

JEE Main 2023 April 15 Shift 1 Question Paper with Solutions

Time Allowed :3 Hours

Maximum Marks :300

Total Questions :90

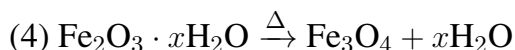
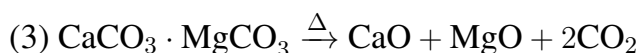
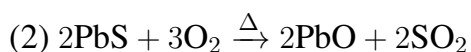
General Instructions

Read the following instructions very carefully and strictly follow them:

1. The test is of 3 hours duration.
2. The question paper consists of 90 questions, out of which 75 are to attempted.
The maximum marks are 300.
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.
 - (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

(Chemistry) Section-A

1. Which one of the following is not an example of calcination?



Correct Answer: (2)

Solution: Calcination is a process in which an ore is heated to high temperature in the

absence or limited supply of air. This leads to the decomposition of the ore, typically releasing volatile components such as water or carbon dioxide.

- In the reaction $\text{CaCO}_3 \xrightarrow{\Delta} \text{CaO} + \text{CO}_2$, calcium carbonate is heated to produce calcium oxide and carbon dioxide, which is a classic example of calcination.

- In the reaction $2\text{PbS} + 3\text{O}_2 \xrightarrow{\Delta} 2\text{PbO} + 2\text{SO}_2$, lead sulfide is oxidized, which is an oxidation reaction, not calcination.

- The reaction $\text{CaCO}_3 \cdot \text{MgCO}_3 \xrightarrow{\Delta} \text{CaO} + \text{MgO} + 2\text{CO}_2$ is a calcination reaction, as it involves heating the carbonate to produce oxides and release carbon dioxide.

- In the reaction $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O} \xrightarrow{\Delta} \text{Fe}_3\text{O}_4 + x\text{H}_2\text{O}$, water is driven off from iron ore, which is another example of calcination.

Thus, option (2) is not an example of calcination.

Quick Tip

Calcination specifically refers to the thermal decomposition of an ore, often to remove water or carbon dioxide. Oxidation reactions like the one in option (2) are not classified as calcination.

2. During water-gas shift reaction

(1) Water is evaporated in presence of catalyst.

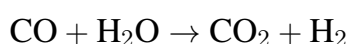
(2) Carbon monoxide is oxidized to carbon dioxide.

(3) Carbon is oxidized to carbon monoxide.

(4) Carbon dioxide is reduced to carbon monoxide.

Correct Answer: (2)

Solution: The water-gas shift reaction is given by:

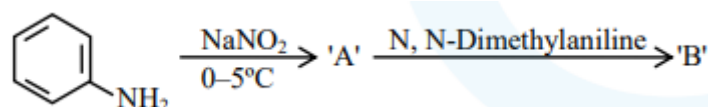


This is a reaction in which carbon monoxide reacts with water to produce carbon dioxide and hydrogen. The correct statement from the options is that carbon monoxide is oxidized to carbon dioxide, making option (2) the right choice.

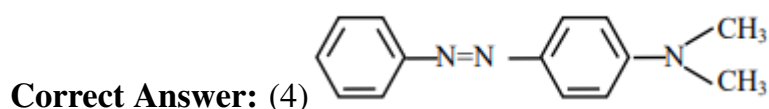
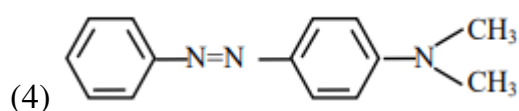
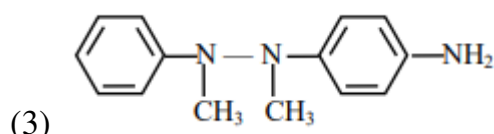
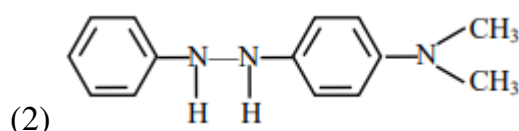
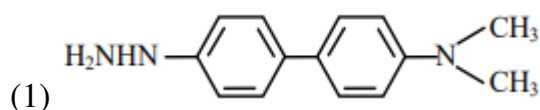
Quick Tip

In the water-gas shift reaction, carbon monoxide reacts with water to produce carbon dioxide and hydrogen, which is an important industrial reaction used in hydrogen production.

3. Consider the following sequence of reaction:



The product *B* is:



Solution: In the first step, aniline $C_6H_5NH_2$ reacts with sodium nitrite $NaNO_2$ at 0°C to form diazonium salt $C_6H_5N_2^+$.

In the second step, the reaction proceeds to form N, N-dimethylaniline. This reaction involves the introduction of a methyl group (CH_3) to the nitrogen of the diazonium salt, producing the product $\text{N} = \text{NC}_6\text{H}_5$, making option (4) the correct answer.

Quick Tip

When preparing diazonium salts, be sure to control temperature and reactants carefully. The formation of N, N-dimethylaniline involves nucleophilic substitution on the diazonium ion.

4. Given below are two statements: One is labeled as Assertion A and the other is labeled as Reason R:

Assertion (A): $BeCl_2$ and $MgCl_2$ Produce characteristic flame

Reason (R): The excitation energy is high in $BeCl_2$ and $MgCl_2$

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

- (1) (A) is False but (R) is true
- (2) Both (A) and (R) are true and (R) is the correct explanation of (A)
- (3) Both (A) and (R) are true but (R) is NOT the correct explanation of (A)
- (4) (A) is true but (R) is false

Correct Answer: (1)

Solution:

Assertion (A) is false because beryllium and magnesium do not impart characteristic color to the flame.

Reason (R) is true because the excitation energy in $BeCl_2$ and $MgCl_2$ is indeed high.

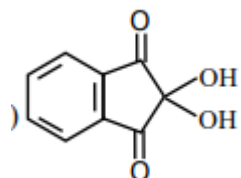
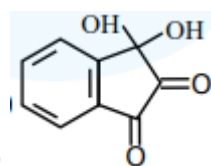
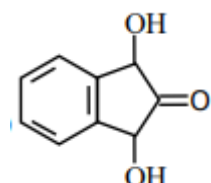
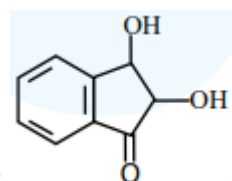
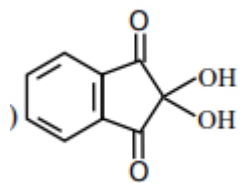
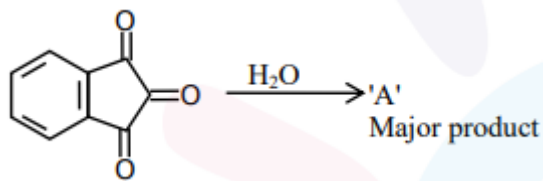
However, this is not the reason why they do not produce characteristic flames.

Hence, the correct answer is (1).

Quick Tip

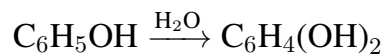
When considering flame colors in metal salts, remember that metals like beryllium and magnesium have high ionization energies and do not produce characteristic flame colors.

5. 'A' formed in the above reaction is:



Correct Answer: (1)

Solution: The reaction involves phenol undergoing hydration with water to form a hydrogen-bonded intermediate. The product A formed in this reaction is the ortho-hydroxyphenol.



The reaction forms ortho-hydroxyphenol, which is the major product. Hence, the correct answer is option (1).

Quick Tip

In reactions involving phenols and water, ortho-hydroxyphenols are often formed due to hydrogen bonding interactions.

6. For a good quality cement, the ratio of silica to alumina is found to be

- (1) 2
- (2) 3
- (3) 4.5
- (4) 1.5

Correct Answer: (3) 4.5

Solution: The ratio of silica to alumina for a good quality cement should be between 2.5 to 4:1. This ensures proper setting and strength of the cement. Hence, the correct answer is 4.5.

Quick Tip

For good quality cement, the ideal ratio of silica to alumina is between 2.5:1 and 4:1.

7. Which of the following expressions is correct in case of a CaCl unit cell (edge length 'a')?

- (1) $r_{cs} + r_{cr} = \frac{a}{\sqrt{2}}$
- (2) $r_{cs} + r_{cr} = a$
- (3) $r_{cs} + r_{cr} = \frac{\sqrt{3}}{2}a$
- (4) $r_{cs} + r_{cr} = \frac{a}{2}$

Correct Answer: (3)

Solution: In a CaCl unit cell, the Ca^{2+} ions are present at the body center and the Cl^{-} ions are present at the corners of the unit cell. The distance between the center and corner ions is given by the expression $\frac{\sqrt{3}}{2}a$.

Thus, the correct relation is $r_{cs} + r_{cr} = \frac{\sqrt{3}}{2}a$.

Quick Tip

For CaCl unit cells, the distance between the ions at the body center and the corners is derived from the geometric properties of the cell and is $\frac{\sqrt{3}}{2}a$.

8. Given below are two statements:

Statement I: According to Bohr's model of hydrogen atom, the angular momentum of an electron in a given stationary state is quantised.

Statement II: The concept of electron in Bohr's orbit violates the Heisenberg uncertainty principle.

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

- (1) Statement I is correct but Statement II is incorrect
- (2) Both Statement I and Statement II are incorrect
- (3) Statement I is incorrect but Statement II is correct
- (4) Both Statement I and Statement II are correct

Correct Answer: (1) Statement I is correct but Statement II is incorrect

Solution: According to Bohr's model, the angular momentum of an electron is quantised and given by:

$$L = \frac{nh}{2\pi}$$

where n is an integer (quantum number) and h is Planck's constant. Thus, Statement I is correct.

However, the concept of an electron in Bohr's orbit does not violate the Heisenberg uncertainty principle. The uncertainty principle does apply in quantum mechanics, but Bohr's model was developed before the full understanding of this principle. In Bohr's model, the electron's position and momentum are considered precisely, which is against the spirit of the Heisenberg uncertainty principle. Hence, Statement II is incorrect.

Quick Tip

Bohr's model of the atom, while explaining discrete energy levels, does not incorporate the Heisenberg uncertainty principle, which is central in modern quantum mechanics.

9. In the above conversion the correct sequence of reagents to be added is:

- (1) Br_2/Fe , (ii) Fe/H^+ , (iii) KMnO_4 , (iv) Cl_2
(2) (i) Br_2/Fe , (ii) Fe/H^+ , (iii) HONO, (iv) CuCl , (v) KMnO_4
(3) (i) Fe/H^+ , (ii) HONO, (iii) CuCl , (iv) KMnO_4 , (v) Br_2
(4) (i) KMnO_4 , (ii) Br_2/Fe , (iii) Fe/H^+ , (iv) Cl_2

Correct Answer: (2) (i) Br_2/Fe , (ii) Fe/H^+ , (iii) HONO, (iv) CuCl , (v) KMnO_4

Solution: The transformation shown in the image is from a nitrobenzene to a chlorobenzoic acid derivative, with a bromine substitution. This involves a series of reactions as follows:

Step 1: First, bromination of nitrobenzene is performed to add a bromine atom on the benzene ring. This can be achieved using bromine (Br_2) in the presence of iron (Fe) to facilitate the electrophilic substitution, resulting in the formation of the brominated intermediate. Hence, the first reagent is Br_2/Fe .

Step 2: Then, the intermediate undergoes reduction by using Fe/H^+ , which reduces the nitro group $-\text{NO}_2$ into an amino group $-\text{NH}_2$.

Step 3: Next, the amino group undergoes oxidation, which is achieved using HONO (nitrous acid), which can effectively oxidize the amine group into a hydroxyl group, converting it into a hydroxy group ($-\text{OH}$).

Step 4: After oxidation, copper chloride (CuCl) is used to introduce the chlorine atom (Cl) at the desired position on the benzene ring.

Step 5: Finally, the transformation into the benzoic acid group occurs using potassium permanganate (KMnO_4) as the oxidizing agent, which further oxidizes the remaining group to the carboxylic acid ($-\text{COOH}$) group.

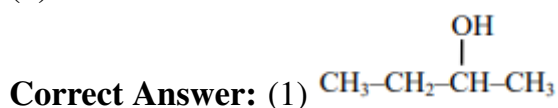
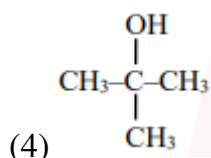
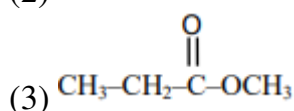
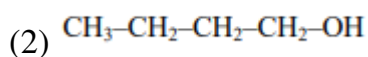
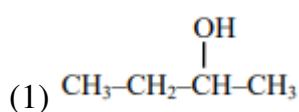
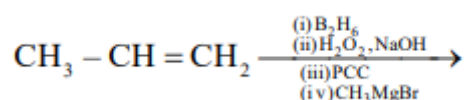
Therefore, the correct sequence of reagents is:

- (i) Br_2/Fe , (ii) Fe/H^+ , (iii) HONO, (iv) CuCl , (v) KMnO_4

Quick Tip

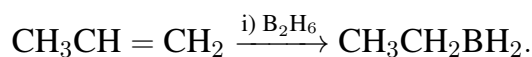
For reactions involving electrophilic substitution and reduction, be sure to understand the reactivity of the functional groups. Bromine and iron are used in the initial stages for substitution, followed by selective reductions and oxidations using reagents like Fe^+/H^+ , KMnO_4 , and HONO .

10. The product formed in the following multistep reaction is:

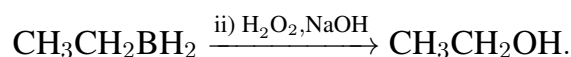


Solution:

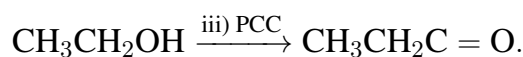
Step 1: The reaction starts with the alkene $\text{CH}_3\text{CH} = \text{CH}_2$ undergoing hydroboration with B_2H_6 (diborane), which adds a boron atom across the double bond in an anti-Markovnikov fashion, resulting in an alkylborane intermediate:



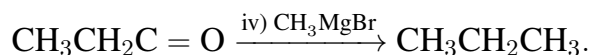
Step 2: Oxidation of the alkylborane with H_2O_2 and NaOH converts the boron group to a hydroxyl group, yielding an alcohol:



Step 3: The PCC (Pyridinium chlorochromate) oxidizes the alcohol to an aldehyde:



Step 4: Finally, treatment with CH_3MgBr (methyl magnesium bromide, a Grignard reagent) results in a nucleophilic attack, converting the aldehyde into a secondary alcohol, which is the final product:



Thus, the product formed is $\text{CH}_3\text{CH}_2\text{CH}_3$.

Quick Tip

For multi-step organic reactions, track each functional group transformation and use the appropriate reagents for each step. In this case, the hydroboration-oxidation sequence adds an alcohol group, while PCC oxidizes it to an aldehyde, which is finally reduced by a Grignard reagent.

11. The possibility of photochemical smog formation will be minimum at:

- (1) Srinagar, Jammu and Kashmir in January
- (2) New Delhi in August (Summer)
- (3) Kolkata in October
- (4) Mumbai in May

Correct Answer: (1) Srinagar, Jammu and Kashmir in January

Solution: Photochemical smog is produced when sunlight reacts with nitrogen oxides and hydrocarbons. The smog formation is affected by temperature and sunlight intensity. In areas with lower temperatures and less sunlight, the formation of photochemical smog is minimized. Srinagar, Jammu and Kashmir experiences cold temperatures in January, which leads to reduced sunlight intensity and lower chances of photochemical smog formation. Therefore, the correct answer is (1) Srinagar, Jammu and Kashmir in January.

Quick Tip

Photochemical smog formation is minimized during winter months in regions with low temperatures and lower sunlight intensity, such as Srinagar during January.

12. Consider the following statements:

- (A) NF_3 molecule has a trigonal planar structure.
- (B) Bond length of N_2 is shorter than O_2 .
- (C) Isoelectronic molecules or ions have identical bond order.
- (D) Dipole moment of HS is higher than that of water molecule.

Choose the correct answer from the options given below:

- (1) (A) and (B) are correct
- (2) (C) and (D) are correct
- (3) (B) and (C) are correct
- (4) (A) and (D) are correct

Correct Answer: (3) (B) and (C) are correct

Solution:

- Statement (A) is incorrect: NF_3 has a trigonal pyramidal structure, not planar.
 - Statement (B) is correct: N_2 has a shorter bond length than O_2 because N_2 has a stronger triple bond.
 - Statement (C) is correct: Isoelectronic molecules or ions have the same number of electrons and hence the same bond order.
 - Statement (D) is incorrect: The dipole moment of HS is less than that of water because water has a highly electronegative oxygen atom, leading to a significant dipole moment.
- Thus, (B) and (C) are correct.

Quick Tip

For isoelectronic species, the bond order is often the same due to identical electron configurations, which influences their chemical behavior.

13. The number of P–O–P bonds in $\text{H}_4\text{P}_2\text{O}_7$, $(\text{HPO}_3)_3$, and P_4O_{10} are respectively:

- (1) 1, 3, 6
- (2) 0, 3, 6
- (3) 0, 3, 4
- (4) 1, 2, 4

Correct Answer: (1) 1, 3, 6

Solution:

- In $\text{H}_4\text{P}_2\text{O}_7$ (pyrophosphoric acid), there is 1 P–O–P bond.
- In $(\text{HPO}_3)_3$ (phosphoric acid), there are 3 P–O–P bonds.
- In P_4O_{10} (tetraphosphorus decaoxide), there are 6 P–O–P bonds.

Thus, the correct answer is (1) 1, 3, 6.

Quick Tip

To count P–O–P bonds, always examine the structure of the molecule and the connectivity of phosphorus atoms with oxygen bridges.

14. Which is not true for arginine?

- (1) It has high solubility in benzene
- (2) It is associated with more than one pK_a values.
- (3) It is a crystalline solid.
- (4) It has a fairly high melting point.

Correct Answer: (1) It has high solubility in benzene.

Solution: Arginine is a zwitterion (a molecule with both positive and negative charges). It is polar, has a high melting point, and is soluble in polar solvents like water, but it does not have high solubility in non-polar solvents such as benzene. Additionally:

- It is a crystalline solid.
- It has 3 pK_a values because it can donate and accept protons due to its amino and carboxyl groups.

Thus, the statement "It has high solubility in benzene" is false.

Quick Tip

Zwitterions are polar molecules that typically dissolve in polar solvents like water and not in non-polar solvents like benzene.

15. The complex with highest magnitude of crystal field splitting energy (Δ_o) is

- (1) $[\text{Mn}(\text{H}_2\text{O})_6]^{3+}$
- (2) $[\text{Fe}(\text{OH}_2)_6]^{3+}$
- (3) $[\text{Cr}(\text{OH}_2)_6]^{3+}$
- (4) $[\text{Ti}(\text{OH}_2)_6]^{3+}$

Correct Answer: (3) $[\text{Cr}(\text{OH}_2)_6]^{3+}$

Solution:

To determine the crystal field splitting energy, we consider the electronic configuration of the metal ion in the complex:

- For Mn^{3+} : $3d^5$, hence the crystal field splitting energy (CFSE) is low.
- For Fe^{3+} : $3d^5$, it has zero CFSE because the electrons fill the orbitals symmetrically.
- For Cr^{3+} : $3d^3$, with a higher CFSE due to less electron-electron repulsion.
- For Ti^{3+} : $3d^1$, having the lowest CFSE due to minimal splitting.

Thus, Cr^{3+} with $3d^3$ configuration has the highest CFSE.

Quick Tip

The crystal field splitting energy increases as the metal ion's d-electron count increases up to a point, where the highest splitting occurs in the middle of the d-block elements.

16. Which of the following statement is correct for paper chromatography?

- (1) Water present in the pores of the paper forms the stationary phase.
- (2) Water present in the mobile phase gets absorbed by the paper which then forms the stationary phase.
- (3) Paper sheet forms the stationary phase.
- (4) Paper and water present in its pores together form the stationary phase.

Correct Answer: (1) Water present in the pores of the paper forms the stationary phase.

Solution: In paper chromatography, the stationary phase is formed by the water present in the pores of the paper, and the mobile phase is typically a solvent that moves through the paper. The analyte moves through the stationary phase at different rates, depending on its interaction with the stationary phase, allowing separation.

Quick Tip

In paper chromatography, the stationary phase is often water retained within the fibers of the paper.

17. Which of the following statement(s) is/are correct?

- (A) The pH of 1×10^{-8} M HCl solution is 8
- (B) The conjugate base of H_2PH_4^+ is HPO_4^{2-}
- (C) K_w increases with increase in temperature.
- (D) When a solution of a weak monoprotic acid is titrated against a strong base at half neutralisation point, $\text{pH} = \frac{1}{2} \text{pK}_a$.
- (1) (A), (B), (C)
- (2) (A), (D)
- (3) (B), (C)
- (4) (B), (C), (D)

Correct Answer: (4) (B), (C), (D)

Solution: - (A) The pH of 1×10^{-8} M HCl is not 8. It is less than 7 because even though it is a very dilute solution, the presence of HCl will contribute to a pH lower than 7 due to the dissociation of water. Hence, this statement is incorrect.

- (B) The conjugate base of H_2PH_4^+ is indeed HPO_4^{2-} . This is correct.

- (C) K_w increases with increasing temperature because the dissociation of water increases at higher temperatures. This is also true.

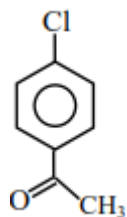
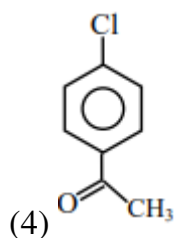
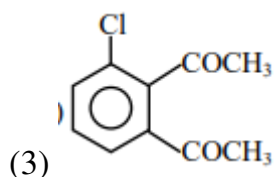
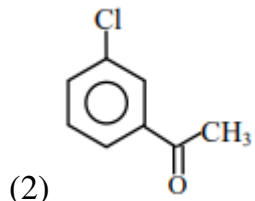
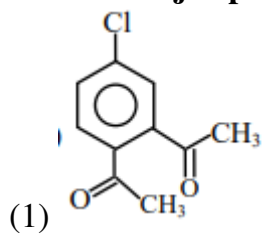
- (D) At the half neutralisation point in a weak monoprotic acid titration with a strong base, the pH equals $\frac{1}{2} \text{pK}_a$, which is a known fact. This is correct.

Thus, the correct statements are (B), (C), and (D).

Quick Tip

At the half-neutralisation point of a weak acid titration, $\text{pH} = \frac{1}{2} \text{pK}_a$.

18. The major product in the Friedel-Craft acylation of chlorobenzene is:



Correct Answer: (4)

Solution: In Friedel-Crafts acylation, acyl groups (RCO) are added to an aromatic ring in the presence of a catalyst like AlCl_3 . Chlorobenzene is an ortho/para-directing group, meaning the acyl group will predominantly attach at the positions ortho and para to the chlorine atom. In this case, the para product is favored due to steric factors, making it the major product.

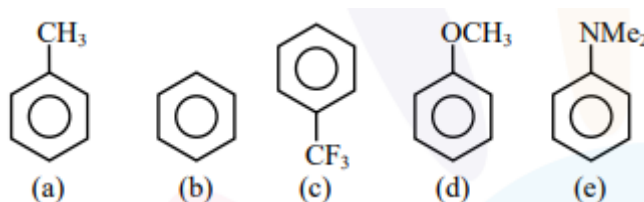
Thus, the major product of the Friedel-Crafts acylation of chlorobenzene is the para product:



Quick Tip

In Friedel-Crafts acylation, the position of the incoming group is influenced by the directing effects of substituents already present on the benzene ring. Chlorine, being an electron-donating group, directs new substituents to the ortho and para positions.

19. Decreasing order of reactivity towards electrophilic substitution for the following compounds is:



- (1) $a > d > e > b > c$
- (2) $c > b > a > d > e$
- (3) $e > d > a > b > c$
- (4) $d > a > e > c > b$

Correct Answer: (3) $e > d > a > b > c$

Solution: In electrophilic aromatic substitution reactions, the reactivity of the compounds is determined by the electron-donating or electron-withdrawing nature of the substituents on the benzene ring.

- Electron-donating groups (EDG) like NMe₂, OCH₃, and CH₃ increase the electron density on the benzene ring, making it more reactive towards electrophilic substitution. These groups direct substitution to the ortho and para positions.

- Electron-withdrawing groups (EWG) like CF₃ decrease the electron density on the benzene ring, making it less reactive towards electrophilic substitution. These groups direct substitution to the meta position.

Order of reactivity based on electron-donating and electron-withdrawing effects:

- NMe₂ (strong electron-donating group) has the highest reactivity.
- OCH₃ (electron-donating group) comes next.
- CH₃ (weak electron-donating group) follows.
- CF₃ (electron-withdrawing group) has the lowest reactivity.

Thus, the decreasing order of reactivity towards electrophilic substitution is:

$$e > d > a > b > c.$$

Quick Tip

Electron-donating groups increase the reactivity of the benzene ring towards electrophilic substitution, while electron-withdrawing groups decrease it. Always consider the nature of the substituent when predicting reactivity.

20. Match List-I with List-II :

Monomer (List-I)	Polymer (List-II)
(A) Tetrafluoroethene	(I) Orlon
(B) Acrylonitrile	(II) Natural rubber
(C) Caprolactam	(III) Teflon
(D) Isoprene	(IV) Nylon-6

Choose the correct answer from the options given below:

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

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

Solution:

The monomers and their corresponding polymers can be matched as follows:

- (A) Tetrafluoroethene polymerizes to form Teflon. The polymerization of Tetrafluoroethene yields Teflon, which is a highly stable polymer.
- (B) Acrylonitrile polymerizes to form Orlon. Orlon is a synthetic fiber made from the polymerization of acrylonitrile.
- (C) Caprolactam is used to form Nylon-6. Nylon-6 is made by polymerizing caprolactam through ring-opening polymerization.
- (D) Isoprene polymerizes to form Natural rubber. Isoprene is the monomer used in the production of natural rubber.

Thus, the correct matching is:

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

Quick Tip

Remember that the polymerization of specific monomers leads to different polymers. Tetrafluoroethene polymerizes to form Teflon, acrylonitrile forms Orlon, caprolactam leads to Nylon-6, and isoprene is used in natural rubber production.

Section - B

21. The homoleptic and octahedral complex of Co^{2+} and H_2O has ____ unpaired electron(s) in the t_{2g} set of orbitals.

Solution:

The electronic configuration of Co^{2+} is $[\text{Ar}]3d^7$. In an octahedral field, the five degenerate d -orbitals split into two sets: e_g and t_{2g} .

The $3d^7$ configuration in an octahedral field will have electrons placed in the t_{2g} and e_g orbitals. In this case, one electron will be unpaired in the t_{2g} orbitals. Therefore, there is 1 unpaired electron in the t_{2g} set.

Quick Tip

In octahedral complexes, the t_{2g} and e_g orbitals split in energy. The number of unpaired electrons in the t_{2g} orbitals depends on the electron configuration and ligand field strength.

22. 30.4 kJ of heat is required to melt one mole of sodium chloride and the entropy change at the melting point is $28.4 \text{ J K}^{-1}\text{mol}^{-1}$ at 1 atm. The melting point of sodium chloride is ____ K. (Nearest Integer)

Solution:

We are given the following data:

- $\Delta H = 30.4 \text{ kJ/mol}$ (Heat required to melt 1 mole of NaCl)

- $\Delta S = 28.4 \text{ J/K}\cdot\text{mol}$ (Entropy change at the melting point)

We can use the formula:

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

At the melting point, $\Delta G = 0$. Therefore, at the melting point:

$$0 = \Delta H - T_m\Delta S$$

Solving for T_m (the melting point temperature):

$$T_m = \frac{\Delta H}{\Delta S} = \frac{30.4 \times 10^3 \text{ J/mol}}{28.4 \text{ J/K}\cdot\text{mol}} = 1070.42 \text{ K}$$

Thus, the melting point of sodium chloride is approximately 1070 K.

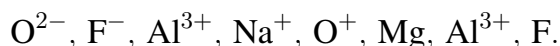
Quick Tip

To calculate the melting point, use the relationship $\Delta H = T\Delta S$, where ΔH is the enthalpy change, and ΔS is the entropy change at the phase transition point.

23. The total number of isoelectronic species from the given set is

Solution:

The given species are:



The number of electrons in each species is as follows:

- O^{2-} has 10 electrons

- F^- has 10 electrons

- Al^{3+} has 10 electrons

- Na^+ has 10 electrons

- O^+ has 9 electrons

- Mg has 10 electrons

- Al^{3+} has 10 electrons

- F has 9 electrons

The isoelectronic species are those with the same number of electrons. The isoelectronic species in the set are: - O^{2-} , F^{-} , Al^{3+} , Na^{+} , Mg , F

Therefore, the total number of isoelectronic species is 5.

Quick Tip

Isoelectronic species have the same number of electrons, but may differ in the number of protons.

24. For a reversible reaction $A \rightleftharpoons B$, the $\Delta H_{\text{forward}} = 20 \text{ kJ/mol}$. The activation energy of the uncatalysed forward reaction is 300 kJ/mol . When the reaction is catalysed keeping the reactant concentration same, the rate of the catalysed forward reaction at 27°C is found to be same as that of the uncatalysed reaction at 327°C . The activation energy of the catalysed backward reaction is ____ kJ/mol .

Solution:

Given,

- $\Delta H_{\text{forward}} = 20 \text{ kJ/mol}$

- Activation energy of uncatalysed forward reaction: $E_a = 300 \text{ kJ/mol}$

From the Arrhenius equation:

$$E_a \propto \frac{1}{T}$$

The rate of the catalysed forward reaction at 27°C is found to be the same as that of the uncatalysed reaction at 327°C . Therefore, we use the equation:

$$\frac{300}{600} = \frac{E_{a,f}}{T_2}$$

$$E_{a,f} = 150 \text{ kJ/mol}$$

The activation energy of the catalysed backward reaction is:

$$E_{a,b} = 150 - E_{a,f} = 150 - 20 = 130 \text{ kJ/mol}$$

Thus, the activation energy of the catalysed backward reaction is 130 kJ/mol .

Quick Tip

For reversible reactions, the sum of activation energies for the forward and backward reactions is related to the total activation energy change.

25. The vapour pressure of 30% (w/v) aqueous solution of glucose is _____ mm Hg at 25°C. [Given: The density of 30% (w/v), aqueous solutions of glucose is 1.2 g cm⁻³ and vapour pressure of pure water is 24 mm Hg. (Molar mass of glucose is 180 g mol⁻¹)]

Solution:

The vapour pressure of the solution can be calculated using Raoult's Law:

$$P_1 = P_0 \left(1 - \frac{m}{m + M} \right)$$

where P_1 is the vapour pressure of the solution, P_0 is the vapour pressure of the pure solvent, m is the mass of the solute, and M is the molar mass of the solute.

Given: - Mass of glucose (solute) = 30 g

- Volume of solution = 100 mL

- Density of solution = 1.2 g cm⁻³

- Vapour pressure of pure water = 24 mm Hg

- Molar mass of glucose = 180 g mol⁻¹

First, calculate the weight of the solvent:

$$\text{Weight of solvent} = 100 \text{ g} - 30 \text{ g} = 70 \text{ g}$$

Next, calculate the moles of glucose:

$$\text{Moles of glucose} = \frac{30}{180} = 0.1667 \text{ mol}$$

Now, calculate the vapour pressure of the solution:

$$P_s = \left(1 - \frac{30}{100} \right) \times 24 = 23.22 \text{ mm Hg}$$

Therefore, the vapour pressure of the solution is 23.22 mm Hg.

Quick Tip

For Raoult's Law, the vapour pressure of the solution is directly proportional to the concentration of the solvent, which is inversely related to the mole fraction of the solute.

26. In Chromyl chloride, the oxidation state of chromium is (+)

Solution:

In Chromyl chloride, the molecular formula is CrO_2Cl_2 . The oxidation state of oxygen is -2, and the chlorine atoms have an oxidation state of -1 each. Since the compound is neutral, the sum of oxidation states must equal zero.

Let the oxidation state of chromium be x :

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

$$x - 4 - 2 = 0$$

$$x = +6$$

Thus, the oxidation state of chromium is +6.

Quick Tip

When solving for oxidation states, remember to balance the charges in a neutral compound or a polyatomic ion.

27. The volume (in mL) of 0.1 M AgNO_3 required for complete precipitation of chloride ions present in 20 mL of 0.01 M solution of $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_2$ as silver chloride is

Solution:

The reaction for precipitation of chloride ions is:



The millimoles of chloride ions in the solution:

$$\text{Chloride ions} = 0.01 \times 20 = 0.2 \text{ millimoles}$$

Now, use the stoichiometric relationship:

$$0.4 \text{ millimoles} = 0.1 \times V \text{ (mL)} \Rightarrow V = 4 \text{ mL}$$

Quick Tip

In precipitation reactions, ensure you balance the moles of reactants using stoichiometry.

28. 20 mL of 0.5 M NaCl is required to coagulate 200 mL of As₂S₃ solution in 2 hours. The coagulating value of NaCl is

Solution:

The coagulating value is calculated as the millimoles of electrolyte needed to coagulate 1 L solution in 2 hours.

Given: - Volume of NaCl = 20 mL

- Concentration of NaCl = 0.5 M

- Volume of As₂S₃ = 200 mL

Coagulating value:

$$\text{Coagulating value} = \frac{20 \times 0.5 \times 1000}{200} = 50$$

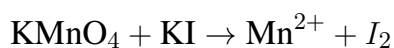
Quick Tip

The coagulating value is useful for understanding how much electrolyte is needed to coagulate a certain volume of colloid.

29. The total change in the oxidation state of manganese involved in the reaction of KMnO₄ and potassium iodide in the acidic medium is

Solution:

The reaction is:



Oxidation state of manganese in KMnO_4 is +7, and in Mn^{2+} it is +2. Therefore, the change in oxidation state is:

$$\Delta\text{Oxidation state} = 7 - 2 = 5$$

Quick Tip

When calculating oxidation state changes, carefully track the initial and final states of the element involved.

30. The number of correct statements from the following is ____.

- (A) Conductivity always decreases with decrease in concentration for both strong and weak electrolysis.
- (B) The number of ions per unit volume that carry current in a solution increases on dilution.
- (C) Molar conductivity increases with decrease in concentration.
- (D) The variation in molar conductivity is different for strong and weak electrolysis.
- (E) For weak electrolysis, the change in molar conductivity with dilution is due to the decrease in degree of dissociation.

Solution:

- (A) Conductivity decreases with dilution for both strong and weak electrolytes.
- (B) The number of ions per unit volume decreases on dilution for weak electrolytes but increases for strong electrolytes.
- (C) Molar conductivity increases with dilution due to the increased number of ions.
- (D) The variation in molar conductivity is indeed different for strong and weak electrolytes.
- (E) For weak electrolytes, the molar conductivity increases with dilution due to the dissociation.

Thus, the correct statements are (A), (C), and (D).

Quick Tip

In electrolysis, remember that for weak electrolytes, molar conductivity increases with dilution, while for strong electrolytes, the conductivity decreases with dilution due to ion pairing.
