# JEE Main 2023 8 April Shift 2 Chemistry Question Paper with Solutions

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| **Time Allowed :**3 Hours | **Maximum Marks :**300 | **Total Questions :**90 |

## General Instructions

**Read the following instructions very carefully and strictly follow them:**

1. The Duration of test is 3 Hours.
2. This Question paper consists of 90 Questions.
3. There are three parts in the question paper consisting of Physics, Chemistry and Mathematics having 30 questions in each part of equal weightage..
4. Each part (subject) has two sections.
   (i) Section-A: This section contains 20 multiple choice questions which have only one correct answer. Each question carries 4 marks for correct answer and –1 mark for wrong answer..
5. (ii) Section-B: This section contains 10 questions. In Section-B, attempt any five questions out of 10. The answer to each of the questions is a numerical value. Each question carries 4 marks for correct answer and –1 mark for wrong answer. For Section-B, the answer should be rounded off to the nearest integer.

**Question 1: The statement/s which are true about antagonists from the following is/are:**

**A. They bind to the receptor site.**

**B. Get transferred inside the cell for their action.**

**C. Inhibit the natural communication of the body.**

**D. Mimic the natural messenger.**

**Choose the correct answer from the options given below:**

(1) A and B

(2) A and C

(3) A, C and D

(4) B only

**Correct Answer:** (2)

**Solution:** Antagonists are substances that bind to receptor sites to block the effects of natural messengers. They do not get transferred into the cell but inhibit the natural communication of the body.

Option A: Correct. Antagonists bind to receptor sites.

Option B: Incorrect. Antagonists act at the receptor site and are not transferred inside the cell.

Option C: Correct. They inhibit the natural communication of the body.

Option D: Incorrect. Antagonists do not mimic natural messengers; they block them.

Thus, the correct answer is (2) A and C.

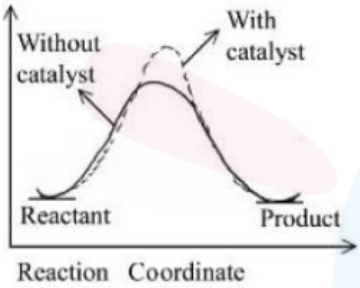
**Quick Tip**

Antagonists block receptor sites and inhibit the natural signaling process. They prevent natural messengers from binding but do not mimic or enter the cell for their action.

**Question 2: The correct reaction profile diagram for a positive catalyst reaction is:**

Choose the correct answer from the options given below:

(1)

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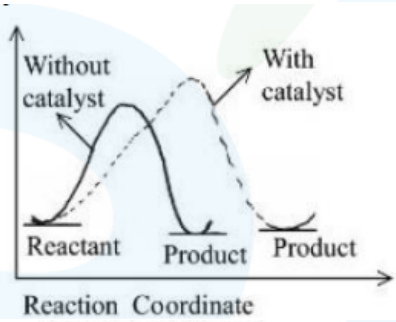


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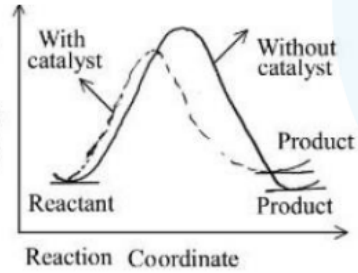


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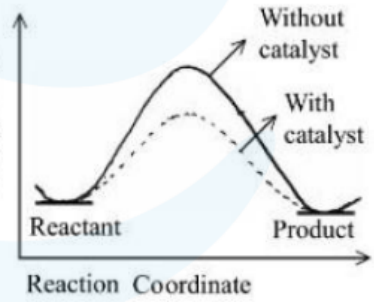


**Correct Answer:** (4)

**Solution:** A positive catalyst increases the reaction rate by lowering the activation energy. Activation energy is the minimum energy required for reactants to form products. In the given diagrams:

Option (1): This graph does not represent the effect of a catalyst, as the activation energy remains unchanged.

Option (2): Incorrect. The diagram does not depict a lowered activation energy.

Option (3): Incorrect. While the curve changes, it does not correctly indicate the role of a

positive catalyst.

Option (4): Correct. This diagram clearly shows a decrease in the activation energy when a catalyst is present while keeping the relative energies of reactants and products unchanged.

Thus, the correct diagram representing a positive catalyst is option (4)

**Quick Tip**

Catalysts speed up reactions by decreasing activation energy, but they do not alter the enthalpy change ($\Delta H$) of the reaction.

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**Question 3: Given below are two statements: One is labeled as Assertion A, and the other is labeled as Reason R.**

**Assertion A:** Sodium is about 30 times as abundant as potassium in the oceans.

**Reason R:** Potassium is bigger in size than sodium.

In the light of the above statements, choose the correct answer from the options given below:

(1) Both A and R are true, but R is NOT the correct explanation of A.

(2) A is true, but R is false.

(3) A is false, but R is true.

(4) Both A and R are true, and R is the correct explanation of A.

**Correct Answer:** (1)

**Solution: Assertion A:** Sodium is about 30 times more abundant than potassium in the oceans. This is correct because sodium ions are more soluble in water compared to potassium ions, and sodium salts are more readily dissolved and transported into water bodies.

**Reason R:** Potassium is larger in size than sodium due to its position below sodium in Group 1 of the periodic table. This is also correct.

However, the larger size of potassium does not explain the higher abundance of sodium. The abundance is influenced by the higher solubility of sodium salts rather than atomic size. Hence, the reason does not justify the assertion.

Thus, both the assertion and reason are correct, but the reason is not the correct explanation for the assertion. The correct answer is option (1).

**Quick Tip**

When evaluating assertion-reason questions, ensure the reason directly explains the assertion. If both are correct but unrelated, choose the option that reflects this distinction.

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**Question 4: Which of these reactions is not a part of the breakdown of ozone in the stratosphere?**

(1) $CF_2Cl_2(g) \xrightarrow{uv} Cl(g) + CF_2Cl(g)$

(2) $Cl(g) + O_3(g) \rightarrow ClO(g) + O_2(g)$

(3) $2\,ClO(g) \rightarrow ClO_2(g) + Cl(g)$

(4) $ClO(g) + O(g) \rightarrow Cl(g) + O_2(g)$

**Correct Answer:** (3)

**Solution:** The breakdown of ozone in the stratosphere involves the following steps:

1.Initiation: Chlorofluorocarbons (CFCs), such as $CF_2Cl_2$, are photodissociated by ultraviolet radiation to release chlorine atoms.

$$CF_2Cl_2(g) \xrightarrow{uv} CF_2Cl(g) + Cl(g)$$

2.Ozone Destruction (Catalytic Cycle): Chlorine atoms react with ozone molecules to produce chlorine monoxide (ClO) and oxygen gas.

$$Cl(g) + O_3(g) \rightarrow ClO(g) + O_2(g)$$

Chlorine monoxide reacts with atomic oxygen to regenerate chlorine atoms and produce more oxygen gas.

$$ClO(g) + O(g) \rightarrow Cl(g) + O_2(g)$$

3.Net Reaction: The overall reaction destroys ozone while regenerating chlorine atoms, allowing the cycle to continue.

$$O_3 + O \rightarrow 2O_2$$

Analysis of options: Option (1): This reaction represents the photodissociation of $CF_2Cl_2$, which is part of the initiation step in ozone breakdown.

Option (2): This reaction shows chlorine reacting with ozone to form chlorine monoxide and oxygen gas, which is part of the catalytic cycle.

Option (3): This reaction suggests that two chlorine monoxide molecules react to form $ClO_2$ and Cl. This does not occur in the stratosphere and is not part of the catalytic cycle.

Option (4): This reaction shows chlorine monoxide reacting with atomic oxygen to regenerate chlorine and produce oxygen gas, which is part of the catalytic cycle.

Thus, the correct answer is (3).

**Quick Tip**

The breakdown of ozone in the stratosphere involves a catalytic cycle where chlorine atoms and chlorine monoxide are continuously regenerated to destroy ozone. Reactions outside this cycle are not part of the process.

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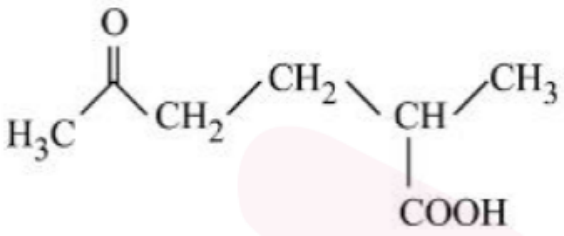
**Question 5: The correct IUPAC nomenclature for the following compound is.**




(1) 2 Methyl 5 oxohexanoic acid

(2) 2 Formyl 5 methylhexan 6 oic acid

(3) 5 Formyl 2 methylhexanoic acid

(4) 5 Methyl 2 oxohexan 6 oic acid

**Correct Answer:** (1)

**Solution:** To name the compound correctly, we follow IUPAC nomenclature rules.

1. Identify the parent chain. The longest continuous chain containing the carboxylic acid group is chosen. In this case, the parent chain has six carbon atoms, so the base name is

hexanoic acid.

2. Number the chain. Number the chain starting from the carboxylic acid group, giving it the lowest possible number. The carboxylic acid group is at position 1.

3. Identify substituents and functional groups. There is a keto group at position 5, named as oxo. There is a methyl group attached to position 2.

4. Combine the names. Combine the substituent positions, names, and parent chain name. The correct name is 2 Methyl 5 oxohexanoic acid.

Analysis of options. Option (1). Correct. Matches the IUPAC rules.

Option (2). Incorrect. The naming improperly places formyl instead of oxo for the keto group.

Option (3). Incorrect. The substituent positions and functional groups are misplaced.

Option (4). Incorrect. The positions of oxo and methyl groups are incorrect.

Thus, the correct answer is option (1).

**Quick Tip**

To name organic compounds, always prioritize the principal functional group and number the chain accordingly. Substituents and functional groups are named based on their positions.

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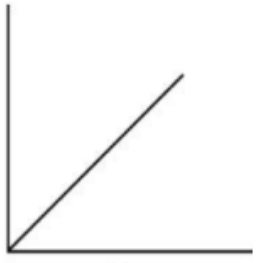
**Question 6: Henry Moseley studied characteristic X-ray spectra of elements. The graph which represents his observation correctly is:**

**Given: $\nu$ = frequency of X-ray emitted**

**$Z$ = atomic number**

(1)



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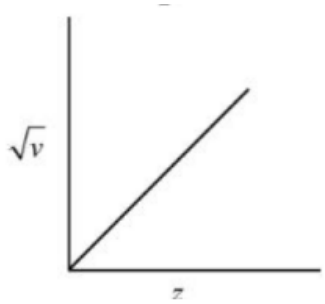


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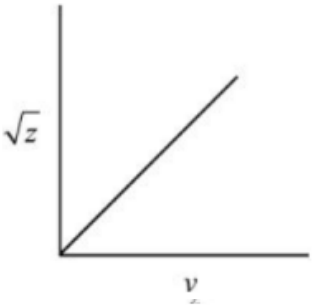


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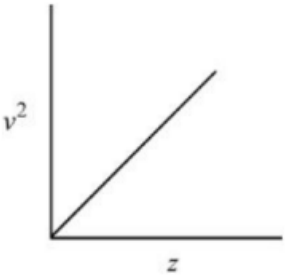


**Correct Answer:** (2)

**Solution:** Moseley's law describes the relationship between the square root of the frequency of X-rays emitted ($\nu$) and the atomic number ($Z$). According to Moseley's observations:

$$\sqrt{\nu} \propto (Z - \sigma)$$

where $\sigma$ is a constant that accounts for the screening effect of inner electrons. The graph of $\sqrt{\nu}$ versus $Z$ is a straight line, as frequency is directly proportional to the square of the atomic number minus the screening constant.

Analysis of options: 1. $\nu$ vs $Z$: This does not follow Moseley's law, as the relationship is not linear.

2. $\sqrt{\nu}$ vs $Z$: This correctly represents Moseley's observation, as the relationship is linear.

3. $\sqrt{Z}$ vs $\nu$: This is incorrect, as the relationship does not involve the square root of the atomic number.

4. $\nu^2$ vs $Z$: This is incorrect, as the relationship is based on the square root of frequency, not

the square of frequency.

Thus, the correct answer is option (2).

**Quick Tip**

Moseley's law shows that the square root of the frequency of X-rays emitted is linearly proportional to the atomic number of the element. Always match the correct mathematical relationship to the graph.

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**Question 7: Match List I with List II.**

| List I (Coordination Complex) | List II (Number of Unpaired Electrons) |
|---|---|
| A. $[Cr(CN)_6]^{3-}$ | I. 0 |
| B. $[Fe(H_2O)_6]^{2+}$ | II. 3 |
| C. $[Co(NH_3)_6]^{3+}$ | III. 2 |
| D. $[Ni(NH_3)_6]^{2+}$ | IV. 4 |

Choose the correct answer from the options given below:

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

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

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

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

**Correct Answer:** (1)

**Solution:** For option (A): The complex $[Cr(CN)_6]^{3-}$ contains $Cr^{3+}$ with an electronic configuration of $3d^3$. Cyanide ($CN^-$) is a strong field ligand (SFL), which causes pairing of electrons. Number of unpaired electrons = 3.

For option (B): The complex $[Fe(H_2O)_6]^{2+}$ contains $Fe^{2+}$ with an electronic configuration of $3d^6$. Water ($H_2O$) is a weak field ligand (WFL), which does not cause electron pairing. Number of unpaired electrons = 4.

For option (C): The complex $[Co(NH_3)_6]^{3+}$ contains $Co^{3+}$ with an electronic configuration of $3d^6$. Ammonia ($NH_3$) is a strong field ligand (SFL), which causes pairing of electrons. Number of unpaired electrons = 0.

For option (D): The complex $[Ni(NH_3)_6]^{2+}$ contains $Ni^{2+}$ with an electronic configuration of

$3d^8$. Ammonia ($NH_3$) is a strong field ligand (SFL), which causes partial pairing of electrons.

Number of unpaired electrons = 2.

Final matching: A-II, B-IV, C-I, D-III

Thus, the correct answer is option (1).

**Quick Tip**

To determine the number of unpaired electrons in coordination complexes, consider the oxidation state of the central metal atom, its electronic configuration, and whether the ligand is a strong or weak field ligand.

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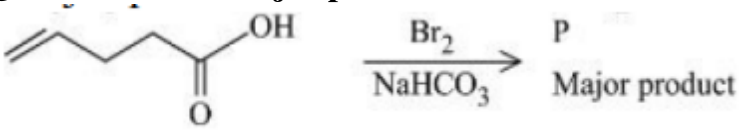
**Question 8: The major product 'P' formed in the following reaction is:**

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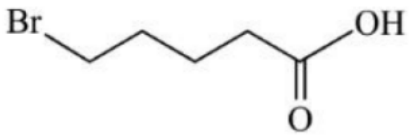


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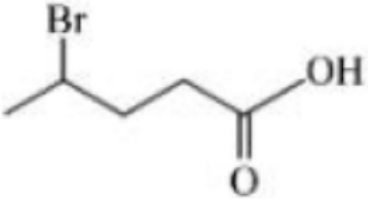


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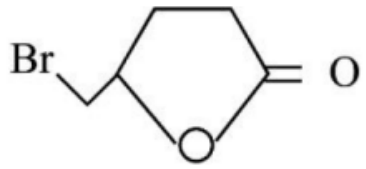
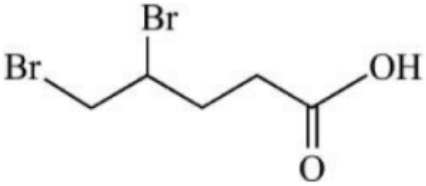



(4)




**Correct Answer:** (3)

**Solution:** The reaction is a Hell-Volhard-Zelinsky (HVZ) reaction, which involves bromination of the $\alpha$-carbon atom of a carboxylic acid in the presence of bromine ($Br_2$) and sodium bicarbonate ($NaHCO_3$).

Reaction mechanism: 1. The $\alpha$-carbon of the carboxylic acid is halogenated through the formation of an enol intermediate:

$$CH_3\text{-}CH_2\text{-}CH(OH)\text{-}COOH \xrightarrow{Br_2/NaHCO_3} CH_3\text{-}CH_2\text{-}CBr\text{-}COOH.$$

2. Cyclization occurs via intramolecular nucleophilic attack of the hydroxyl group (-OH) on the $\alpha$-brominated carboxylic acid, leading to the formation of a bromolactone:

$$CH_3\text{-}CH_2\text{-}CBr\text{-}COOH \rightarrow \text{Cyclobromo-lactone}.$$

3. The final product is the formation of a five-membered cyclic structure with a bromine atom at one position and a carbonyl group at another.

Analysis of options:

Option (1): Incorrect. This structure does not represent the cyclic lactone product.

Option (2): Incorrect. This structure has a hydroxyl (-OH) group instead of a bromine atom.

Option (3): Correct. This is the bromolactone formed as the major product.

Option (4): Incorrect. This structure has multiple bromine atoms, which are not consistent with the reaction mechanism.

Thus, the major product is represented by option (3).

**Quick Tip**

The Hell-Volhard-Zelinsky (HVZ) reaction specifically brominates the $\alpha$-carbon of carboxylic acids and can lead to lactone formation through intramolecular cyclization.

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**Question 9: For a good quality cement, the ratio of lime to the total of the oxides of Si, Al, and Fe should be as close as to:**

(1) 2

(2) 1

(3) 3

(4) 4

**Correct Answer:** (1)

**Solution:** The quality of cement is assessed based on the ratio of lime (CaO) to the sum of oxides ($SiO_2$, $Al_2O_3$, and $Fe_2O_3$). The formula for this ratio is:

$$\text{Ratio} = \frac{\%\text{CaO}}{\%\text{SiO}_2 + \%\text{Al}_2\text{O}_3 + \%\text{Fe}_2\text{O}_3}.$$

For good quality cement, this ratio lies in the range of 1.9 to 2.1, which ensures the proper strength and binding properties of the cement. If the ratio deviates significantly:

A higher ratio may make the cement weak in resistance to environmental effects.

A lower ratio may reduce the binding efficiency and durability of the cement.

Since the ratio is closest to 2, the correct answer is option (1).

**Quick Tip**

For high-quality cement, the lime to oxide ratio must be within the range of 1.9–2.1, ensuring good binding properties and durability.

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**Question 10: Match List I with List II.**

| List I (Natural Amino Acid) | List II (One Letter Code) |
|---|---|
| A. Glutamic acid | I. Q |
| B. Glutamine | II. W |
| C. Tyrosine | III. E |
| D. Tryptophan | IV. Y |

Choose the correct answer from the options given below:

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

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

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

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

**Correct Answer:** (1)

**Solution:** The single-letter codes for natural amino acids are used as shorthand for their identification. Here is the reasoning:

Glutamic acid: Its single-letter code is E due to its structure and classification as an acidic amino acid.

Glutamine: Its single-letter code is Q, as it is a derivative of glutamic acid with an amide group.

Tyrosine: Its single-letter code is Y, classified as an aromatic amino acid due to the presence of a phenol group.

Tryptophan: Its single-letter code is W, an aromatic amino acid with an indole group.

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

Thus, the correct answer is option (1).

**Quick Tip**

Remember the single-letter codes of amino acids for quick identification. Practice with mnemonics to remember these codes easily.

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**Question 11: Which of the following have the same number of significant figures?**

(A) 0.00253

(B) 1.0003

(C) 15.0

(D) 163

Choose the correct answer from the options given below:

(1) B and C only

(2) A, B and C only

(3) A, C and D only

(4) C and D only

**Correct Answer:** (3)

**Solution:** Significant figures represent all the digits in a number that are meaningful in terms of precision. They include all non-zero digits, zeros between non-zero digits, and trailing zeros in decimal numbers. Here is the breakdown:

0.00253: Contains 3 significant figures (leading zeros are not counted).

1.0003: Contains 5 significant figures (includes all digits, including zeros between non-zero digits).

15.0: Contains 3 significant figures (the trailing zero is significant in decimal numbers).

163: Contains 3 significant figures (all digits are non-zero).

Thus, 0.00253 (option A), 15.0 (option C), and 163 (option D) all have the same number of significant figures, which is 3.

Therefore, the correct answer is option (3).

**Quick Tip**

Significant figures include all meaningful digits in a number. Use the rules for counting significant figures carefully, especially for decimals and trailing zeros.

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**Question 12: Given below are two statements:**

**Statement I:** Methyl orange is a weak acid.

**Statement II:** The benzenoid form of methyl orange is more intense/deeply coloured than the quinonoid form.

In the light of the above statements, choose the most appropriate answer from the options given below:

(1) Both Statement I and Statement II are incorrect

(2) Both Statement I and Statement II are correct

(3) Statement I is correct but Statement II is incorrect

(4) Statement I is incorrect but Statement II is correct

**Correct Answer:** (1)

**Solution: Statement I:** Methyl orange is not a weak acid; it is an acid-base indicator that exists in different structural forms depending on the pH of the solution. In acidic solutions, it exists in its protonated form, while in basic solutions, it undergoes deprotonation to form a

conjugate base. Therefore, Statement I is incorrect.

**Statement II:** The color intensity of methyl orange depends on its structural form. The quinonoid form of methyl orange is more intensely or deeply colored than its benzenoid form. The quinonoid form is responsible for the orange/red coloration in acidic media, while the benzenoid form contributes to the yellow coloration in basic media. Since the question incorrectly states that the benzenoid form is more intensely colored, Statement II is also incorrect. Since both Statement I and Statement II are incorrect, the correct answer is option (1).

**Quick Tip**

Acid-base indicators like methyl orange change color due to structural transformations between their benzenoid and quinonoid forms. The quinonoid form is generally more deeply colored.

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**Question 13: The descending order of acidity for the following carboxylic acids is –**

A. $CH_3COOH$

B. $F_3C–COOH$

C. $ClCH_2–COOH$

D. $BrCH_2–COOH$

Choose the correct answer from the options given below:

(1) D > B > A > E > C

(2) B > D > C > E > A

(3) E > D > B > A > C

(4) B > C > D > E > A

**Correct Answer:** (2)

**Solution:**

The acidity of carboxylic acids is directly proportional to the stability of the conjugate base. The presence of electron-withdrawing groups enhances the stability of the conjugate base by delocalizing the negative charge. The stability order of the conjugate bases is as follows:

$$F_3C–COO > F–CH_2–COO > Cl–CH_2–COO > Br–CH_2–COO > CH_3–COO$$

This translates to the following acidity order:

$$F_3C–COOH\ (B) > ClCH_2–COOH\ (C) > BrCH_2–COOH\ (D) > CH_3COOH\ (A)$$

Hence, the correct answer is option (2).

**Quick Tip**

The more electronegative and closer the electron-withdrawing group is to the carboxyl group, the stronger the acid becomes.

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**Question 14: In the Hall-Héroult process, the following is used for reducing $Al_2O_3$:**

(1) Magnesium

(2) Graphite

(3) $Na_3AlF_6$

(4) $CaF_2$

**Correct Answer:** (2)

**Solution:** In the Hall-Héroult process, aluminum oxide ($Al_2O_3$) is electrolyzed to produce aluminum. Graphite serves as the anode material, where oxygen gas is released, while the cathode is where aluminum is deposited. Graphite also acts as a reducing agent in the process by reacting with oxygen.

Thus, the correct answer is option (2).

**Quick Tip**

The Hall-Héroult process is a widely used method for extracting aluminum from its oxide. Graphite not only provides a surface for the reaction but also helps reduce $Al_2O_3$.

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**Question 15: Arrange the following gases in increasing order of van der Waals constant $a$:**

A. Ar

B. $CH_4$

C. $H_2O$

D. $C_6H_6$

Choose the correct answer from the options given below:

(1) A, B, C and D

(2) B, C, D and A

(3) C, D, B and A

(4) D, C, B and A

**Correct Answer:** (1)

**Solution:** The van der Waals constant $a$ represents the magnitude of intermolecular attractive forces. It increases with molecular size, molecular mass, and the presence of hydrogen bonding. Let us analyze the given gases:

1. Argon (Ar): Being a noble gas, Ar has the weakest intermolecular forces and the lowest value of $a$.

2. Methane ($CH_4$): $CH_4$ has stronger London dispersion forces than Ar due to its larger molecular size.

3. Water ($H_2O$): $H_2O$ has significant hydrogen bonding, increasing its $a$ value further.

4.Benzene($C_6H_6$):$C_6H_6$ is a large aromatic molecule with strong dispersion forces, giving it the highest $a$ value among the given gases.

Thus, the increasing order of $a$ is:

$$\text{Ar (A)} < CH_4 \text{ (B)} < H_2O \text{ (C)} < C_6H_6 \text{ (D)}.$$

**Quick Tip**

Van der Waals constant $a$ is proportional to the strength of intermolecular forces. Hydrogen bonding and larger molecular size significantly increase the value of $a$.

**Question 16: Given below are two statements:**

**Statement I:** In redox titration, the indicators used are sensitive to change in pH of the solution.

**Statement II:** In acid-base titration, the indicators used are sensitive to change in oxidation potential.

In the light of the above statements, choose the most appropriate answer from the options given below:

(1) Both Statement I and Statement II are incorrect

(2) Statement I is incorrect but Statement II is correct

(3) Statement I is correct but Statement II is incorrect

(4) Both Statement I and Statement II are correct

**Correct Answer:** (1)

**Solution:** Statement I Analysis:

Redox titration indicators, such as starch or ferroin, are sensitive to changes in oxidation potential, not pH. Hence, Statement I is incorrect.

Statement II Analysis:

In acid-base titration, indicators like phenolphthalein and methyl orange respond to changes in pH, not oxidation potential. Thus, Statement II is also incorrect.

Since both statements are incorrect, the correct answer is option (1).

**Quick Tip**

Understand the role of indicators in titrations. Acid-base indicators respond to pH changes, while redox indicators respond to oxidation potential changes.

---

**Question 17: Which of the following can reduce decomposition of $H_2O_2$ on exposure to light?**

(1) Dust

(2) Urea

(3) Glass containers

(4) Alkali

**Correct Answer:** (2)

**Solution:** Hydrogen peroxide ($H_2O_2$) decomposes readily in the presence of light, heat, and impurities like dust or alkali. Urea acts as a stabilizer for hydrogen peroxide by forming a complex that reduces the rate of decomposition.

Analysis of options:

1. Dust: Catalyzes the decomposition of $H_2O_2$.
2. Urea:Stabilizes $H_2O_2$ and reduces its decomposition.
3. Glass containers: Do not actively stabilize $H_2O_2$.
4. Alkali: Increases the decomposition rate of $H_2O_2$.

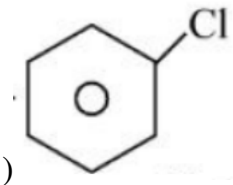
Hence, the correct answer is option (2).

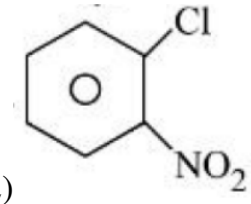
**Quick Tip**

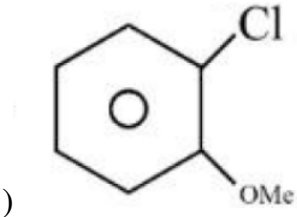
Store $H_2O_2$ in cool, dark places and stabilize it with compounds like urea to prevent decomposition.

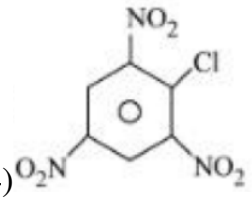
---

**Question 18: The correct order of reactivity of the following haloarenes towards nucleophilic substitution with aqueous NaOH is:**

(1) 


(2) 


(3) 

(4) 

Choose the correct answer from the options given below:

(1) D > B > A > C

(2) A > B > D > C

(3) C > A > D > B

(4) D > C > B > A

**Correct Answer:** (1)

**Solution:** The nucleophilic substitution reaction in haloarenes depends on the presence of electron-withdrawing groups, which stabilize the negative charge formed during the transition state or intermediate.

Compound D contains two nitro ($-NO_2$) groups at ortho and para positions. These strongly electron-withdrawing groups significantly stabilize the intermediate formed during nucleophilic substitution, making D the most reactive.

Compound B has a single nitro group at the para position. The electron-withdrawing nature of the $-NO_2$ group enhances the reactivity towards nucleophilic substitution but is less effective than D.

Compound A does not have any electron-withdrawing groups. Its reactivity is due solely to the halogen (chlorine) attached to the aromatic ring, which is less favorable for nucleophilic substitution.

Compound C has a methoxy ($-OCH_3$) group, which is an electron-donating group. It destabilizes the intermediate, making C the least reactive of the four.

The correct order of reactivity is:

$$\text{D} > \text{B} > \text{A} > \text{C}.$$

Quick Tip

Electron-withdrawing groups like $-NO_2$ enhance the reactivity of haloarenes towards nucleophilic substitution, while electron-donating groups like $-OCH_3$ reduce the reactivity.

---

**Question 19: A compound 'X' when treated with phthalic anhydride in the presence of concentrated $H_2SO_4$, yields 'Y'. 'Y' is used as an acid-base indicator. 'X' and 'Y' are respectively:**

(1) Anisole, methyl orange

(2) Toluidine, Phenolphthalein

(3) Carbolic acid, Phenolphthalein

(4) Salicylaldehyde, Phenolphthalein

**Correct Answer:** (3)

**Solution:** The reaction between a compound and phthalic anhydride in the presence of concentrated sulfuric acid ($H_2SO_4$) leads to the formation of various derivatives depending on the starting compound. Phenolphthalein is formed when carbolic acid (phenol) reacts with phthalic anhydride.

Reaction Mechanism: Phenol reacts with phthalic anhydride in an electrophilic aromatic substitution reaction catalyzed by concentrated sulfuric acid. This results in the formation of phenolphthalein, which is a widely used acid-base indicator.

Analysis of options:

1.Anisole, methyl orange: Incorrect, as methyl orange is formed by a different reaction pathway involving sulfonation of dimethylaniline, not phthalic anhydride.

2. Toluidine, Phenolphthalein: Incorrect, as toluidine does not react with phthalic anhydride to yield phenolphthalein.

3. Carbolic acid, Phenolphthalein: Correct, as carbolic acid (phenol) reacts with phthalic anhydride to produce phenolphthalein.

4. Salicylaldehyde, Phenolphthalein: Incorrect, as salicylaldehyde reacts with phthalic anhydride to form other derivatives, not phenolphthalein.

Thus, the correct answer is option (3).

**Quick Tip**

Phenolphthalein is a common acid-base indicator prepared by reacting phenol with phthalic anhydride in the presence of concentrated $H_2SO_4$.

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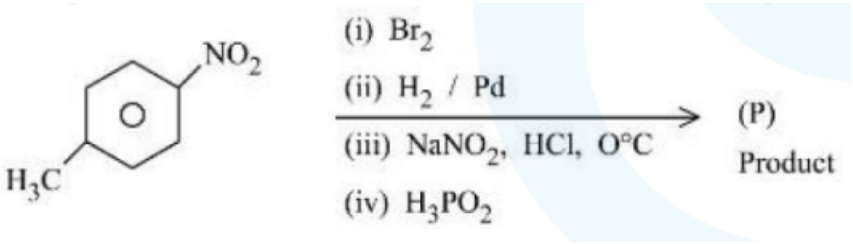
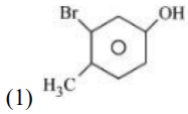
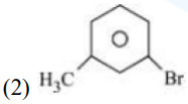
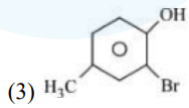
**Question 20: The product (P) formed from the following multistep reaction is:**

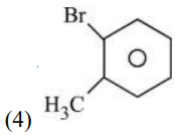



Choose the correct answer from the options given below:

(1) 


(2) 


(3) 


(4) 


**Correct Answer:** (4)

**Solution:** The multistep reaction involves the following transformations:

Step 1: Bromination ($Br_2$): The nitrobenzene derivative undergoes bromination, where the bromine atom attaches to the para position relative to the nitro group due to its electron-withdrawing nature.

Step 2: Reduction ($H_2$/Pd): The nitro group is reduced to an amine group (-$NH_2$), forming a bromoaniline derivative.

Step 3: Diazotization ($NaNO_2$, HCl, 0°C): The amine group reacts with nitrous acid (generated in situ from $NaNO_2$ and HCl), forming a diazonium salt (-$N^+{}_2Cl$).

Step 4: Reduction ($H_3PO_2$): The diazonium group is replaced by hydrogen, yielding the final product where the nitro group is completely removed, and the bromine atom remains attached at the para position relative to the methyl group.

The final product is:

4-bromo-1-methylbenzene (P).

**Quick Tip**

Multistep organic reactions often involve strategic functional group transformations. Understanding the role of each reagent is crucial for predicting the final product.

---

**Question 21: The observed magnetic moment of the complex $[Mn(NCS)_6]^4$ is 6.06 BM. The numerical value of $x$ is:**

**Correct Answer:** 4

**Solution:** The magnetic moment ($\mu$) is related to the number of unpaired electrons ($n$) by the formula:

$$\mu = \sqrt{n(n+2)}\,\text{BM}.$$

Given $\mu = 6.06\,\text{BM}$, solve for $n$:

$$6.06 = \sqrt{n(n+2)}.$$

Squaring both sides:

$$36.72 = n(n+2).$$

This gives $n \approx 5$ (nearest integer).

Since Mn has 5 unpaired electrons, its oxidation state must be $+2$, as follows:

$$Mn^{2+} \implies x = 4.$$

**Quick Tip**

Magnetic moment calculations provide insights into the number of unpaired electrons in coordination complexes.

**Question 22: For the complete combustion of ethane,**

$$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l),$$

**the amount of heat produced as measured in a bomb calorimeter is 1406 kJ mol$^1$ at 300 K. The minimum value of $T\Delta S$ needed to reach equilibrium is:**

**Correct Answer:** 1411 kJ

**Solution:** The thermodynamic relationship is given by:

$$\Delta G = \Delta H - T\Delta S.$$

At equilibrium, $\Delta G = 0$, so:

$$T\Delta S = \Delta H - \Delta n_g RT.$$

Here:

$$\Delta H = -1406\,\text{kJ mol}^1, \quad R = 8.3\,\text{J K}^1\,\text{mol}^1, \quad T = 300\,\text{K}.$$

First, calculate $\Delta n_g$:

$$\Delta n_g = \text{moles of gaseous products} - \text{moles of gaseous reactants}.$$

From the reaction:

$$\Delta n_g = 2 - \frac{7}{2} = -\frac{3}{2}.$$

Substitute values into the equation for $T\Delta S$:

$$T\Delta S = -1406 + \Delta n_g RT.$$

Convert $R$ to kJ to match units:

$$R = 8.3\,\text{J K}^1\,\text{mol}^1 = 0.0083\,\text{kJ K}^1\,\text{mol}^1.$$

Now substitute values:

$$T\Delta S = -1406 + \left(-\frac{3}{2} \cdot 0.0083 \cdot 300\right).$$

Simplify:

$$T\Delta S = -1406 + (-3.735) \approx -1409.735\,\text{kJ}.$$

Round to the nearest integer:

$$T\Delta S \approx 1411\,\text{kJ}.$$

Thus, the minimum value of $T\Delta S$ needed to reach equilibrium is:

**1411 kJ**.

**Quick Tip**

Always include the $\Delta n_g RT$ correction term in bomb calorimetry problems when calculating thermodynamic equilibrium parameters.

---

**Question 23: The solubility product of $BaSO_4$ is $1 \times 10^{-10}$ at 298 K. The solubility of $BaSO_4$ in 0.1 M $K_2SO_4$(aq) is $x \times 10^{-9}$ g $L^1$. Calculate the value of $x$.**

**Correct Answer:** 233

**Solution:**

Given:

$$K_{sp} = [\text{Ba}^{2+}][\text{SO}_4{}^{2-}] = 1 \times 10^{-10}.$$

Let the solubility of $BaSO_4$ in 0.1 M $K_2SO_4$ be $x$. Since the concentration of $SO_4{}^2$ is dominated by the dissociation of $K_2SO_4$, we approximate:

$$[\text{SO}_4{}^{2-}] \approx 0.1.$$

From the solubility equilibrium:

$$[\text{Ba}^{2+}] = \frac{K_{sp}}{[\text{SO}_4{}^{2-}]} = \frac{1 \times 10^{-10}}{0.1} = 1 \times 10^{-9}\,\text{mol L}^1.$$

The molar mass of $BaSO_4$ is $233\,\text{g mol}^1$. Thus, the solubility in grams per liter is:

$$\text{Solubility} = (1 \times 10^{-9}) \times 233 = 233 \times 10^{-9}\,\text{g L}^1.$$

Hence, $x = 233$.

**Quick Tip**

In the presence of a common ion, the solubility of sparingly soluble salts decreases significantly.

**Question 24: The number of atomic orbitals from the following having 5 radial nodes is:**

**7s, 7p, 6s, 6p, 8d.**

**Correct Answer:** 3

**Solution:** The number of radial nodes for an atomic orbital is calculated as:

$$\text{Radial nodes} = n - \ell - 1,$$

where $n$ is the principal quantum number, and $\ell$ is the azimuthal quantum number.

1. For 6s:

$$n = 6,\ \ell = 0.$$

Radial nodes = $6 - 0 - 1 = 5$.

2. For 7p:

$$n = 7,\ \ell = 1.$$

Radial nodes = $7 - 1 - 1 = 5$.

3. For 8d:

$$n = 8,\ \ell = 2.$$

Radial nodes = $8 - 2 - 1 = 5$.

4. For 7s:

$$n = 7,\ \ell = 0.$$

Radial nodes = $7 - 0 - 1 = 6$.

5. For 8p:

$$n = 8,\ \ell = 1.$$

Radial nodes = $8 - 1 - 1 = 6$.

The orbitals with 5 radial nodes are:

$$6s,\ 7p,\ 8d.$$

Thus, the total number of atomic orbitals with 5 radial nodes is:

**3**.

**Quick Tip**

Radial nodes depend on both the principal quantum number ($n$) and the azimuthal quantum number ($\ell$). Larger $n$ values increase the number of nodes.

---

**Question 25: The number of incorrect statements from the following is:**

1. The electrical work that a reaction can perform at constant pressure and temperature is equal to the reaction Gibbs energy.

2. $E^\circ_{\text{cell}}$ is dependent on the pressure.

3. $\frac{dE^\circ_{\text{cell}}}{dT} = \frac{\Delta S^\circ}{nF}$.

4. A cell is operating reversibly if the cell potential is exactly balanced by an opposing source of potential difference.

**Correct Answer:** 1

**Solution:** 1. The first statement is correct because, under constant pressure and temperature, the electrical work of a reaction equals the Gibbs free energy ($\Delta G$).

2. The second statement is incorrect. The standard cell potential ($E^\circ_{\text{cell}}$) is defined under standard conditions (1 atm pressure, 298 K), so it is not dependent on pressure.

3. The third statement is correct, as the relationship between $E^\circ_{\text{cell}}$ and temperature involves entropy ($\Delta S^\circ$):

$$\frac{dE^\circ_{\text{cell}}}{dT} = \frac{\Delta S^\circ}{nF}.$$

4. The fourth statement is correct, as a cell operates reversibly when its potential is perfectly balanced by an opposing source of potential difference.

Thus, there is 1 incorrect statement (Statement 2).

**Quick Tip**

Carefully evaluate each statement in electrochemistry questions to determine its validity based on thermodynamic and standard definitions.

---

**Question 26: The coagulating value of the electrolytes $AlCl_3$ and NaCl for $As_2S_3$ are 0.09 and 50.04, respectively. The coagulating power of $AlCl_3$ is $x$ times the coagulating power of NaCl. The value of $x$ is:**

**Correct Answer:** 556

**Solution:** The coagulating power of an electrolyte is inversely proportional to its coagulating value:

$$\text{Coagulating power} \propto \frac{1}{\text{Coagulating value}}.$$

For $AlCl_3$ and NaCl:

$$\frac{(\text{Coagulating power of } AlCl_3)}{(\text{Coagulating power of NaCl})} = \frac{(\text{Coagulating value of NaCl})}{(\text{Coagulating value of } AlCl_3)}.$$

Substitute the given values:

$$\frac{(\text{Coagulating power of } AlCl_3)}{(\text{Coagulating power of NaCl})} = \frac{50.04}{0.09}.$$

Simplify:

$$x = \frac{50.04}{0.09} = 556.$$

Thus, the coagulating power of $AlCl_3$ is 556 times that of NaCl.

**Quick Tip**

Coagulating power is inversely proportional to coagulating value, and higher charge density of ions increases coagulating efficiency.

---

**Question 27: If the boiling points of two solvents X and Y (having the same molecular weights) are in the ratio 2:1, and their enthalpy of vaporizations are in the ratio 1:2, then the boiling point elevation constant of X is $m$ times the boiling point elevation constant of Y. The value of $m$ is:**

**Correct Answer:** 8

**Solution:** The boiling point elevation constant ($K_b$) is given by:

$$K_b = \frac{RT_b^2 M}{1000 \Delta H_{\text{vap}}},$$

where:

$R$ is the universal gas constant,

$T_b$ is the boiling point,

$M$ is the molecular weight,

$\Delta H_{\text{vap}}$ is the enthalpy of vaporization.

For solvents X and Y, taking the ratio of their boiling point elevation constants:

$$\frac{(K_b)_X}{(K_b)_Y} = \frac{\left(\frac{RT_b^2 M}{\Delta H_{\text{vap}}}\right)_X}{\left(\frac{RT_b^2 M}{\Delta H_{\text{vap}}}\right)_Y}.$$

Simplify:

$$\frac{(K_b)_X}{(K_b)_Y} = \frac{\left(T_b^2\right)_X}{\left(T_b^2\right)_Y} \times \frac{\left(\Delta H_{\text{vap}}\right)_Y}{\left(\Delta H_{\text{vap}}\right)_X}.$$

Substitute the given ratios:

$$\frac{(T_b)_X}{(T_b)_Y} = 2, \quad \frac{\left(\Delta H_{\text{vap}}\right)_X}{\left(\Delta H_{\text{vap}}\right)_Y} = \frac{1}{2}.$$

So:

$$\frac{(K_b)_X}{(K_b)_Y} = \frac{(2^2)}{1^2} \times \frac{2}{1} = \frac{8}{1}.$$

Hence, $m = 8$.

**Quick Tip**

The boiling point elevation constant depends on both the square of the boiling point and the inverse of the enthalpy of vaporization.

---

**Question 28: The number of species from the following carrying a single lone pair on the central atom Xenon is:**

Given species: $XeF_5^+$, $XeO_3$, $XeO_2F_2$, $XeF_5$, $XeO_3F_2$, $XeOF_4$, $XeF_4$.

**Correct Answer:** 4

**Solution:** To determine the number of lone pairs on the central atom Xenon (Xe), use VSEPR theory to calculate lone pairs for each species:

1. $XeF_5^+$: Xenon has 8 valence electrons. It forms 5 bonds with fluorine, and 1 electron is removed due to the positive charge. Lone pairs = $8 - 5 - 1 = 2$ (not a single lone pair).

2. $XeO_3$: Xenon forms 3 bonds with oxygen atoms. Lone pairs = $8 - 6 = 2$ (not a single lone pair).

3. $XeO_2F_2$: Xenon forms 4 bonds (2 with oxygen and 2 with fluorine). Lone pairs = $8 - 4 = 1$ (single lone pair).

4. $XeF_5$: Xenon forms 5 bonds with fluorine atoms. One extra electron is added due to the negative charge. Lone pairs = $8 - 5 + 1 = 2$ (not a single lone pair).

5. $XeO_3F_2$: Xenon forms 5 bonds (3 with oxygen and 2 with fluorine). Lone pairs = $8 - 5 = 1$ (single lone pair).

6. $XeOF_4$: Xenon forms 5 bonds (1 with oxygen and 4 with fluorine). Lone pairs = $8 - 5 = 1$ (single lone pair).

7. $XeF_4$: Xenon forms 4 bonds with fluorine atoms. Lone pairs = $8 - 4 = 2$ (not a single lone pair).

The species with a single lone pair are:

$$XeO_2F_2, XeO_3F_2, XeOF_4, XeF_5.$$

Thus, the total number of such species is:

**4**.

**Quick Tip**

Lone pairs are calculated using the formula:

Lone pairs = Valence electrons on Xe − Bonding electrons (shared) − Extra electrons.

---

**Question 29: The ratio of sigma and pi bonds present in pyrophosphoric acid is:**

**Correct Answer:** 6

**Solution:** The structure of pyrophosphoric acid ($H_4P_2O_7$) is as follows:

O=P-O-P=O structure with terminal hydroxyl groups (OH).

To determine the ratio of sigma ($\sigma$) and pi ($\pi$) bonds:

Each single bond (P-O and O-H) is a sigma bond.

Each double bond (P=O) consists of 1 sigma bond and 1 pi bond.

Count the bonds in the structure:

Total sigma bonds: 12 (8 single P-O and O-H bonds + 4 sigma components from P=O bonds).

Total pi bonds: 2 (from P=O bonds).

The ratio of sigma to pi bonds is:

$$\frac{\sigma}{\pi} = \frac{12}{2} = 6.$$

Thus, the ratio of sigma and pi bonds is:

**6**.

**Quick Tip**

In polyatomic structures, count sigma and pi bonds systematically by identifying single and double bonds.

---

**Question 30: The sum of oxidation states of the metals in $Fe(CO)_5$, $VO^{2+}$, and $WO_3$ is:**

**Correct Answer:** 10

**Solution:** Calculate the oxidation state of each metal:

1.$Fe(CO)_5$: Carbon monoxide (CO) is a neutral ligand, and the oxidation state of Fe in $Fe(CO)_5$ is:

$$\text{Oxidation state of Fe} = 0.$$

2.$VO^{2+}$: Oxygen has an oxidation state of $-2$. For $VO^{2+}$:

$$x - 2 = +2 \implies x = +4.$$

The oxidation state of V is $+4$.

3.$WO_3$: Each oxygen contributes $-2$, and tungsten (W) has:

$$x + (-2 \times 3) = 0 \implies x = +6.$$

The oxidation state of W is $+6$.

Now sum the oxidation states:

$$0 + 4 + 6 = 10.$$

Thus, the total sum of oxidation states is:

**10**.

**Quick Tip**

To calculate oxidation states in coordination complexes, consider the charge of ligands and the net charge of the compound.

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