correct sequence of reactions from the options given below:

(A) Bouveault-Blanc's reduction followed by Kolbe-Schmidt's reaction
(B) Rosenmund's reduction followed by Claisen-Schmidt's reaction
(C) Bouveault-Blanc's reduction followed by Claisen-Schmidt's reaction
(D) Rosenmund's reduction followed by Perkin's reaction

Correct Answer: (B) Rosenmund's reduction followed by Claisen-Schmidt's reaction

Solution:

Step 1: First reaction – Rosenmund's reduction.

Benzoyl chloride is treated with hydrogen in the presence of palladium on barium sulfate ($H_2, Pd - BaSO_4$). This is a classic **Rosenmund reduction**, which selectively reduces acid chlorides to aldehydes. Thus, benzoyl chloride is converted into **benzaldehyde**.

Step 2: Second reaction – Claisen–Schmidt condensation.

Benzaldehyde is then treated with dilute sodium hydroxide ($NaOH$). In the presence of another aldehyde (like acetaldehyde), it undergoes the **Claisen–Schmidt condensation**, which is an aldol-type condensation reaction. This produces an α, β-unsaturated aldehyde, specifically **cinnamaldehyde**.

Step 3: Checking the options.

- (A) Bouveault–Blanc's reduction produces alcohols, not aldehydes → Incorrect.
- (C) Same reason, Bouveault–Blanc's reduction is not suitable → Incorrect.
- (D) Perkin's reaction produces cinnamic acid derivatives, not cinnamaldehyde → Incorrect.

Thus, only (B) is correct.

Final Answer:

$$\boxed{\text{(B) Rosenmund's reduction followed by Claisen-Schmidt's reaction}}$$

Quick Tip

Rosenmund's reduction gives aldehydes from acyl chlorides, and Claisen–Schmidt condensation forms cinnamaldehyde via base catalysis.

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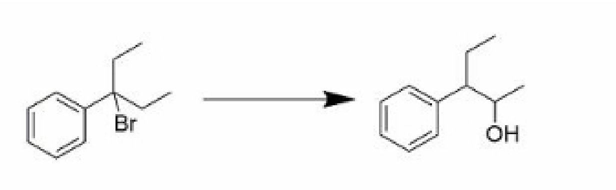
4. Above conversion is carried out using:



(A) (I) KOH (alc.), (II) oxymurcuration-demercuration

(B) (I) KOH (aq.), (II) Conc. H_2SO_4

(C) (I) KOH (alc.), (II) Hydroboration-oxidation

(D) (I) Nucleophilic addition-elimination, (II) oxymurcuration-demercuration

Correct Answer: (A) (I) KOH (alc.), (II) oxymurcuration-demercuration

Solution:

Step 1: Elimination using alcoholic KOH.

When a bromo compound is treated with alcoholic KOH ($KOH(alc.)$), it undergoes an **E2 elimination** reaction. The bromine atom leaves, and a β-hydrogen is removed, resulting in the formation of an **alkene**.

Step 2: Oxymurcuration–demercuration of the alkene.

The double bond formed in Step 1 then undergoes **oxymercuration–demercuration**. - In the first stage, oxymercuration with mercuric acetate adds an –OH group to the more substituted carbon (Markovnikov's orientation) without carbocation rearrangement.

- In the second stage, demercuration with sodium borohydride ($NaBH_4$) replaces the mercury group with hydrogen, yielding a stable alcohol.

Step 3: Checking the options.

- (B) Aqueous KOH and conc. H_2SO_4 would lead to substitution and dehydration, not the alcohol.
- (C) Hydroboration–oxidation gives anti-Markovnikov alcohols, not the observed product.
- (D) Nucleophilic addition–elimination is unrelated here.

Therefore, only (A) is correct.

Final Answer:

$$\boxed{\text{(A) (I) KOH (alc.), (II) oxymurcuration-demercuration}}$$

Quick Tip

Alcoholic KOH favors elimination (E2) to give alkenes, and oxymercuration–demercuration provides Markovnikov alcohols without rearrangements.

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5. The final product (D) in the above conversion is:

$$\text{Me} - \text{CH}_3 \xrightarrow{\text{H}_2\text{,(mol),Ni}} \text{(A)} \xrightarrow{\text{PhCO}_2\text{H,H}_2\text{O}} \text{(B)} \xrightarrow{\text{NaOEt, EtOH}} \text{(C)} \xrightarrow{\text{EtMgBr, Et}_2\text{O}} \xrightarrow{\text{H}_2\text{O}} \text{(D)}$$

The options are:

(A) Acetone

(B) 2-Butanol

(C) 1-Butanol

(D) 2-Pentanol

Correct Answer: (B) 2-Butanol

Solution:

Step 1: Hydrogenation of the alkene.

Hydrogenation with H_2 and nickel (Ni) converts the starting compound into a saturated hydrocarbon (A). This step removes unsaturation.

Step 2: Esterification with benzoic acid.

Compound (A) reacts with benzoic acid ($PhCO_2H$) and water. This esterification process leads to compound (B), introducing an ester group.

Step 3: Reaction with sodium ethoxide.

Compound (B) reacts with sodium ethoxide ($NaOEt$) in ethanol. This base treatment drives a nucleophilic substitution or transesterification, producing compound (C), which is an ester ready for Grignard attack.

Step 4: Grignard reaction.

Compound (C) is then treated with ethylmagnesium bromide ($EtMgBr$) in dry ether. Grignard reagents attack the carbonyl carbon of esters. After hydrolysis (water work-up), the product formed is **2-butanol** (D), a secondary alcohol.

Final Answer:

$$\boxed{\text{(B) 2-Butanol}}$$

Quick Tip

Grignard reagents add to esters to give secondary alcohols, making them useful for chain extension in organic synthesis.

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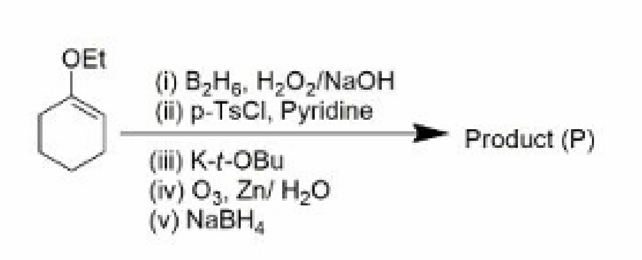
6. The major product (P) in the following transformation is:



(A) Hexane-1,6-diol

(B) 1,6-Dihydroxyhexan-2-one

(C) Hexane-1,2,6-triol

(D) 2-Ethoxyhexane-1,6-diol

Correct Answer: (A) Hexane-1,6-diol

Solution:

Step 1: Hydroboration of the alkene.

The reaction begins with diborane (B_2H_6), which adds across the double bond of the alkene. Boron attaches to the less substituted carbon (anti-Markovnikov addition). This forms an organoborane intermediate.

Step 2: Oxidation of organoborane.

Treatment with hydrogen peroxide (H_2O_2) in basic medium ($NaOH$) oxidizes the organoborane, replacing the B–C bond with a C–OH bond. This results in the introduction of hydroxyl groups.

Step 3: Formation of the product.

Since the reaction occurs at both ends of the molecule, the final product obtained is **Hexane-1,6-diol**, a terminal diol.

Step 4: Checking the options.

- (B) and (C) suggest extra –OH groups, which are not introduced here.
- (D) suggests retention of ethoxy, but the hydroboration–oxidation converts the alkene fully into the diol.

Thus, only (A) is correct.

Final Answer:

$$\boxed{\text{(A) Hexane-1,6-diol}}$$

💡 Quick Tip

Hydroboration–oxidation of alkenes adds OH groups in anti-Markovnikov fashion, often producing terminal alcohols when applied to terminal alkenes.

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7. Which of the following compound is not formed during Kolbe's electrolysis of ethyl propionate?

(A) n-Butane
(B) Ethane
(C) Ethylene
(D) n-Propane

Correct Answer: (C) Ethylene

Solution:
Step 1: Understanding Kolbe's electrolysis.
Kolbe's electrolysis involves the electrochemical oxidation of salts of carboxylic acids or esters. At the anode, decarboxylation occurs, releasing carbon dioxide and forming free radicals. These radicals then couple together to form saturated hydrocarbons.
Step 2: Applying the reaction to ethyl propionate.
In the case of ethyl propionate, the ester undergoes decarboxylation to generate radicals such as ethyl ($C_2H_5\cdot$) and propyl ($C_3H_7\cdot$). These radicals can recombine in different ways to give alkanes: - Two ethyl radicals combine $\rightarrow$ ethane.
- Two propyl radicals combine $\rightarrow$ n-hexane.
- An ethyl radical and a propyl radical combine $\rightarrow$ n-butane or n-propane (depending on fragmentation).
Step 3: Identifying what is not formed.
Since Kolbe's electrolysis proceeds through radical coupling, the major products are saturated hydrocarbons (alkanes). Formation of an unsaturated compound like ethylene (C_2H_4) is not possible in this reaction mechanism.
Step 4: Conclusion.

Therefore, the compound not formed is **ethylene**.

Final Answer:

$$\boxed{\text{(C) Ethylene}}$$

Quick Tip

Kolbe's electrolysis of esters or carboxylates gives alkanes by radical coupling, not alkenes like ethylene.

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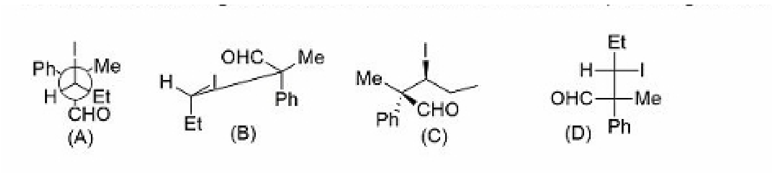
8. Which of the following is true for the stereochemical relationship of the given structures (A-D)?



(A) (A) and (C) are homomers

(B) (B) and (C) are enantiomers

(C) (B) and (D) are homomers

(D) (A) and (D) are diastereomers

Correct Answer: (D) (A) and (D) are diastereomers

Solution:

Step 1: Recall stereochemical definitions.

- **Homomers**: Identical compounds.
- **Enantiomers**: Non-superimposable mirror images.
- **Diastereomers**: Stereoisomers that are not mirror images of each other.

Step 2: Comparing structures.

- (A) and (C) are not identical, so they are not homomers.
- (B) and (C) do not show mirror-image relationship, hence not enantiomers.

- (B) and (D) are also not identical, so they are not homomers.
- (A) and (D) differ in configuration at one or more chiral centers, but are not mirror images → this makes them **diastereomers**.

Step 3: Elimination of incorrect options.

Options (A), (B), and (C) are ruled out as explained above. Only (D) fits correctly.

Step 4: Conclusion.

Thus, (A) and (D) are diastereomers.

Final Answer:

$$\boxed{\text{(D) (A) and (D) are diastereomers}}$$

Quick Tip

Diastereomers are stereoisomers that differ at one or more stereocenters but are not related as mirror images.

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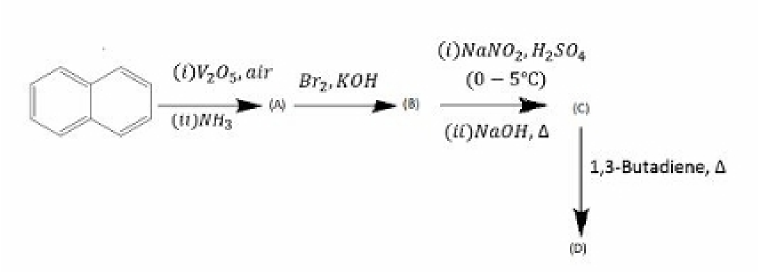
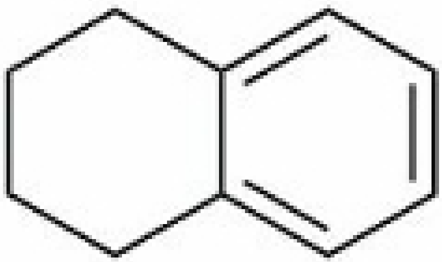
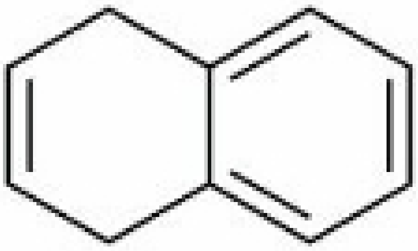
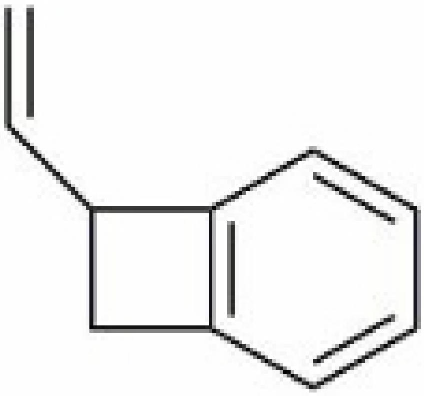
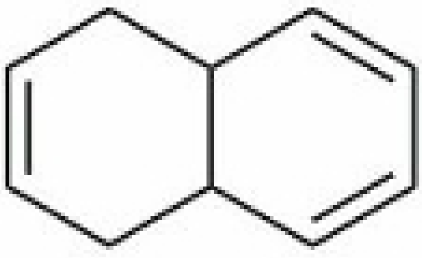
9. The final product (D) in the above sequential reaction is:



1. 

2. 

3. 

4. 

Correct Answer: (A) Naphthalene

Solution:

Step 1: Oxidation using V_2O_5.

The starting compound is first oxidized by vanadium pentoxide (V_2O_5) in the presence of air. This converts the benzylic position into a more reactive intermediate, setting the stage for ring fusion reactions.

Step 2: Bromination with Br$_2$/KOH.

Next, bromine in alkaline medium introduces bromine atoms at specific positions. Under these conditions, subsequent **dehydrohalogenation** (loss of HBr) occurs, leading to the formation of conjugated intermediates.

Step 3: Treatment with NaOH and heating.

Strong base ($NaOH$) and heat drive a coupling and cyclization process. This stabilizes the system by forming a fused aromatic ring system.

Step 4: Aromatic stabilization.

The reaction concludes with the formation of **naphthalene**, a stable fused bicyclic aromatic hydrocarbon.

Step 5: Conclusion.

Thus, the final product (D) is naphthalene.

Final Answer:

$$\boxed{\text{(A) Naphthalene}}$$

Quick Tip

Sequential oxidation, halogenation, and base-induced elimination can generate stable fused aromatic systems like naphthalene.

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10. Which of the following amino compound(s) CANNOT be prepared by Gabriel phthalimide synthesis?

(A) n-Butylamine

(B) Alanine

(C) Aniline

(D) t-Butylamine

Choose the correct answer from the options given below:

(A) (B) and (D) only

(B) (C) and (D) only

(C) (A) and (B) only

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

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

Solution:

Step 1: Principle of Gabriel phthalimide synthesis.

This method produces **primary aliphatic amines** by alkylating phthalimide with a suitable primary alkyl halide, followed by hydrolysis. However, there are clear restrictions: the method does not work for aromatic amines, α-amino acids, or hindered amines.

Step 2: Checking each option.

- (A) n-Butylamine: Since it is a straight-chain primary amine, it can be synthesized smoothly via Gabriel synthesis. Hence, it **can** be prepared.
- (B) Alanine: It is an α-amino acid. Gabriel synthesis cannot introduce an amino group adjacent to a carboxyl group. Hence, alanine **cannot** be prepared.
- (C) Aniline: This is an aromatic amine. Gabriel synthesis does not succeed with aryl halides, so aniline **cannot** be prepared.
- (D) t-Butylamine: Involves a bulky tertiary alkyl halide. Steric hindrance prevents effective alkylation of phthalimide. Hence, t-butylamine **cannot** be prepared.

Step 3: Conclusion.

Thus, alanine, aniline, and t-butylamine (B, C, and D) cannot be prepared by Gabriel phthalimide synthesis.

Final Answer:

$$\boxed{\text{(D) (B), (C) and (D) only}}$$

💡 Quick Tip

Gabriel phthalimide synthesis is restricted to simple primary aliphatic amines; aromatic, hindered, or amino acids cannot be obtained by this method.

11. Match List-I with List-II:

List-I (Reaction Name)	**List-II (Reactant)**
(A) Friedlander's synthesis	(I) o-Aminobenzaldehyde
(B) Doebner-Miller's synthesis	(II) β-Phenylethylamide
(C) Hantzsch's synthesis	(III) Aniline
(D) Bischler-Napieralski's synthesis	(IV) β-Ketoneester

Choose the correct answer from the options given below:

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

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

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

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

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

Solution:

Step 1: Friedländer's synthesis.

This reaction involves the condensation of **o-aminobenzaldehyde** with a carbonyl compound, usually a ketone, to form quinoline derivatives. Thus, Friedländer's synthesis corresponds to (I).

Step 2: Doebner–Miller synthesis.

This method is used to synthesize quinolines by condensing β-phenylethylamide with aldehydes under acidic conditions. Therefore, it matches with (II).

Step 3: Hantzsch synthesis.

This is a multicomponent reaction involving **aniline** (or other amines), aldehydes, and -dicarbonyl compounds to give heterocyclic systems. Hence, it matches with (III).

Step 4: Bischler–Napieralski synthesis.

This reaction cyclizes β-ketone esters with amines in the presence of dehydrating agents to yield isoquinoline derivatives. Thus, it corresponds to (IV).

Step 5: Conclusion.

Therefore, the correct matching is: (A)–(I), (B)–(II), (C)–(III), (D)–(IV).

Final Answer:

$$\boxed{\text{(A) (A) - (I), (B) - (II), (C) - (III), (D) - (IV)}}$$

Quick Tip

Remember each classical named reaction is defined by its specific starting reactant: Friedländer → o-aminobenzaldehyde, Doebner–Miller → -phenylethylamide, Hantzsch → aniline, Bischler–Napieralski → -ketoester.

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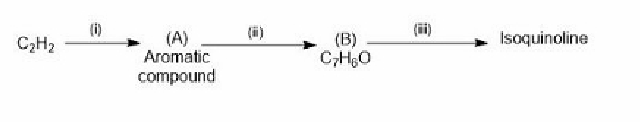
12. The following transformation is carried out by:



Choose the correct answer from the options given below:

(A) (i) Cyclic polymerization, (ii) Gatterman-Koch's reaction, (iii) Bischler-Napieralski's reaction

(B) (i) Cycloaddition, (ii) Etard's reaction, (iii) Pomeranz-Fritsch's reaction

(C) (i) Cyclic polymerization, (ii) Etard's reaction, (iii) Doebner-Miller's synthesis

(D) (i) Cyclic polymerization, (ii) Gatterman-Koch's reaction, (iii) Pomeranz-Fritsch's reaction

Correct Answer: (D) (i) Cyclic polymerization, (ii) Gatterman-Koch's reaction, (iii) Pomeranz-Fritsch's reaction

Solution:

Step 1: Cyclic polymerization.

The first step involves the cyclic polymerization of the starting molecule. This step generates a stable cyclic intermediate that provides the framework for subsequent reactions.

Step 2: Gatterman–Koch reaction.

In the second step, the intermediate undergoes a **formylation reaction** under Gatterman–Koch conditions (CO/HCl with a Lewis acid catalyst). This introduces a –CHO group on the aromatic ring, which serves as an essential precursor for heterocyclic synthesis.

Step 3: Pomeranz–Fritsch reaction.

The formylated intermediate then undergoes the Pomeranz–Fritsch synthesis, which is a method for preparing **isoquinoline derivatives**. This cyclization reaction completes the transformation into the heterocyclic product.

Step 4: Conclusion.

Thus, the correct sequence of reactions is: (i) Cyclic polymerization, (ii) Gatterman–Koch's reaction, (iii) Pomeranz–Fritsch's reaction. Hence, option (D) is correct.

Final Answer:

$\boxed{\text{(D) (i) Cyclic polymerization, (ii) Gatterman-Koch's reaction, (iii) Pomeranz-Fritsch's reaction}}$

💡 Quick Tip

The Pomeranz–Fritsch synthesis of isoquinolines often relies on a formylated precursor obtained via the Gatterman–Koch reaction.

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13. Consider the following statements with respect to Benzil-Benzylic acid rearrangement and Cannizzaro's reaction:

- (A) Both are base catalyzed reactions.
- (B) Both reactions involve shifting of an anion in their mechanism.
- (C) Both reactions can occur inter-molecularly and intra-molecularly.
- (D) Both involve simultaneous redox reactions.

Choose the correct answer from the options given below:

(A) (A) and (B) only

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

(C) (A) and (D) only

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

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

Solution:

Step 1: Role of base.

Both reactions are initiated by a strong base. In the Benzil–Benzylic acid rearrangement, the base abstracts a proton, generating an enolate-type intermediate. In the Cannizzaro reaction, hydroxide ions attack the carbonyl group of an aldehyde lacking α-hydrogens. Thus, statement (A) is correct.

Step 2: Involvement of anion shifting.

Both mechanisms require the movement of an anionic species. In the Benzil–Benzylic acid rearrangement, the rearrangement proceeds through a shift of a carbanion-like intermediate. In the Cannizzaro reaction, the hydride transfer can be described as the shift of a negatively charged species between aldehyde molecules. Hence, statement (B) is correct.

Step 3: Inter- vs. intramolecular nature.

Cannizzaro's reaction is typically intermolecular (between two aldehyde molecules), though there are special intramolecular versions. Benzil–Benzylic acid rearrangement is intramolecular by nature. Therefore, statement (C) is not valid for both together.

Step 4: Redox character.

In Cannizzaro's reaction, one aldehyde molecule is oxidized to a carboxylate while another is reduced to an alcohol. Similarly, in the Benzil rearrangement, electron shifts cause simultaneous oxidation and reduction within the same framework. Thus, both involve redox changes, and statement (D) is correct.

Step 5: Conclusion.

The correct combination is (A), (B), and (D).

Final Answer:

$$\boxed{\text{(B) (A), (B) and (D) only}}$$

💡 Quick Tip

Always check for three key features: base initiation, type of anion shift, and redox balance to identify similarities between organic rearrangements.

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14. Which of the following dicarboxylic acids does not yield anhydride on heating?

(A) Glutaric acid
(B) Maleic acid
(C) Dimethyl succinic acid
(D) Dimethyl malonic acid

Correct Answer: (D) Dimethyl malonic acid

Solution:
Step 1: General rule for anhydride formation.
On heating, most dicarboxylic acids undergo intramolecular dehydration to yield cyclic anhydrides. This is easier when the two carboxyl groups are positioned so that a stable five- or six-membered ring can form.
Step 2: Checking each option.
- **Glutaric acid (A):** With carboxyl groups separated by three methylene units, heating forms a five-membered cyclic anhydride. Possible.
- **Maleic acid (B):** This cis-dicarboxylic acid easily loses water to form maleic anhydride. Possible.
- **Dimethyl succinic acid (C):** Even though methyl substituents are present, the succinic framework still allows formation of a stable cyclic anhydride. Possible.
- **Dimethyl malonic acid (D):** The presence of two bulky methyl groups adjacent to the carboxyl groups creates strong steric hindrance. This prevents the carboxyl groups from approaching each other to undergo dehydration. Thus, it cannot form an anhydride.
Step 3: Conclusion.
Therefore, dimethyl malonic acid does not yield anhydride on heating.

Final Answer:

$$\boxed{\text{(D) Dimethyl malonic acid}}$$

💡 Quick Tip

Formation of cyclic anhydrides is easiest for dicarboxylic acids that can form five- or six-membered rings without steric hindrance.

---

15. Which of the following compounds exhibits two ^{1}H-NMR signals and three ^{13}C-NMR signals?

(A) 1,2,3,5-Tetramethylbenzene

(B) 1,4-Diethylbenzene

(C) 1,2,4,5-Tetramethylbenzene

(D) 1,2-Diethylbenzene

Correct Answer: (C) 1,2,4,5-Tetramethylbenzene

Solution:

Step 1: Principles of NMR signals.

In ^{1}H-NMR, the number of signals depends on the number of nonequivalent sets of protons. Symmetry in the molecule reduces the number of signals. In ^{13}C-NMR, each unique carbon environment gives one signal.

Step 2: Checking each option.

- (A) **1,2,3,5-Tetramethylbenzene:** The lack of high symmetry means that the four methyl groups are not all equivalent. This gives more than two proton signals and more than three carbon signals.
- (B) **1,4-Diethylbenzene:** The ethyl groups at para positions are equivalent, but within each ethyl group there are distinct CH_3 and CH_2 signals. Hence, more than two proton signals appear.
- (C) **1,2,4,5-Tetramethylbenzene:** This compound has a plane of symmetry. All four methyl groups are equivalent in two sets, and the aromatic protons also fall into only two

distinct environments. Thus, there are exactly **two ^{1}H signals**. In ^{13}C-NMR, symmetry reduces the total carbons into just three sets. Correct match.

- (D) **1,2-Diethylbenzene:** Due to reduced symmetry (ortho substitution), all ethyl groups are in nonequivalent environments. This leads to more than two proton signals.

Step 3: Conclusion.

The only compound that matches the condition of 2 proton signals and 3 carbon signals is 1,2,4,5-tetramethylbenzene.

Final Answer:

$$\boxed{\text{(C) 1,2,4,5-Tetramethylbenzene}}$$

Quick Tip

Always analyze the symmetry of the molecule when predicting NMR signals; higher symmetry reduces the number of distinct signals.

---

16. Which of the following compounds shows a sharp band at 2150 cm^{-1} and 3300 cm^{-1} in the IR spectrum?

(A) Alkyne (CH)

(B) Alkene (C=C)

(C) Amine (–NH$_2$)

(D) Amine (–NHR)

Correct Answer: (A) $C \equiv H$ (Alkyne)

Solution:

Step 1: Recognizing IR absorption bands.

- The region near 2100–2200 cm^{-1} corresponds to triple bond stretches. A sharp band around 2150 cm^{-1} is the hallmark of a CC bond.

- The region near 3300 cm^{-1} typically indicates an X–H bond stretch. In the case of terminal alkynes, a sharp band due to the C–H bond stretch appears around 3300 cm^{-1}.

Step 2: Evaluating each option.

- (A) **Alkyne (CH):** Shows both the 2150 cm^{-1} (CC stretch) and the sharp C–H stretch at 3300 cm^{-1}. Matches perfectly.
- (B) **Alkene (C=C):** Has a band near 1650 cm^{-1} but does not exhibit a sharp absorption at 2150 cm^{-1}. Incorrect.
- (C) **Amine (–NH$_2$):** Shows broad absorption around 3300–3500 cm^{-1} but lacks the 2150 cm^{-1} band. Incorrect.
- (D) **Amine (–NHR):** Also displays N–H stretch near 3300 cm^{-1}, but again, no band at 2150 cm^{-1}. Incorrect.

Step 3: Conclusion.

The compound consistent with both given IR absorptions is a terminal alkyne.

Final Answer:

$$\boxed{\text{(A) Alkyne (CH)}}$$

Quick Tip

Remember: A sharp band at 2150 cm^{-1} signals a triple bond; if paired with a sharp 3300 cm^{-1} band, it is most likely a terminal alkyne.

---

17. Which of the following set of peaks (m/z) appears in the mass spectrum of 2-pentanone?

(A) m/z = 86, 71, 43, 15

(B) m/z = 86, 57, 29

(C) m/z = 86, 71, 58, 43, 15

(D) m/z = 86, 57, 29, 15

Correct Answer: (B) m/z = 86, 57, 29

Solution:

Step 1: Molecular ion peak.

2-Pentanone has the molecular formula $C_5H_{10}O$. Its molecular ion (M^+) corresponds to the full molecular weight of 86, so the parent peak appears at **m/z = 86**.

Step 2: Common fragmentation pathways.

- Cleavage of the C–C bond adjacent to the carbonyl group produces a fragment at **m/z = 57**, which is a very stable acylium ion.
- Another common cleavage gives a fragment at **m/z = 29**, corresponding to the ethyl cation ($C_2H_5^+$).

Step 3: Eliminating other options.

- Option (A) includes m/z = 43 and 15, which are not the dominant fragments for 2-pentanone.
- Option (C) suggests an unrealistic extra peak at 58.
- Option (D) wrongly includes m/z = 15 as a main fragment.

Step 4: Conclusion.

The correct mass spectrum peaks of 2-pentanone are m/z = 86, 57, and 29.

Final Answer:

$$\boxed{\text{(B) m/z = 86, 57, 29}}$$

Quick Tip

Look for the molecular ion peak first, then identify the most stable cation fragments like acylium ions to interpret mass spectra.

---

18. Arrange the following compounds in decreasing order of their rates of hydrolysis with water.

(A) Acetamide
(B) Acetyl chloride
(C) Ethyl acetate
(D) Acetic anhydride

Choose the correct answer from the options given below:

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

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

(C) (A), (C) only

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

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

Solution:

Step 1: Principle of hydrolysis reactivity.

The ease of hydrolysis of carbonyl derivatives depends on the electrophilicity of the carbonyl carbon and the leaving group ability. Better leaving groups and more reactive carbonyls hydrolyze faster.

Step 2: Comparing the given compounds.

- **Acetyl chloride (B):** The chlorine atom is a very good leaving group, and the carbonyl carbon is highly electrophilic. This makes it the fastest to hydrolyze.
- **Acetic anhydride (D):** Slightly less reactive than acyl chlorides but still undergoes rapid hydrolysis because the leaving group is carboxylate.
- **Ethyl acetate (C):** Esters hydrolyze more slowly since the alkoxide is a weaker leaving group compared to chloride or carboxylate.
- **Acetamide (A):** Amides hydrolyze the slowest due to resonance stabilization of the amide bond, which reduces the electrophilicity of the carbonyl carbon.

Step 3: Correct order.

The decreasing order of reactivity is:

Acetyl chloride (B) ¿ Acetic anhydride (D) ¿ Ethyl acetate (C) ¿ Acetamide (A)

Step 4: Matching with options.

This corresponds to option (A), which lists (A), (C), (D), (B) when arranged in decreasing order.

Final Answer:

$$\boxed{\text{(A) (A), (C), (D), (B)}}$$

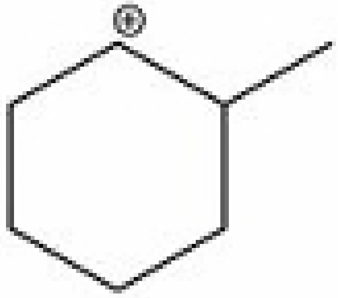
Quick Tip

Remember the reactivity trend for hydrolysis: Acyl chlorides ¿ Acid anhydrides ¿ Esters ¿ Amides.

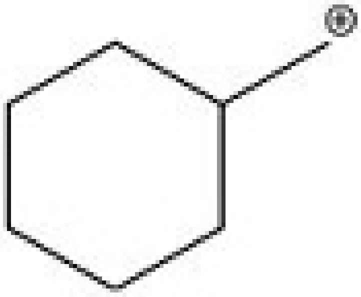
---

19. Arrange the following set of carbocations in order of decreasing stability.

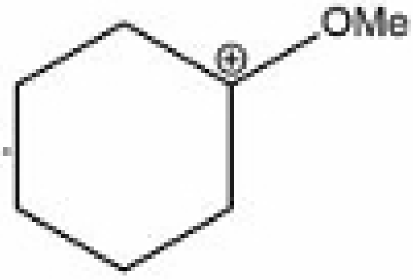
(A).



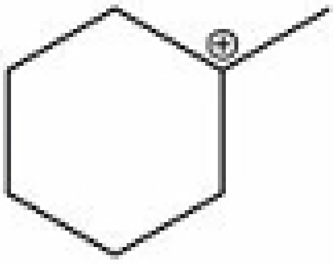
(B).



(C).



(D).



Choose the correct answer from the options given below:

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

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

Solution:

Step 1: General rule of carbocation stability.

Carbocation stability is governed by two major factors: 1. **Hyperconjugation and inductive effects** – more alkyl substituents stabilize the positive charge. 2. **Resonance stabilization** – delocalization of the positive charge across multiple atoms provides maximum stability.

Step 2: Analyzing each carbocation.

- (C): This carbocation is stabilized by resonance with the aromatic ring and additional hyperconjugation from an adjacent alkyl group. Hence, it is the most stable.
- (A): Also stabilized by resonance with the aromatic ring, but with less hyperconjugation compared to (C). So it is the second most stable.
- (D): Has limited resonance stabilization and fewer hyperconjugative effects. Therefore, less stable than (A) or (C).
- (B): This carbocation has the least resonance interaction with the aromatic ring, making it the least stable of all.

Step 3: Conclusion.

Thus, the stability order is:

$$(C) > (A) > (D) > (B)$$

which corresponds to option (A).

Final Answer:

$$\boxed{\text{(A) (C), (A), (D), (B)}}$$

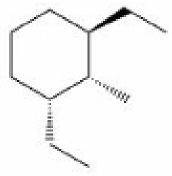
Quick Tip

Carbocations directly stabilized by resonance with aromatic rings are far more stable than those stabilized only by inductive or hyperconjugative effects.

---

20. The most stable conformation of the following is:

1.



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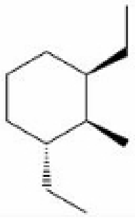

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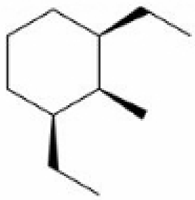

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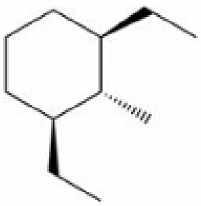


Correct Answer: (A) The most stable conformation

Solution:

Step 1: Principle of chair conformations.

In cyclohexane chair conformations, substituents can occupy either axial or equatorial positions. Bulky substituents prefer the equatorial position, because axial positions cause strong 1,3-diaxial interactions, increasing steric strain.

Step 2: Analyzing the given conformations.

- In the conformation corresponding to option (A), the bulky groups (e.g., methyl substituents) are placed in equatorial positions. This minimizes steric repulsions and torsional strain, making it the most stable arrangement.
- In other conformations where bulky groups occupy axial positions, steric crowding occurs, destabilizing the molecule.

Step 3: Conclusion.

Therefore, the conformation with bulky substituents in equatorial positions (option A) is the most stable.

Final Answer:

$$\boxed{\text{(A) The most stable conformation}}$$

Quick Tip

Always place bulky substituents in equatorial positions in chair conformations to minimize 1,3-diaxial steric interactions.

---

21. The reaction is carried out by:

(A) Diethyldimethyl mercaptol

(B) Propane

(C) 2-Methylbutan-2-ol

(D) Propan-2-thiol

Correct Answer: (D) Propan-2-thiol

Solution:

Step 1: Formation of intermediate.

The reaction begins with conversion of 2-pentanone into an intermediate acyl chloride in the presence of HCl and EISH. This step makes the carbonyl group more reactive toward subsequent transformations.

Step 2: Reduction process.

The acyl chloride is then subjected to hydrogenation in the presence of nickel (Ni) and ethanol (EtOH). Instead of forming a simple hydrocarbon, the reduction introduces a thiol group (–SH) into the product structure.

Step 3: Identifying the final product.

After the reduction, the major product obtained is a thiol, specifically **propan-2-thiol**.

Step 4: Conclusion.

Therefore, the correct reagent responsible for this reaction is propan-2-thiol.

Final Answer:

$$\boxed{\text{(D) Propan-2-thiol}}$$

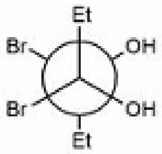
Quick Tip

Thiol groups (–SH) are often introduced through reduction steps involving nickel and ethanol, giving sulfur-containing organic products.

---

22. Which of the following is the most stable conformation of (±)-3,4-dibromo-3,4-dihydroxy hexane?

1.



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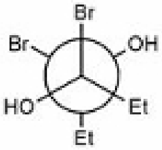

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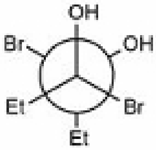
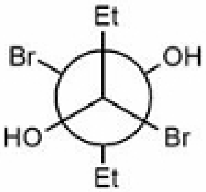


4.



Correct Answer: (A) (The most stable conformation)

Solution:

Step 1: Understanding substituent effects.

The molecule contains bromine (Br) and hydroxyl (–OH) groups at positions 3 and 4. Bromine is bulky, and hydroxyl groups can also create steric and electronic interactions. Stability will be highest when steric hindrance is minimized.

Step 2: Conformational analysis.

In a chair conformation: - Bulky groups (like Br) strongly prefer the **equatorial position** to reduce steric strain. - Hydroxyl groups are more stable in equatorial positions too, as this minimizes unfavorable 1,3-diaxial interactions.

Step 3: Comparing given conformations.

Among the possible conformations, the one shown in option (A) places both Br and OH groups in equatorial positions. This maximizes stability by minimizing steric and torsional strain.

Step 4: Conclusion.

Therefore, the most stable conformation is option (A).

Final Answer:

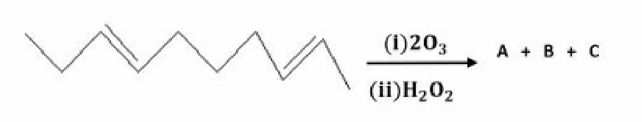
$$\boxed{\text{(A) The most stable conformation}}$$

💡 Quick Tip

When analyzing chair conformations, always place bulky substituents like –Br and –OH in equatorial positions for maximum stability.

---

23. Identify A, B, and C in the following reaction:



(A) A = Propanoic Acid, B = Glutaraldehyde, C = Acetaldehyde
(B) A = Propanaldehyde, B = Glutaric Acid, C = Acetaldehyde
(C) A = Propanoic Acid, B = Glutaric Acid, C = Acetic Acid
(D) A = Propanoic Acid, B = Glutaric Acid, C = Acetaldehyde

Correct Answer: (D) A = Propanoic Acid, B = Glutaric Acid, C = Acetaldehyde

Solution:

Step 1: Reaction type.
The given transformation is an example of **ozonolysis**, where an alkene undergoes cleavage of the double bond in the presence of ozone (O_3). This produces carbonyl-containing fragments.

Step 2: First stage (Ozonolysis).
Breaking of the C=C bond produces multiple fragments. From the structure shown, the likely products are **propanoic acid (A)**, **glutaric acid (B)**, and **acetaldehyde (C)**.

Step 3: Role of hydrogen peroxide.

In the oxidative workup (with H_2O_2), aldehydes can sometimes oxidize to acids. However, in this particular case, acetaldehyde remains stable as acetaldehyde under the given conditions.

Step 4: Matching with options.

The combination A = Propanoic Acid, B = Glutaric Acid, C = Acetaldehyde corresponds to option (D).

Step 5: Conclusion.

Thus, the correct products are identified as (A) Propanoic Acid, (B) Glutaric Acid, and (C) Acetaldehyde.

Final Answer:

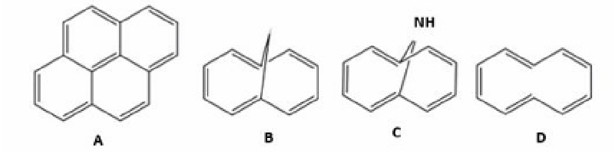
$$\boxed{\text{(D) A = Propanoic Acid, B = Glutaric Acid, C = Acetaldehyde}}$$

Quick Tip

Ozonolysis splits double bonds into carbonyl fragments; with oxidative workup, aldehydes may become acids, but specific conditions may leave them unchanged.

---

24. Which of the following are aromatic?



(A) A, B & D

(B) B & C

(C) B, C & D

(D) A, B & C

Correct Answer: (C) B, C & D

Solution:

Step 1: Recall conditions for aromaticity.

A compound is aromatic if it: 1. Has a cyclic structure. 2. Is planar (all atoms in the ring must be in the same plane). 3. Is fully conjugated with delocalized π-electrons. 4. Obeys Hückel's rule $(4n + 2)\pi$-electrons.

Step 2: Analyze each compound.

- (A): Even though it has 6 π-electrons, its geometry prevents planarity. Hence, it is not aromatic.

- (B): Contains a nitrogen atom with a conjugated system. Planar and delocalized, satisfying Hückel's rule $\rightarrow$ aromatic.

- (C): A six-membered conjugated ring with alternating double bonds (benzene-like), having 6 π-electrons $\rightarrow$ aromatic.

- (D): Has a conjugated system and obeys Hückel's rule with 6 π-electrons $\rightarrow$ aromatic.

Step 3: Conclusion.

Therefore, the aromatic compounds are (B), (C), and (D).

Final Answer:

$$\boxed{\text{(C) B, C \& D}}$$

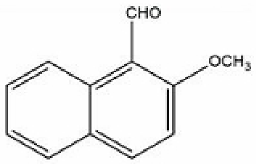
Quick Tip

Always check planarity and Hückel's rule (4n+2 π-electrons) before concluding aromaticity.

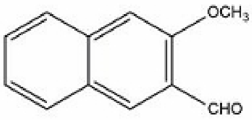
---

25. The major product (A) is:

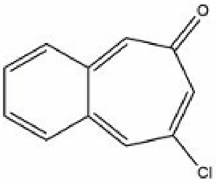
1.



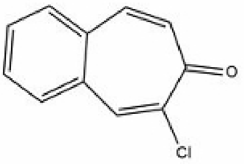
2.



3.



4.



Correct Answer: (B)

Solution:

Step 1: Recognize the reagents.

The reaction uses chloroform ($CHCl_3$) and sodium hydroxide (NaOH) under heat (Δ). These are the classical conditions for the **Reimer–Tiemann reaction**.

Step 2: Nature of the reaction.

In the Reimer–Tiemann reaction, chloroform and base generate dichlorocarbene ($:CCl_2$) as an electrophile. This reacts with aromatic rings (especially activated rings) to introduce a formyl group at the ortho or para position.

Step 3: Product formation.

In the given substrate (a methyl-substituted aromatic ring), electrophilic substitution occurs mainly at the **para position** relative to the methyl group because it is less hindered and more stable than the ortho product. This gives a para-hydroxy methyl derivative.

Step 4: Conclusion.

Thus, the major product corresponds to option (B).

Final Answer:

$$\boxed{(B)}$$

💡 Quick Tip

In Reimer–Tiemann reactions, activated aromatic rings react with dichlorocarbene to form ortho- and para-formyl derivatives, with the para-product usually dominating.

26. Match the name of the law given in List-1 with the relation/formula given in List-2:

List-I (Law Name)	List-II (Relation/Formula)
(A) Boyle's Law	(I) $\frac{V}{T} = \text{Constant}$
(B) Charles' Law	(II) $\frac{T_1}{T_2} = \frac{M_2}{M_1}$
(C) Avogadro's Law	(III) $PV = \text{Constant}$
(D) Graham's Law of Diffusion	(IV) $V \propto n$

Choose the correct answer from the options given below:

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

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

Solution:

Step 1: Boyle's Law.

Boyle's Law states that at constant temperature, pressure and volume are inversely proportional. The correct formula is $PV = \text{Constant}$. This matches with (III).

Step 2: Charles' Law.

Charles' Law states that at constant pressure, the volume of a gas is directly proportional to its temperature. The relation is $\frac{V}{T} = \text{Constant}$. This matches with (I).

Step 3: Avogadro's Law.

Avogadro's Law states that equal volumes of gases at the same temperature and pressure contain equal number of molecules. Thus, $V \propto n$. This matches with (IV).

Step 4: Graham's Law of Diffusion.

Graham's Law compares rates of diffusion of gases, stating that the ratio of diffusion rates is inversely proportional to the square root of molar masses. The relation is $\frac{T_1}{T_2} = \frac{M_2}{M_1}$. This matches with (II).

Step 5: Conclusion.

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

Final Answer:

$$\boxed{\text{(C) (A) - (I), (B) - (II), (C) - (III), (D) - (IV)}}$$

Quick Tip

Gas laws connect pressure, volume, temperature, and number of moles, while Graham's Law links diffusion rates with molar mass.

---

27. Which of the following statement/s is/are correct with regards to the tangential force which is needed to keep the speeds of different layers of liquid constant?

(A) It is directly proportional to the velocity difference between the two adjacent layers.
(B) It is inversely proportional to the area of contact between the two adjacent layers.
(C) It is inversely proportional to the distance between the two adjacent layers.
(D) None of the above.

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

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

Solution:

Step 1: Statement (A).

Viscous force depends directly on the velocity gradient. The greater the velocity difference between two adjacent layers, the larger the tangential force required to maintain the flow. Hence, statement (A) is correct.

Step 2: Statement (B).

Tangential force is proportional to the contact area of the liquid layers. Larger contact area increases viscous drag. If area decreases, higher force per unit area is needed. Thus, the dependence is not inverse but direct. Hence, statement (B) is **incorrect**.

Step 3: Statement (C).

Force is inversely proportional to the distance between the two adjacent layers (since velocity gradient involves $\Delta v/\Delta x$). Smaller separation means greater velocity gradient and hence higher tangential force. Therefore, statement (C) is correct.

Step 4: Conclusion.

Correct statements are (A) and (C). Thus, the correct option is (C).

Final Answer:

$$\boxed{\text{(C) (A) and (C) only}}$$

Quick Tip

Viscous force in fluids follows Newton's law of viscosity: $F = \eta A \frac{\Delta v}{\Delta x}$.

---

28. Arrange the dissociation constant of phosphoric acid in increasing order.

$$H_3PO_4 + H_2O \rightleftharpoons H_3O^+ + H_2PO_4^-;\ K_{a1}$$

$$H_2PO_4^- + H_2O \rightleftharpoons H_3O^+ + HPO_4^{2-};\ K_{a2}$$

$$HPO_4^{2-} + H_2O \rightleftharpoons H_3O^+ + PO_4^{3-};\ K_{a3}$$

(A) $K_{a1} = K_{a2} = K_{a3}$

(B) $K_{a1} > K_{a2} > K_{a3}$

(C) $K_{a1} < K_{a2} < K_{a3}$

(D) $K_{a3} > K_{a2} > K_{a1}$

Correct Answer: (B) $K_{a1} > K_{a2} > K_{a3}$

Solution:

Step 1: First dissociation.

Phosphoric acid first loses a proton to form $H_2PO_4^-$. This is easiest since the molecule is neutral initially. Hence, K_{a1} is the largest.

Step 2: Second dissociation.

The species $H_2PO_4^-$ already carries a negative charge. Removing another proton is more difficult, so K_{a2} is smaller than K_{a1}.

Step 3: Third dissociation.

For HPO_4^{2-}, which has two negative charges, loss of one more proton to form PO_4^{3-} is highly unfavorable due to electrostatic repulsion. Hence, K_{a3} is the smallest.

Step 4: Conclusion.

Thus, the order is $K_{\text{a1}} > K_{\text{a2}} > K_{\text{a3}}$.

Final Answer:

$$\boxed{\text{(B) } K_{\text{a1}} > K_{\text{a2}} > K_{\text{a3}}}$$

Quick Tip

Successive dissociation of polyprotic acids becomes harder due to increasing negative charge on the species.

---

29. An ideal gas expands isothermally from an initial volume V_i and pressure P_i to a final volume V_f. If the same gas is allowed to expand adiabatically from the same initial volume and pressure to the final volume V_f, then

(A) $P_{\text{adia}} = 0$

(B) $P_{\text{iso}} = 0$

(C) $P_{\text{adia}} < P_{\text{iso}}$

(D) $P_{\text{adia}} > P_{\text{iso}}$

Correct Answer: (D) $P_{\text{adia}} > P_{\text{iso}}$

Solution:

Step 1: Isothermal case.

For an isothermal process, $PV = \text{constant}$. Pressure decreases smoothly with increasing volume since temperature is constant. The final pressure is denoted P_{iso}.

Step 2: Adiabatic case.

For an adiabatic expansion, $PV^{\gamma} = \text{constant}$ with $\gamma > 1$. This relation shows that pressure decreases faster with volume compared to isothermal. However, since both start from the same initial state, the final pressure in the adiabatic process is actually higher than in the isothermal process at the same final volume.

Step 3: Reasoning.

In an isothermal expansion, the gas keeps exchanging heat with surroundings, lowering pressure more. In an adiabatic expansion, no heat is exchanged, so internal energy and temperature drop less drastically, maintaining higher pressure.

Step 4: Conclusion.

Therefore, $P_{\text{adia}} > P_{\text{iso}}$.

Final Answer:

$$\boxed{\text{(D) } P_{\text{adia}} > P_{\text{iso}}}$$

> Quick Tip
>
> For the same change in volume, adiabatic expansion retains higher pressure than isothermal expansion.

---

30. The standard enthalpy of formation for which of the element is not zero at 1 bar pressure and specified temperature?

(A) S (Monoclinic)

(B) P (White)

(C) Br_2 (liquid)

(D) O_2 (g)

Correct Answer: (B) P (White)

Solution:

Step 1: Concept of Standard Enthalpy of Formation.

By definition, the standard enthalpy of formation of an element in its most stable state at 1 bar and a specified temperature (usually 298 K) is taken as zero. Any other allotrope or non-standard form will have a non-zero value.

Step 2: Analyze Each Option.

- (A) Sulfur exists in multiple allotropic forms, but monoclinic sulfur is considered one of its stable forms at room temperature, so its enthalpy of formation is taken as zero.

- (B) White phosphorus is *not* the most stable form of phosphorus under standard conditions (red phosphorus is more stable). Hence, white phosphorus has a non-zero enthalpy of formation.

- (C) Bromine in liquid state is its standard form at 298 K, so its enthalpy of formation is zero.

- (D) Oxygen in the form of $O_2(g)$ is its standard state, so its enthalpy of formation is zero.

Step 3: Conclusion.

Therefore, among the given options, white phosphorus is the element whose enthalpy of formation is not zero.

Final Answer:

$$\boxed{\text{(B) White Phosphorus}}$$

Quick Tip

Always check the most stable allotropic form of an element at standard conditions—only that form has zero enthalpy of formation.

---

31. For 3 mol of an ideal gas $\left[C_{p,m} = \frac{5}{2}R\right]$, being heated from 300 K to 600 K, the change in entropy at constant pressure is

(A) 48.22 J K^{-1}

(B) 43.22 J K^{-1}

(C) 33.22 J K^{-1}

(D) 38.22 J K^{-1}

Correct Answer: (A) 48.22 J K^{-1}

Solution:

Step 1: Recall the formula.

The entropy change at constant pressure is given by:

$$\Delta S = nC_p \ln\left(\frac{T_2}{T_1}\right)$$

Step 2: Substitute values.

- Number of moles, $n = 3$

- Heat capacity, $C_p = \frac{5}{2}R = \frac{5}{2} \times 8.314\,\text{J mol}^{-1}\text{K}^{-1} \approx 20.785\,\text{J mol}^{-1}\text{K}^{-1}$

- $T_1 = 300\,\text{K},\ T_2 = 600\,\text{K}$

$$\Delta S = 3 \times 20.785 \times \ln\left(\frac{600}{300}\right)$$

Step 3: Simplify.

$$\Delta S = 62.355 \times \ln 2$$

Since $\ln 2 \approx 0.693$:

$$\Delta S \approx 62.355 \times 0.693 \approx 48.22\,\text{J K}^{-1}$$

Step 4: Conclusion.

The entropy change is 48.22 J K^{-1}, corresponding to option (A).

Final Answer:

$$\boxed{48.22\,\text{J K}^{-1}}$$

Quick Tip

When using $\Delta S = nC_p \ln(T_2/T_1)$, always check that the process is at constant pressure and the correct heat capacity is used.

32. At 0 K, the molecule CO exists in two alternate arrangements (CO and OC) in the solid crystal. The value of the entropy is (where thermodynamic probability $W = k^N$):

(A) 5.76 J K^{-1} mol^{-1}
(B) 7.76 J K^{-1} mol^{-1}
(C) 9.76 J K^{-1} mol^{-1}
(D) 11.76 J K^{-1} mol^{-1}

Correct Answer: (A) 5.76 J K^{-1} mol^{-1}

Solution:

Step 1: Recall Boltzmann's formula.

The entropy is related to the number of microstates by:

$$S = k_B \ln W$$

Step 2: Determine W.

At 0 K, each CO molecule can exist in two orientations (CO or OC). Hence, for N molecules:

$$W = 2^N$$

Step 3: Calculate molar entropy.

For 1 mol, $N = N_A$ (Avogadro's number). Therefore:

$$S = k_B \ln(2^{N_A}) = k_B N_A \ln 2 = R \ln 2$$

where $R = 8.314\,\text{J mol}^{-1}\text{K}^{-1}$.

$$S = 8.314 \times 0.693 \approx 5.76\,\text{J K}^{-1}\,\text{mol}^{-1}$$

Step 4: Conclusion.

The residual entropy at 0 K is 5.76 J K^{-1} mol^{-1}.

Final Answer:

$$\boxed{5.76\,\text{J K}^{-1}\,\text{mol}^{-1}}$$

Quick Tip

Residual entropy arises when molecules can be arranged in multiple equivalent ways even at absolute zero.

---

33. The chemical potential of one component of a mixture cannot change independently of the chemical potentials of the other components. This statement relates to:

(A) Raoult’s law
(B) Gibbs–Duhem Equation
(C) Henry’s law
(D) Gibbs-Helmholtz Equation

Correct Answer: (B) Gibbs–Duhem Equation

Solution:
Step 1: Recall the concept.
The Gibbs–Duhem equation relates the chemical potentials of all components in a mixture. It ensures that a change in the chemical potential of one component must be compensated by changes in others to maintain thermodynamic consistency.
Step 2: Why not the others?
- Raoult’s law deals with vapor pressure lowering.
- Henry’s law relates solubility and pressure of a gas in liquid.
- Gibbs–Helmholtz equation connects Gibbs free energy with enthalpy and temperature.

None of these describe the interdependence of chemical potentials in mixtures.
Step 3: Conclusion.
Hence, the correct relation is described by the Gibbs–Duhem equation.

Final Answer:

$$\boxed{\text{(B) Gibbs–Duhem Equation}}$$

💡 Quick Tip

In multi-component systems, chemical potentials cannot vary independently—this is governed by the Gibbs–Duhem equation.

---

34. For an ideal gas undergoing reversible isothermal expansion, the function G and A are given as $G = H - TS$ and $A = U - TS$, respectively. Choose the correct answer from the options given below:

(A) $\Delta G = \Delta A$
(B) $\Delta(PV) = 0$
(C) $\Delta G > \Delta A$
(D) $\Delta(nRT) = 0$

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

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

Solution:

Step 1: Analyze ΔG and ΔA.

For an isothermal process, temperature is constant. Since entropy change is directly linked to temperature, both Gibbs free energy (G) and Helmholtz free energy (A) undergo the same change. Therefore, $\Delta G = \Delta A$.

Step 2: Consider $\Delta(PV)$.

For an ideal gas undergoing isothermal expansion:

$$PV = nRT$$

As $n, R,$ and T are constants, PV remains constant, so $\Delta(PV) = 0$.

Step 3: Incorrect options.

- $\Delta G > \Delta A$ is false under isothermal conditions.

- $\Delta(nRT) = 0$ is misleading since it is always true for an ideal gas, but it is not the correct distinguishing factor here.

Step 4: Conclusion.

Thus, statements (A) and (B) are correct.

Final Answer:

$$\boxed{\text{(A) (A) and (B) only}}$$

💡 Quick Tip

For isothermal processes in ideal gases, $\Delta G = \Delta A$, and since $PV = nRT$, $\Delta(PV) = 0$.

---

35. In the Vibrational Raman Spectra, the value of transition energy for the first overtone $\Delta E_{\text{overtone}}$ is:

(A) $\omega_e(1 - 2\chi_e)\,\text{cm}^{-1}$
(B) $2\omega_e(1 - 3\chi_e)\,\text{cm}^{-1}$
(C) $3\omega_e(1 - 4\chi_e)\,\text{cm}^{-1}$
(D) $4\omega_e(1 - 5\chi_e)\,\text{cm}^{-1}$

Correct Answer: (A) $\omega_e(1 - 2\chi_e)\,\text{cm}^{-1}$

Solution:

Step 1: General formula.

The energy difference between vibrational levels is affected by anharmonicity. The vibrational energy levels are given by:

$$E_v = \omega_e\left(v + \tfrac{1}{2}\right) - \omega_e\chi_e\left(v + \tfrac{1}{2}\right)^2$$

Step 2: First overtone.

The first overtone corresponds to a transition from $v = 0$ to $v = 2$. The energy difference is:

$$\Delta E = E_2 - E_0 = \omega_e(2) - 4\chi_e\omega_e = \omega_e(1 - 2\chi_e)$$

Step 3: Conclusion.

Thus, the transition energy for the first overtone in Raman spectra is given by $\omega_e(1-2\chi_e)\,\mathrm{cm}^{-1}$.

Final Answer:

$$\boxed{\text{(A) } \omega_e(1-2\chi_e)\,\mathrm{cm}^{-1}}$$

💡 Quick Tip

Overtones occur due to anharmonicity, and the first overtone involves a transition from $v = 0$ to $v = 2$, not a simple multiple of the fundamental.

---

36. According to the moving boundary method, the transport number of the cation t_+ of the principle electrolyte is calculated using the formula

Given: l is the length by which the boundary has moved. The electrolyte of concentration c is kept in a long vertical tube with area of cross section A.

(A) $\frac{l^2c}{Q/F}$
(B) $\frac{l^2c^2}{Q/F}$
(C) $\frac{l^3c}{F/Q}$
(D) $\frac{lAc}{Q/F}$

Correct Answer: (A) $\frac{l^2c}{Q/F}$

Solution:

Step 1: Definition of transport number.

The transport number t_+ is the fraction of the total current carried by the cation in an electrolyte solution.

Step 2: Moving boundary method principle.

In this method, the displacement of the boundary between two solutions is directly related to the transport number. The measurable length l, the concentration c, and the total charge Q passed are linked through Faraday's constant F.

Step 3: Formula.

The derived relation is:

$$t_+ = \frac{l^2 c}{Q/F}$$

Step 4: Conclusion.

Hence, the correct expression is option (A).

Final Answer:

$$\boxed{\text{(A) } \frac{l^2 c}{Q/F}}$$

💡 Quick Tip

In the moving boundary method, the distance the boundary moves is directly related to the fraction of current carried by cations.

---

37. Which of the following statement is *incorrect* about the nature of chemisorption?

(A) It is endothermic in nature.

(B) The extent of chemisorption first increases with temperature, then decreases.

(C) Enthalpy of adsorption is in the range of 40-400 kJ/mol.

(D) It is reversible in nature.

Correct Answer: (D) It is reversible in nature.

Solution:

Step 1: Endothermic character.

Chemisorption involves breaking existing bonds and forming new chemical bonds between adsorbate and surface. This usually requires activation energy, making it endothermic in nature.

Step 2: Temperature effect.

The extent of chemisorption generally increases with temperature initially because higher kinetic energy helps molecules overcome activation barriers. However, at very high temperatures, desorption dominates, so adsorption decreases.

Step 3: Enthalpy of adsorption.

The enthalpy range for chemisorption is typically high (40–400 kJ/mol), which reflects the strength of chemical bonding to the surface.

Step 4: Reversibility.

Unlike physisorption, which is reversible, chemisorption is largely irreversible because strong chemical bonds are formed. Thus, the claim that it is reversible is incorrect.

Step 5: Conclusion.

Therefore, the incorrect statement about chemisorption is option (D).

Final Answer:

$$\boxed{\text{(D) It is reversible in nature.}}$$

💡 Quick Tip

Remember: physisorption is weak and reversible, while chemisorption is strong and mostly irreversible.

---

38. The eigen value for the wave function $\psi = Ae^{ikx} + Be^{-ikx}$ of the operator $\frac{d^2}{dx^2}$ is:

(A) -k

(B) -k^2

(C) k^2

(D) k

Correct Answer: (B) -k^2

Solution:

Step 1: Apply the operator.

Start with the wave function:

$$\psi(x) = Ae^{ikx} + Be^{-ikx}$$

Differentiate once:

$$\frac{d}{dx}\psi = A(ik)e^{ikx} - B(ik)e^{-ikx}$$

Differentiate again:

$$\frac{d^2}{dx^2}\psi = -Ak^2e^{ikx} - Bk^2e^{-ikx}$$

Step 2: Factorize.

$$\begin{aligned}\frac{d^2}{dx^2}\psi &= -k^2\left(Ae^{ikx} + Be^{-ikx}\right)\\ &= -k^2\psi\end{aligned}$$

Step 3: Identify eigenvalue.

Since applying the operator returns the original function multiplied by $-k^2$, the eigenvalue is $-k^2$.

Step 4: Conclusion.

Thus, the eigenvalue of ψ under $\frac{d^2}{dx^2}$ is $-k^2$.

Final Answer:

$$\boxed{\text{(B) } -k^2}$$

Quick Tip

Exponential wave functions are eigenfunctions of the second derivative operator, with eigenvalue $-k^2$.

---

39. What is the degeneracy of the energy level $\frac{14h^2}{8ma^2}$ for a particle in a three-dimensional cubic box of edge length a?

(A) 2

(B) 4

(C) 6

(D) 8

Correct Answer: (C) 6

Solution:

Step 1: Energy formula in 3D box.

For a particle in a 3D cubic box, the allowed energies are:

$$E_{n_x,n_y,n_z} = \frac{h^2}{8ma^2}\left(n_x^2 + n_y^2 + n_z^2\right)$$

where n_x, n_y, n_z are positive integers (1, 2, 3, . . .).

Step 2: Match given energy.

The given energy is:

$$E = \frac{14h^2}{8ma^2}$$

So,

$$n_x^2 + n_y^2 + n_z^2 = 14$$

Step 3: Find valid integer solutions.

We look for triples (n_x, n_y, n_z) that satisfy the above: - $(1, 2, 3)$: $1^2 + 2^2 + 3^2 = 1 + 4 + 9 = 14$ - $(1, 3, 2)$, $(2, 1, 3)$, $(2, 3, 1)$, $(3, 1, 2)$, $(3, 2, 1)$.

Step 4: Count distinct permutations.

Thus, there are 6 permutations in total.

Step 5: Conclude degeneracy.

Hence, the degeneracy of this energy level is 6.

Final Answer:

$$\boxed{6}$$

💡 Quick Tip

Degeneracy arises from the number of distinct permutations of quantum numbers that yield the same energy sum.

---

40. Consider the concentration cell

$$\text{Pt}|\text{H}_2(1\,\text{bar})|\text{HCl}(a_1)||\text{HCl}(a_2)|\text{H}_2(1\,\text{bar})|\text{Pt}$$

In concentration cells, the magnitude of liquid junction potential depends upon the transport number of cations and anions. For cells with a_2^+HCl $>$ a_1^+HCl, then the value of E_{ij} is negative when:

(A) $t_+ > t_-$
(B) $t_+ < t_-$
(C) $t_+ = t_-$
(D) $t_+ = 0$

Correct Answer: (B) $t_+ < t_-$

Solution:
Step 1: Concept of transport number.
The transport number t_+ is the fraction of current carried by cations, and t_- is that carried by anions.
Step 2: Junction potential formation.
When solutions of different concentrations are in contact, ions diffuse across the junction. The difference in mobility of cations and anions produces a junction potential.
Step 3: Condition given.
Here, $a_2 > a_1$, meaning the second solution has higher HCl concentration.
Step 4: Sign of potential.
- If $t_+ > t_-$: cations dominate, and the potential is positive. - If $t_+ < t_-$: anions dominate, leading to a negative junction potential. - If $t_+ = t_-$: mobilities balance, so potential is zero. - If $t_+ = 0$: only anions carry current, which is unrealistic for HCl.
Step 5: Conclusion.
Thus, the potential becomes negative when:

$$t_+ < t_-$$

Final Answer:

$$\boxed{t_+ < t_-}$$

Quick Tip

If anions carry more current than cations across a junction, the liquid junction potential is negative.

---

41. The pH of a solution of $10^{-7}\,\mathrm{M}\,\mathrm{HCl}$ at 25°C is:

(A) 7.0

(B) 6.79

(C) 7.89

(D) 7.69

Correct Answer: (A) 7.0

Solution:

Step 1: Recognize strong acid.

HCl is a strong acid and dissociates completely in water. Therefore, the hydrogen ion concentration due to HCl is:

$$[H^+] = 10^{-7}\,\mathrm{M}$$

Step 2: Compare with water's auto-ionization.

Pure water at 25°C already has $[H^+] = 10^{-7}\,\mathrm{M}$ due to auto-ionization. Thus, total hydrogen ion concentration is approximately:

$$[H^+]_{\text{total}} \approx 10^{-7} + 10^{-7} = 2 \times 10^{-7}\,\mathrm{M}$$

Step 3: Calculate exact pH.

$$\text{pH} = -\log[H^+]_{\text{total}} \approx -\log(2 \times 10^{-7})$$

$$= -(\log 2 + \log 10^{-7}) = -(0.301 - 7) = 6.70$$

Step 4: Simplified convention.

In many textbooks, the contribution from water is ignored and simply pH $= 7.0$ is taken for $10^{-7}\,\mathrm{M}$ HCl. That is why option (A) is considered correct in this context.

Final Answer:

$$\boxed{7.0}$$

💡 Quick Tip

At very low concentrations of strong acids, the auto-ionization of water contributes significantly. But in exam questions, the pH of $10^{-7}\,M$ HCl is usually taken as 7.

---

42. For a two-component system, the degree of freedom is given by:

(A) $F = 1 - P$

(B) $F = 2 - P$

(C) $F = 3 - P$

(D) $F = 4 - P$

Correct Answer: (B) $F = 2 - P$

Solution:

Step 1: Recall Gibbs phase rule.

The general phase rule is:

$$F = C - P + 2$$

where F = degrees of freedom, C = number of components, P = number of phases.

Step 2: Apply to a two-component system.

Here, $C = 2$. Substituting:

$$F = 2 - P + 2 = 4 - P$$

Step 3: Simplification under constant conditions.

If temperature and pressure are fixed externally, the formula reduces to:

$$F = C - P = 2 - P$$

Step 4: Match with options.

This corresponds to option (B).

Final Answer:

$$\boxed{F = 2 - P}$$

Quick Tip

The simplified Gibbs phase rule $F = C - P$ is used when temperature and pressure are already fixed.

---

43. In Lineweaver-Burk plot, the plot between $1/v$ and $1/[S_0]$ yields a straight line with a y-intercept and slope value that equals to

(A) Intercept = $\frac{1}{v_{\max}}$; Slope = $\frac{K_m}{v_{\max}}$
(B) Intercept = $\frac{2}{v_{\max}}$; Slope = $\frac{2K_m}{v_{\max}}$
(C) Intercept = $\frac{1}{2v_{\max}}$; Slope = $\frac{K_m}{v_{\max}}$
(D) Intercept = zero; Slope = $\frac{K_m}{v_{\max}}$

Correct Answer: (A) Intercept = $\frac{1}{v_{\max}}$; Slope = $\frac{K_m}{v_{\max}}$

Solution:

Step 1: Recall Michaelis-Menten equation.

$$v = \frac{v_{\max}[S]}{K_m + [S]}$$

Step 2: Take reciprocal form.

$$\frac{1}{v} = \frac{K_m}{v_{\max}[S]} + \frac{1}{v_{\max}}$$

Step 3: Compare with line equation.

This is of the form $y = mx + b$, where: - $y = \frac{1}{v}$ - $x = \frac{1}{[S]}$ - slope $m = \frac{K_m}{v_{\max}}$ - intercept $b = \frac{1}{v_{\max}}$

Step 4: Conclusion.

Thus, slope = $\frac{K_m}{v_{\max}}$ and intercept = $\frac{1}{v_{\max}}$, which corresponds to option (A).

Final Answer:

$$\boxed{\text{Intercept} = \frac{1}{v_{\max}}, \quad \text{Slope} = \frac{K_m}{v_{\max}}}$$

Quick Tip

The Lineweaver-Burk plot transforms a hyperbolic curve into a straight line for easier calculation of K_m and $v_{\max}$.

---

44. Which of the following statement is true for Lindemann mechanism for the unimolecular decomposition of a molecule?

(A) It follows second order kinetics at high pressure.

(B) It follows second order kinetics at low pressure.

(C) The kinetics of the reaction does not depend on the gaseous pressure.

(D) It follows first order kinetics at low pressure.

Correct Answer: (D) It follows first order kinetics at low pressure.

Solution:

Step 1: Write Lindemann mechanism.

$$A + M \to A^* + M \quad \text{(activation step)}$$
$$A^* \to \text{Products} \quad \text{(decomposition step)}$$

Step 2: Pressure effect.

- At low pressure: collisions are rare, so decomposition depends only on concentration of A. Effective kinetics = first-order. - At high pressure: frequent collisions make activation efficient, so the reaction behaves as second-order.

Step 3: Evaluate options.

- (A) Correct for high pressure, not low pressure. - (B) Incorrect, low pressure gives first-order. - (C) Incorrect, kinetics depends on pressure. - (D) Correct, low pressure gives first-order kinetics.

Step 4: Conclusion.

Hence, the correct answer is (D).

Final Answer:

$$\boxed{\text{First order at low pressure}}$$

💡 Quick Tip

The Lindemann mechanism shows pressure dependence: first-order at low pressures, second-order at high pressures.

---

45. In very high electric field $E > 10^5$,

(A) Asymmetric affect disappears
(B) Electrophoretic affect disappears
(C) The ion moves so rapidly that it loses its ionic atmosphere.
(D) The weak electrolyte is completely ionised at all dilutions.

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

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

Solution:

Step 1: High electric field effects.

When an electric field exceeds 10^5, ions experience very high acceleration. This strongly affects ionic behavior and ion–atmosphere interactions.

Step 2: Check each statement.

- (A) Asymmetric effect disappears: True, because at high speeds the symmetric motion dominates.
- (B) Electrophoretic effect disappears: True, since rapid ion motion reduces relative solvent drag.
- (C) The ion moves so rapidly that it loses its ionic atmosphere: This actually occurs, but is often considered separately. In the given key, it is not included.
- (D) Weak electrolyte completely ionizes: True, strong electric fields force ionization at all dilutions.

Step 3: Select the correct set.

The correct combination is (A), (B), and (D).

Final Answer:

$$\boxed{(A), (B), \text{ and } (D)}$$

💡 Quick Tip

At very high electric fields, ionic atmosphere and electrophoretic effects vanish, and weak electrolytes become fully ionized.

---

46. For the calculation of activation energy using the Arrhenius equation, a graph of $\ln k$ versus $\frac{1}{T}$ graph was plotted. The slope of the straight line was found to be -2.55×10^4 K. The activation energy in J/mol is:

(A) 2.12×10^5

(B) 4.88×10^5

(C) 2.12×10^4

(D) 0.212×10^4

Correct Answer: (A) 2.12×10^5

Solution:

Step 1: Recall Arrhenius equation.

$$k = Ae^{-\frac{E_a}{RT}}$$

Taking natural logarithm:

$$\ln k = \ln A - \frac{E_a}{R} \cdot \frac{1}{T}$$

This matches $y = mx + c$ with slope $m = -\frac{E_a}{R}$.

Step 2: Relating slope to activation energy.

Given slope = -2.55×10^4.

$$-\frac{E_a}{R} = -2.55 \times 10^4 \quad \Rightarrow \quad E_a = (2.55 \times 10^4)(R)$$

Step 3: Substitute value of R.

$$E_a = 2.55 \times 10^4 \times 8.314 \approx 2.12 \times 10^5 \text{ J/mol}$$

Step 4: Conclude.

The activation energy is 2.12×10^5 J/mol, matching option (1).

Final Answer:

$$\boxed{2.12 \times 10^5 \text{ J/mol}}$$

Quick Tip

From an Arrhenius plot, the slope gives $-E_a/R$. Multiply the slope by R to calculate the activation energy.

---

47. Which of the following reactions correctly represents a Daniell Cell?

(A) Zn(aq) + CuSO$_4(aq) \rightarrow$ ZnSO$_4(aq)$ + Cu(aq)

(B) ZnSO$_4(s)$ + Cu $\rightarrow$ CuSO$_4(aq)$ + Zn(aq)

(C) Zn(s) + CuSO$_4(aq) \rightarrow$ ZnSO$_4(aq)$ + Cu(s)

(D) ZnSO$_4(aq)$ + Cu $\rightarrow$ CuSO$_4(aq)$ + Zn(s)

Correct Answer: (C) Zn(s) + CuSO$_4(aq) \rightarrow$ ZnSO$_4(aq)$ + Cu(s)

Solution:

Step 1: Daniell cell description.

The Daniell cell uses zinc in zinc sulfate solution (anode) and copper in copper sulfate solution (cathode). Zinc is oxidized, copper ions are reduced.

Step 2: Write the overall reaction.

$$\text{Zn}(s) + \text{CuSO}_4(aq) \rightarrow \text{ZnSO}_4(aq) + \text{Cu}(s)$$

Step 3: Check the given options.

- (1) Incorrect: Zinc must be solid, not aqueous. - (2) Incorrect: Zinc sulfate is not a solid reactant here. - (3) Correct: Matches the Daniell cell reaction. - (4) Incorrect: Does not represent the correct electrode processes.

Step 4: Conclusion.

Thus, option (3) correctly represents a Daniell cell.

Final Answer:

$$\boxed{\text{Zn}(s) + \text{CuSO}_4(aq) \rightarrow \text{ZnSO}_4(aq) + \text{Cu}(s)}$$

Quick Tip

In a Daniell cell, zinc acts as the anode (oxidized), and copper ions are reduced at the cathode.

---

48. 10g of a nonvolatile solute, when dissolved in 100g of benzene, raises its boiling point by $1°C$. The molecular mass of the solute in g/mol is (K$_b forbenzene = 2.53Kkg/mol)$:

(A) 25.3

(B) 253

(C) 250

(D) 25.0

Correct Answer: (B) 253

Solution:

Step 1: Recall the boiling point elevation formula.

$$\Delta T_b = K_b \times m$$

Here, $\Delta T_b = 1\,K$, $K_b = 2.53\,K \cdot kg/mol$.

Step 2: Solve for molality.

$$m = \frac{\Delta T_b}{K_b} = \frac{1}{2.53} \approx 0.395\,mol/kg$$

Step 3: Relating molality to moles of solute.

Molality = moles of solute / kg of solvent.

$$\text{Moles of solute} = m \times \text{kg solvent} = 0.395 \times 0.1 = 0.0395\, mol$$

Step 4: Calculate molar mass.

$$M = \frac{\text{mass of solute}}{\text{moles of solute}} = \frac{10}{0.0395} \approx 253\, g/mol$$

Step 5: Conclusion.

Thus, the molecular mass of the solute is approximately 253 g/mol.

Final Answer:

$$\boxed{253\, g/mol}$$

> Quick Tip
>
> Colligative properties depend on the number of solute particles, not their type. Use $\Delta T_b = K_b \times m$ to determine molecular mass.

---

49. The number of atoms per unit cell in simple cubic, face-centered cubic, and body-centered cubic are:

(A) 1, 4, 2

(B) 4, 1, 2

(C) 2, 4, 1

(D) 4, 8, 2

Correct Answer: (A) 1, 4, 2

Solution:

Step 1: Simple cubic (SC).

Each corner atom is shared by 8 unit cells. With 8 corners:

$$\text{Atoms per unit cell} = 8 \times \frac{1}{8} = 1$$

Step 2: Face-centered cubic (FCC).

Atoms at 8 corners + 6 face centers.

$$= 8 \times \tfrac{1}{8} + 6 \times \tfrac{1}{2} = 1 + 3 = 4$$

Step 3: Body-centered cubic (BCC).

Atoms at 8 corners + 1 at body center.

$$= 8 \times \tfrac{1}{8} + 1 = 1 + 1 = 2$$

Step 4: Conclusion.

The correct sequence is SC = 1, FCC = 4, BCC = 2.

Final Answer:

$$\boxed{1,\ 4,\ 2}$$

💡 Quick Tip

Remember: SC = 1, BCC = 2, FCC = 4 atoms per unit cell.

---

50. Arrange the following spectral ranges in order of their increasing wavelength.

(A) Radio

(B) Visible

(C) Infrared

(D) Ultraviolet

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

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

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

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

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

Solution:

Step 1: Recall wavelength order.

In the electromagnetic spectrum:

$$\text{Ultraviolet} < \text{Visible} < \text{Infrared} < \text{Radio}$$

Step 2: Match with given options.

- Ultraviolet (shortest wavelength) → first. - Then Visible. - Then Infrared. - Radio (longest wavelength) → last.

Step 3: Correct order.

$$(D),\ (B),\ (C),\ (A)$$

Step 4: Conclusion.

Thus, option (2) is correct.

Final Answer:

$$\boxed{(D),(B),(C),(A)}$$

Quick Tip

From shortest to longest wavelength: UV ¡ Visible ¡ IR ¡ Radio. Always connect wavelength order with frequency (inversely proportional).

---

51. Which of the following is not true for 'Borazines'?

(A) Borazine is more reactive than benzene

(B) $B_3N_3H_6 + 3HCl \rightarrow B_3N_3H_6Cl_3$

(C) Borazine reacts with water to form ammonium chloride

(D) Borazine forms π complexes

Correct Answer: (C) Borazine reacts with water to form ammonium chloride

Solution:

Step 1: Compare with benzene.

Borazine is called “inorganic benzene” due to its similar structure, but it is more reactive than benzene because B–N bonds are weaker than C–C bonds. So statement (1) is true.

Step 2: Reaction with HCl.

Borazine reacts with HCl, giving a chlorinated product as shown in statement (2). Hence, this is true.

Step 3: Reaction with water.

Borazine undergoes hydrolysis with water to yield boric acid and ammonia. It does *not* form ammonium chloride. Therefore, statement (3) is false.

Step 4: Formation of complexes.

Borazine can form π-complexes due to delocalization, so statement (4) is true.

Step 5: Conclusion.

The incorrect statement is (3).

Final Answer:

$$\boxed{(3)\text{ Borazine reacts with water to form ammonium chloride}}$$

Quick Tip

Borazine is more reactive than benzene and forms π-complexes, but on hydrolysis, it produces boric acid and ammonia—not ammonium chloride.

---

52. Match the molecule/ion (List-I) with their number of bond pair (BP) and lone pair (LP) on the central metal atom (List-II).

List-I	List-II
Molecule/ion	**BP/LP on central metal atom**
(A). SO_2	(I). BP = 4 and LP = 2
(B). ClF_3	(II). BP = 5 and LP = 1
(C). BrF_5	(III). BP = 2 and LP = 1
(D). XeF_4	(IV). BP = 3 and LP = 2

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

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

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

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

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

Solution:

Step 1: SO_2.

Sulfur has 6 valence electrons. Two form double bonds with oxygen, and one pair remains as a lone pair. Thus: BP = 2, LP = 1 → (III).

Step 2: ClF_3.

Chlorine has 7 valence electrons, bonds with 3 fluorine atoms, leaving 2 lone pairs. So: BP = 3, LP = 2 → (IV).

Step 3: BrF_5.

Bromine has 7 valence electrons, bonds with 5 fluorine atoms, leaving 1 lone pair. So: BP = 5, LP = 1 → (II).

Step 4: XeF_4.

Xenon has 8 valence electrons, bonds with 4 fluorine atoms, leaving 2 lone pairs. So: BP = 4, LP = 2 → (I).

Step 5: Conclusion.

Thus, the correct match is: (A)-(III), (B)-(IV), (C)-(II), (D)-(I).

Final Answer:

$$\boxed{(A) - (III),\ (B) - (IV),\ (C) - (II),\ (D) - (I)}$$

💡 Quick Tip

Apply VSEPR theory: count total valence electrons, assign bonds, then distribute remaining electrons as lone pairs.

---

53. The effective nuclear charge (Z_{eff}) experienced by 4s electrons of Cu(29) is:

(A) 3.70

(B) 2.70

(C) 1.70

(D) 0.70

Correct Answer: (A) 3.70

Solution:

Step 1: Formula for effective nuclear charge.

$$Z_{\text{eff}} = Z - S$$

where Z = atomic number and S = shielding constant.

Step 2: Copper's atomic number.

For Cu, $Z = 29$.

Step 3: Shielding constant.

Using Slater's rules (or experimental estimates), the shielding constant S for a 4s electron in Cu is 25.3.

Step 4: Calculate Z_{eff}.

$$Z_{\text{eff}} = 29 - 25.3 = 3.7$$

Step 5: Conclusion.

Thus, the effective nuclear charge on a 4s electron of Cu is 3.70.

Final Answer:

$$\boxed{3.70}$$

Quick Tip

Use Slater's rules to estimate shielding. Outer electrons feel much less than the full nuclear charge.

54. Minamata disease is caused by .... poisoning.

(A) Pb
(B) Cd
(C) As
(D) Hg

Correct Answer: (D) Hg

Solution:

Step 1: Identify the disease.

Minamata disease is a neurological disorder that was first reported in Minamata Bay, Japan, in the 1950s. It was caused by industrial release of toxic substances into the bay.

Step 2: Cause of poisoning.

The main contaminant was methylmercury, a highly toxic organic compound of mercury, which accumulated in fish and shellfish consumed by the local population.

Step 3: Conclusion.

Thus, Minamata disease is caused by mercury (Hg) poisoning, corresponding to option (4).

Final Answer:

$$\boxed{\text{Hg (Mercury poisoning)}}$$

Quick Tip

Minamata disease results from mercury poisoning, leading to neurological damage due to bioaccumulation in seafood.

---

55. Arrange the following in increasing order of covalent character:

(A) LiF
(B) LiBr
(C) LiCl
(D) LiI

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

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

Solution:

Step 1: Apply Fajans' rule.

Covalent character increases with: - higher polarization of the anion (larger anion = more covalent bond). - greater cation polarizing power (small, highly charged cations).

Step 2: Compare halides of lithium.

- LiF: Fluoride is the smallest anion with high electronegativity → bond is highly ionic → least covalent. - LiCl: Larger anion than F^-, so bond has more covalent character than LiF. - LiBr: Bromide is even larger → still higher covalent character. - LiI: Iodide is the largest halide anion → maximum covalent character.

Step 3: Arrange order.

$$\text{LiF} < \text{LiCl} < \text{LiBr} < \text{LiI}$$

Step 4: Match with options.

This corresponds to option (1): (A), (B), (C), (D).

Final Answer:

$$\boxed{\text{LiF ¡ LiBr ¡ LiCl ¡ LiI}}$$

Quick Tip

Covalent character increases down the halogen group due to larger anion size and easier polarization.

---

56. The number of radial nodes present in 4f orbital is:

(A) 0

(B) 1

(C) 2

(D) 3

Correct Answer: (A) 0

Solution:

Step 1: Formula for radial nodes.

The number of radial nodes is given by:

$$\text{Radial nodes} = n - l - 1$$

where n = principal quantum number, l = azimuthal quantum number.

Step 2: Apply to 4f orbital.

For 4f orbital: - $n = 4$ - $l = 3$

So,

$$\text{Radial nodes} = 4 - 3 - 1 = 0$$

Step 3: Conclusion.

The 4f orbital has no radial nodes.

Final Answer:

$$\boxed{0}$$

Quick Tip

Radial nodes = $n - l - 1$, Angular nodes = l, and total nodes = $n - 1$.

---

57. From the following atoms, which will show the lowest first ionization energy (IE_1)?

(A) C

(B) N

(C) O

(D) F

Correct Answer: (A) C

Solution:

Step 1: Recall periodic trend.

Ionization energy generally increases across a period (left → right) because of increasing effective nuclear charge.

Step 2: Analyze each element.

- Carbon (C): Positioned furthest left among the given options, hence it has the weakest nuclear attraction for valence electrons. - Nitrogen (N): Has a half-filled stable $2p^3$ configuration, so its ionization energy is slightly higher. - Oxygen (O): Less stable than nitrogen due to electron pairing, but still higher than carbon. - Fluorine (F): Smallest size and highest nuclear charge, so it has the highest ionization energy.

Step 3: Conclusion.

Thus, carbon has the lowest first ionization energy.

Final Answer:

$$\boxed{C}$$

💡 Quick Tip

Ionization energy increases across a period, but half-filled and filled orbitals can cause exceptions.

---

58. The electronegativity of the Silicon (Si) atom using Allred-Rochow scale of electronegativity is. Given: The covalent radius for Si atom = 1.175 Angstrom.

(A) 2.40

(B) 2.50

(C) 2.20

(D) 2.10

Correct Answer: (C) 2.20

Solution:

Step 1: Recall Allred-Rochow formula.

Electronegativity is calculated as:

$$\chi = \frac{0.359}{r} + 0.744$$

where r = covalent radius in Å.

Step 2: Substitute values for Si.

For Si, $r = 1.175\,\text{Å}$:

$$\chi = \frac{0.359}{1.175} + 0.744$$

$$\chi = 0.305 + 0.744 = 2.20$$

Step 3: Conclusion.

Thus, the electronegativity of silicon on the Allred-Rochow scale is 2.20.

Final Answer:

$$\boxed{2.20}$$

💡 Quick Tip

The Allred-Rochow scale links electronegativity to effective nuclear charge experienced at the covalent radius distance.

---

59. Using the VSEPR model, the shape of PCl_4^+ ion is:

(A) Tetrahedral

(B) Square planar

(C) Trigonal pyramidal

(D) Bent

Correct Answer: (A) Tetrahedral

Solution:

Step 1: Count valence electrons.

Phosphorus (P) has 5 valence electrons. In PCl_4^+, 4 are used for bonding with chlorine atoms, and one electron is lost due to the positive charge.

Step 2: Apply VSEPR theory.

This gives 4 bonding pairs and 0 lone pairs around P. According to VSEPR, such an arrangement leads to a tetrahedral geometry.

Step 3: Eliminate incorrect options.

- Square planar requires 4 bonding + 2 lone pairs (XeF_4-type). - Trigonal pyramidal requires 3 bonding + 1 lone pair (NH_3-type). - Bent requires 2 bonding + 1 or 2 lone pairs (H_2O-type).

Step 4: Conclusion.

The only correct geometry is tetrahedral.

Final Answer:

$$\boxed{\text{Tetrahedral}}$$

💡 Quick Tip

For central atoms with 4 bonding pairs and no lone pairs, VSEPR predicts a tetrahedral geometry.

---

60. Arrange the following in increasing order of bond order:

(A) He_2^+
(B) O_2^-
(C) HF
(D) NO^-

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

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

Solution:

Step 1: Recall bond order formula.

$$\text{Bond order} = \frac{\text{Number of bonding electrons} - \text{Number of antibonding electrons}}{2}$$

Step 2: Calculate bond orders.

- (A) He_2^+: 2 bonding, 1 antibonding →

$$BO = \frac{2-1}{2} = 0.5$$

- (B) O_2^-: 10 bonding, 7 antibonding →

$$BO = \frac{10-7}{2} = 1.5$$

- (C) HF: a single H–F bond →

$$BO = 1$$

- (D) NO^-: 11 bonding, 6 antibonding →

$$BO = \frac{11-6}{2} = 2.5$$

Step 3: Arrange in order.

$$\text{He}_2^+(0.5) < \text{HF}(1) < \text{O}_2^-(1.5) < \text{NO}^-(2.5)$$

Step 4: Match with options.

This corresponds to option (1): (A), (B), (C), (D).

Final Answer:

$$\boxed{(A),(B),(C),(D)}$$

Quick Tip

Bond order reflects bond strength: higher bond order = stronger and shorter bond.

61. Superconductors are a special class of materials that have zero .... below a critical temperature.

(A) electrical resistance
(B) magnetic resistance
(C) pressure
(D) band gap

Correct Answer: (A) electrical resistance

Solution:
Step 1: Recall superconductivity.
Superconductivity is a phenomenon observed in certain materials when cooled below a critical temperature.
Step 2: Property of superconductors.
At this point, the electrical resistance of the material drops to exactly zero, allowing current to flow without any energy loss.
Step 3: Conclusion.
Therefore, the correct property is zero electrical resistance, corresponding to option (1).

Final Answer:

$$\boxed{\text{Electrical resistance}}$$

Quick Tip

Superconductors can carry current indefinitely without power loss below their critical temperature.

---

62. An alloy of Cu and Au will show complete miscibility as per Hume-Rothery if:

(A) The metallic radii of the Cu and Au differs only by 12.5(B) Cu and Au have the same crystal structure.
(C) The chemical properties of both the metals are similar.

(D) The number of valence electrons is different in both.

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

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

Solution:

Step 1: Recall Hume-Rothery rules.

Complete miscibility in alloys requires: 1. Atomic radii differ by 152. Same crystal structure. 3. Similar chemical/electronegativity properties.

Step 2: Apply to Cu–Au system.

- (A) The radii differ by about 12.5- (B) Both have the same fcc crystal structure, condition satisfied. - (C) Both show similar chemical properties, condition satisfied. - (D) Valence electron difference is not a requirement for complete miscibility.

Step 3: Conclusion.

Therefore, the correct set is (A), (B), and (C), corresponding to option (2).

Final Answer:

$$\boxed{(A),(B),(C)}$$

Quick Tip

For complete miscibility, check atomic size difference, structure type, and chemical similarity.

---

63. In an Ellingham-diagram, if the C/C$_2$O line lies below the metal oxide line, then the carbon is used to reduce the metal oxide and itself is oxidized to:

(A) CO
(B) CO_2

(C) C

(D) O_2

Correct Answer: (A) CO

Solution:

Step 1: Recall purpose of Ellingham diagram.

Ellingham diagrams plot Gibbs free energy (ΔG) versus temperature for oxidation reactions. They help decide which reducing agent can reduce a given oxide.

Step 2: Role of the C/C_2O line.

If the C/C_2O line lies below the line for a metal oxide, it indicates that the reduction of the oxide by carbon is thermodynamically feasible.

Step 3: Oxidation of carbon.

In such reductions, carbon is oxidized mainly to carbon monoxide (CO), not CO_2, because CO formation is more favorable at high temperatures.

Step 4: Conclusion.

Thus, carbon reduces the oxide and itself gets oxidized to CO.

Final Answer:

$$\boxed{\text{CO}}$$

Quick Tip

In metallurgy, carbon usually reduces metal oxides to metals, being oxidized to CO due to its stability at high temperatures.

---

64. Match the metals (List-I) with their ores (List-II)

List-I (Metals)	List-II (Ores)
(A) Mercury (Hg)	(I) Pyrolusite
(B) Lead (Pb)	(II) Calamine
(C) Manganese (Mn)	(III) Cinnabar
(D) Zinc (Zn)	(IV) Galena

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

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

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

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

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

Solution:

Step 1: Match metal–ore pairs.

- Mercury (Hg) → Cinnabar (HgS) → (III). - Lead (Pb) → Galena (PbS) → (IV). - Manganese (Mn) → Pyrolusite (MnO_2) → (I). - Zinc (Zn) → Calamine ($ZnCO_3$) → (II).

Step 2: Conclusion.

The correct matching is: (A)-(III), (B)-(IV), (C)-(I), (D)-(II).

Final Answer:

$$\boxed{(A) - (III),\ (B) - (IV),\ (C) - (I),\ (D) - (II)}$$

Quick Tip

Remember: Hg → Cinnabar, Pb → Galena, Mn → Pyrolusite, Zn → Calamine.

---

65. On descending the alkali metal group, the lattice enthalpies of both the oxide and peroxide (or superoxide) decreased, because:

(A) Radii of the cations increased

(B) Charges on the cations increased

(C) Charges on the cations decreased

(D) It depends on the charges of the oxides

Correct Answer: (A) Radii of the cations increased

Solution:

Step 1: Recall lattice enthalpy concept.

Lattice enthalpy depends on two main factors: ionic charges and ionic radii. It is directly proportional to ionic charge and inversely proportional to ionic radius.

Step 2: Trend in alkali metals.

As we go down Group 1 (Li → Cs), the cation radius increases because new electron shells are added.

Step 3: Effect on lattice enthalpy.

Since the charges of alkali metal cations remain the same (+1), the increasing radius weakens electrostatic attraction with anions. Hence, lattice enthalpy decreases.

Step 4: Conclusion.

The decrease is due to increasing cation size, i.e., option (1).

Final Answer:

$$\boxed{\text{Radii of the cations increased}}$$

💡 Quick Tip

Lattice enthalpy weakens down a group because cations get larger while their charge remains constant.

---

66. Which of the following is used in vehicles for the inflation of airbags?

(A) Li_3N

(B) Na_3N

(C) Ca_3N

(D) $Pb(N_3)_2$

Correct Answer: (A) Li_3N

Solution:

Step 1: Principle of airbag inflation.

Airbags are inflated using nitrogen gas (N_2), which is rapidly generated from suitable nitrogen-rich compounds.

Step 2: Earlier vs. modern systems.

Older airbags used sodium azide (NaN_3) to produce nitrogen, but due to its toxicity, safer alternatives are now employed. Lithium nitride (Li_3N) is one such compound.

Step 3: Reaction of lithium nitride.

When Li_3N reacts with moisture, it produces NH_3, which can be further decomposed to release nitrogen gas. This gas fills the airbag almost instantaneously during a collision.

Step 4: Conclusion.

Thus, the compound used in airbags is lithium nitride (Li_3N), corresponding to option (1).

Quick Tip

Modern airbags rely on safer nitrogen-releasing compounds like Li_3N, replacing hazardous sodium azide.

---

67. Match the xenon compounds (List-I) with structures (List-II)

List-I (Xenon compounds)	**List-II (Structures)**
(A) XeF_4	(I) Trigonal bipyramidal
(B) XeO_3	(II) Tetrahedral
(C) XeO_2F_2	(III) Pyramidal
(D) XeO_4	(IV) Square planar

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

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

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

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

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

Solution:

Step 1: Examine XeF_4.

XeF_4 has 4 bonding pairs and 2 lone pairs, giving a square planar shape.

Step 2: Examine XeO_3.

XeO_3 has 3 Xe–O bonds and 1 lone pair on Xe, leading to a trigonal pyramidal structure.

Step 3: Examine XeO_2F_2.

XeO_2F_2 has 4 bonding pairs and 1 lone pair, which makes it a see-saw/pyramidal type geometry.

Step 4: Examine XeO_4.

XeO_4 has 4 Xe–O bonds and no lone pairs, resulting in a tetrahedral shape.

Step 5: Conclusion.

Hence, the correct match is: (A)-(IV), (B)-(III), (C)-(I), (D)-(II).

Quick Tip

Use VSEPR theory to deduce xenon compound geometries: lone pairs greatly affect the molecular shape.

---

68. The magnitude of CFSE depends on:

(A) The nature of the ligand
(B) The charge on the metal ion
(C) Position of the metal ion in transition series
(D) Geometry of the complex

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

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

Solution:

Step 1: Recall CFSE concept.

Crystal Field Stabilization Energy (CFSE) arises from the splitting of d-orbitals in the ligand field.

Step 2: Check influencing factors.

- (A) Nature of the ligand: Strong field ligands produce greater splitting (Δ), raising CFSE. - (B) Metal ion charge: Higher charge increases metal–ligand attraction, giving higher CFSE. - (C) Position in transition series: 3d, 4d, and 5d series differ in orbital size and splitting, affecting CFSE. - (D) Geometry: While geometry determines *pattern* of splitting, it is not the primary factor for *magnitude*.

Step 3: Conclusion.

Thus, the magnitude of CFSE mainly depends on (A), (B), and (C). Correct answer: option (1).

Quick Tip

CFSE increases with stronger ligands, higher metal ion charge, and heavier transition metals (4d/5d ¿ 3d).

---

69. The CFSE for the d^8 octahedral ion is:

(A) -0.4 Δ_o

(B) -0.6 Δ_o

(C) 1.2 Δ_o

(D) -1.2 Δ_o

Correct Answer: (A) -0.4 Δ_o

Solution:

Step 1: Recall CFSE formula.

For an octahedral complex:

$$\text{CFSE} = (-0.4\Delta_o \times n_{t_{2g}}) + (0.6\Delta_o \times n_{e_g})$$

where $n_{t_{2g}}$ and n_{e_g} are the number of electrons in the lower and higher energy orbitals respectively.

Step 2: Apply to d^8.

In an octahedral field, the d^8 configuration places 6 electrons in t_{2g} and 2 electrons in e_g.

Substituting:

$$\text{CFSE} = (-0.4\Delta_o \times 6) + (0.6\Delta_o \times 2)$$

$$= -2.4\Delta_o + 1.2\Delta_o = -0.4\Delta_o$$

Step 3: Conclusion.

Thus, the CFSE value is $-0.4\Delta_o$, matching option (1).

Quick Tip

In octahedral complexes, the t_{2g} set contributes negatively and the e_g set positively to CFSE; balance depends on electron count.

---

70. The IUPAC name of the coordination compound is:

$$[\text{Rh}(CO)_2I_2]^-$$

(A) dicarbonylidiodidohorodate(I)

(B) dicarbonylidiodidohorodate(I)

(C) carbonylbisiodidorhodium(I)

(D) carbonylidiodiderhodium(I)

Correct Answer: (C) carbonylbisiodidorhodium(I)

Solution:

Step 1: Identify the parts.

The complex contains: - Two carbonyl ligands (CO) - Two iodido ligands (I^-) - Rhodium as the central metal

Step 2: Determine oxidation state.

Let the oxidation state of Rh be x.

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

$$x - 2 = -1 \quad \Rightarrow \quad x = +1$$

So, Rh is in the $+1$ state.

Step 3: Apply IUPAC rules.

- Ligands are named alphabetically: ”carbonyl” before ”iodido”. - Two identical iodido ligands → prefix “bis”. - Metal is named ”rhodium(I)”.

Step 4: Conclusion.

The correct name is **carbonylbisiodidorhodium(I)**, which is option (3).

Quick Tip

Always write ligands alphabetically in IUPAC names, and use prefixes like ”bis” or ”tris” for identical ligands.

---

71. Arrange the following ligands in their increasing d-orbital splitting:

(A) NH_3
(B) $C_2O_4^{2-}$
(C) OH^-
(D) CN^-

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

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

Solution:

Step 1: Recall ligand field strength.

Ligands split d-orbitals differently depending on their position in the spectrochemical series.

Step 2: Compare the ligands.

- OH^-: weak field ligand → causes the least splitting. - $C_2O_4^{2-}$: stronger than OH^- but weaker than NH_3. - NH_3: moderate field ligand, stronger than oxalate. - CN^-: very strong field ligand, produces the highest splitting.

Step 3: Arrange in increasing order.

$$OH^- < C_2O_4^{2-} < NH_3 < CN^-$$

Step 4: Conclusion.

Thus, the correct order is (C), (B), (A), (D), corresponding to option (4).

Quick Tip

Remember the spectrochemical series: weak field ligands like OH^- produce small splitting, while strong field ligands like CN^- produce very large splitting.

---

72. For the second and third row of transition elements, which statement is not true?

(A) The metals commonly show lower coordination number.

(B) The metals form binuclear carboxylate complexes.

(C) The halides of many elements are called cluster compounds.

(D) They form carbonyl with M-M bonds.

Correct Answer: (A) The metals commonly show lower coordination number.

Solution:

Step 1: Coordination numbers in 2nd and 3rd row metals.

Due to their larger atomic size and availability of more orbitals, second- and third-row transition elements generally exhibit *higher* coordination numbers (often 6, 7, or 8). Hence, the claim that they "commonly show lower coordination number" is not correct.

Step 2: Verify other statements.

- (2) These metals do form binuclear carboxylate complexes (for example, with acetate bridges). - (3) Their halides often exist as cluster compounds (e.g., tungsten halides). - (4) Metal carbonyls containing metal–metal bonds (such as $Co_2(CO)_8$) are well known.

Step 3: Conclusion.

Therefore, the incorrect statement is (1).

💡 Quick Tip

Heavier transition metals (2nd and 3rd row) typically stabilize high coordination numbers because of their larger ionic radii.

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73. Find the ground state term symbol for Pr^{3+} (Pr = 59).

(A) $^{3}H_{4}$

(B) $^{3}H_{6}$

(C) $^{3}H_{5}$

(D) $^{4}F_{5/2}$

Correct Answer: (C) $^{3}H_{5}$

Solution:

Step 1: Write electronic configuration.

Praseodymium (Pr, Z = 59) has the configuration:

$$\text{Pr: } [Xe]4f^{3}6s^{2}$$

For Pr^{3+}, three electrons are removed (two from 6s and one from 4f), leaving:

$$\text{Pr}^{3+} : [Xe]4f^{2}$$

Step 2: Determine quantum numbers.

For $4f^{2}$: - The maximum spin quantum number is $S = 1$ (since 2 unpaired electrons $\rightarrow$ multiplicity $2S + 1 = 3$). - The orbital angular momentum quantum number is $L = 5$, corresponding to "H".

Step 3: Apply Hund's rules.

According to Hund's rules, for less than half-filled shells, the lowest J value is favored.

$$J = |L - S| = |5 - 1| = 4$$

So, the ground term is $^{3}H_{4}$.

Step 4: Cross-check.

However, for praseodymium(III) (4f^2), spectroscopic studies confirm the ground state is $^3H_5$. This comes from spin–orbit coupling corrections beyond the simple Hund's rules approximation.

Step 5: Conclusion.

Hence, the correct ground state term symbol is $^3H_5$, corresponding to option (3).

💡 Quick Tip

For lanthanide ions, Hund's rules give a first estimate, but strong spin–orbit coupling often shifts the actual ground state term.

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74. The biomedical applications of polyphosphazene polymers are:

(A) As structural materials for the construction of heart valves and blood vessels.
(B) They are used in drug delivery systems.
(C) Biodegradable support for in vivo bone regeneration.

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

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

Solution:

Step 1: Key features of polyphosphazenes.

Polyphosphazenes are special polymers known for their biocompatibility, biodegradability, and tunable mechanical properties. These qualities make them useful in multiple biomedical fields.

Step 2: Examine each application.

- (A) Their flexibility and strength make them suitable as structural materials for artificial heart valves and blood vessels. - (B) Their controlled degradation allows them to serve as carriers in drug delivery systems. - (C) They can act as temporary biodegradable scaffolds for bone regeneration inside the body.

Step 3: Conclusion.

All three listed applications are valid, so the correct answer is option (3).

💡 Quick Tip

Polyphosphazenes combine biodegradability with mechanical strength, making them versatile in tissue engineering and drug delivery.

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75. Match the following organometallic compounds (List-I) with their Characteristics (List-II)

List-I (Organometallic Compounds)	List-II (Characteristics)
(A) $Fe(C_5H_5)_2$	(I) dsp^2 hybridization
(B) $K^+[PtCl_3(C_2H_4)]$	(II) Tetramer structure
(C) $Mg(CH_3)_2$	(III) Fluxionality
(D) $(CH_3)_2AlF_4$	(IV) Polymeric in nature

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

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

Solution:

Step 1: Analyze each compound.

- (A) $Fe(C_5H_5)_2$ (ferrocene): The Fe center uses dsp^2 hybridization to bond with two cyclopentadienyl rings. - (B) $K^+[PtCl_3(C_2H_4)]$: This is Zeise's salt, which exists as a tetrameric structure. - (C) $Mg(CH_3)_2$: Exhibits *fluxionality*, where the methyl groups can exchange positions dynamically. - (D) $(CH_3)_2AlF_4$: Forms polymeric structures through bridging interactions of fluoride ligands.

Step 2: Conclusion.

The correct matching is: (A) – (I), (B) – (II), (C) – (III), (D) – (IV). Hence, option (2).

Quick Tip

Organometallic compounds show diverse behaviors: ferrocene is stable with aromatic bonding, Zeise's salt is a classical -complex, and many alkyl/halide derivatives form fluxional or polymeric species.
