JEE Main 2023 April 6 Shift 1 Chemistry 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

Question 1: Match List I with List II

List I **(Natural Amino acid)**	**List II** **(One Letter Code)**
(A) Arginine	**(I) D**
(B) Aspartic acid	**(II) N**
(C) Asparagine	**(III) A**
(D) Alanine	**(IV) R**

Choose the correct answer from the options given below:

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

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

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

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

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

Solution:

The one-letter codes for the given amino acids are:

- Arginine: R
- Aspartic acid: D
- Asparagine: N
- Alanine: A

Matching these with the options:

Natural Amino acid	One Letter Code
(i) Arginine	R
(ii) Aspartic acid	D
(iii) Asparagine	N
(iv) Alanine	A

Therefore, the correct matching is:

(A) Arginine - (IV) R

(B) Aspartic acid - (I) D

(C) Asparagine - (II) N

(D) Alanine - (III) A

Quick Tip

Memorizing the one-letter codes for amino acids is essential in biochemistry. Use mnemonics or flashcards to help remember them.

Question 2: Formation of which complex, among the following, is not a confirmatory test of Pb^{2+} ions

(1) lead sulphate

(2) lead nitrate

(3) lead chromate

(4) lead iodide

Correct Answer: **(2)** lead nitrate

Solution:

Lead nitrate, $Pb(NO_3)_2$, is a soluble colorless compound. Confirmatory tests for ions usually involve the formation of a precipitate or a distinctly colored complex. Lead sulphate (white precipitate), lead chromate (yellow precipitate), and lead iodide (yellow precipitate) are all used as confirmatory tests for lead(II) ions. Since lead nitrate is colorless and soluble, it's not used as a confirmatory test.

Quick Tip

Confirmatory tests usually involve the formation of a precipitate or a colored complex. Solubility and color are important factors to consider.

Question 3: The volume of 0.02 M aqueous HBr required to neutralize 10.0 mL of 0.01 M aqueous $Ba(OH)_2$ is (Assume complete neutralization)

(1) 5.0 mL

(2) 10.0 mL

(3) 2.5 mL

(4) 7.5 mL

Correct Answer: (2) 10.0 mL

Solution:

For neutralization, the milliequivalents of acid must equal the milliequivalents of base. Milliequivalents = Molarity × n-factor × Volume For HBr, n-factor = 1. For $Ba(OH)_2$, n-factor = 2.

Let V be the volume of HBr required.

$$\text{m.eq. of HBr} = \text{m.eq. of Ba(OH)}_2$$

$$0.02 \times 1 \times V = 0.01 \times 2 \times 10$$

$$0.02V = 0.2$$

$$V = \frac{0.2}{0.02} = 10 \text{ mL}.$$

Quick Tip

For neutralization reactions, milliequivalents of acid equal milliequivalents of base. Remember n-factor is important for polyprotic acids and bases.

Question 4: Group-13 elements react with O_2 in amorphous form to form oxides of type M_2O_3 (M = element). Which among the following is the most basic oxide?

(1) Al_2O_3

(2) Tl_2O_3

(3) Ga_2O_3

(4) B_2O_3

Correct Answer: (2) Tl_2O_3

Solution:

As we move down Group 13, the metallic character increases, and hence the electropositive character increases. As electropositivity increases, the basicity of the oxides increases. The order of basicity for Group 13 oxides is B_2O_3 ¡ Al_2O_3 ¡ Ga_2O_3 ¡ In_2O_3 ¡ Tl_2O_3. Therefore, Tl_2O_3 is the most basic oxide.

Quick Tip

Metallic (electropositive) character increases down a group, and so does the basicity of the oxides.

Question 5: The IUPAC name of $K_3[Co(C_2O_4)_3]$ is -

(1) Potassium tris(oxalate)cobaltate(III)

(2) Potassium trioxalatocobalt(III)

(3) Potassium tris(oxalato)cobaltate(III)

(4) Potassium tris(oxalate)cobalt(III)

Correct Answer: (3) Potassium tris(oxalato)cobaltate(III)

Solution:

The IUPAC name of $K_3[Co(C_2O_4)_3]$ is Potassium trioxalatocobaltate(III). The oxalate anion ($C_2O_4^{2-}$) is a bidentate ligand, and the prefix ”tri” indicates there are three oxalate ligands. The complex anion is $[Co(C_2O_4)_3]^{3-}$, and since the potassium ion has a +1 charge, there must be three potassium ions to balance the charge. The oxidation state of cobalt is +3, indicated by the Roman numeral (III).

Quick Tip

When naming coordination compounds, identify the cation and anion, use prefixes for the number of ligands, and indicate the oxidation state of the central metal ion in Roman numerals. The correct name uses ”oxalato” not ”oxalate”.

Question 6: If the radius of the first orbit of hydrogen atom is a_0, then de Broglie’s wavelength of electron in 3^{rd} orbit is

(1) $\frac{\pi a_0}{6}$

(2) $\frac{\pi a_0}{3}$

(3) $6\pi a_0$

(4) $3\pi a_0$

Correct Answer: (3) $6\pi a_0$

Solution:

According to the de Broglie principle, the circumference of an electron's orbit in an atom is an integer multiple of the electron's wavelength:

$$2\pi r = n\lambda$$

where r is the radius of the orbit, n is the principal quantum number, and λ is the de Broglie wavelength.

The radius of the nth orbit of a hydrogen-like atom is given by:

$$r_n = \frac{n^2}{Z}a_0$$

where a_0 is the Bohr radius and Z is the atomic number. For hydrogen, Z = 1.

For the 3rd orbit (n=3) of hydrogen (Z=1), the radius is

$$r_3 = \frac{3^2}{1}a_0 = 9a_0.$$

Substituting this into the de Broglie equation:

$$2\pi(9a_0) = 3\lambda$$

$$\lambda = \frac{18\pi a_0}{3} = 6\pi a_0.$$

Quick Tip

Remember the de Broglie relation $2\pi r = n\lambda$ and the formula for the radius of the nth orbit $r_n = \frac{n^2}{Z}a_0$.

Question 7: The group of chemicals used as pesticide is

(1) Sodium chlorate, DDT, PAN

(2) DDT, Aldrin

(3) Aldrin, Sodium chlorate, Sodium arsinite

(4) Dieldrin, Sodium arsinite, Tetrachloroethene

Correct Answer: (2) DDT, Aldrin

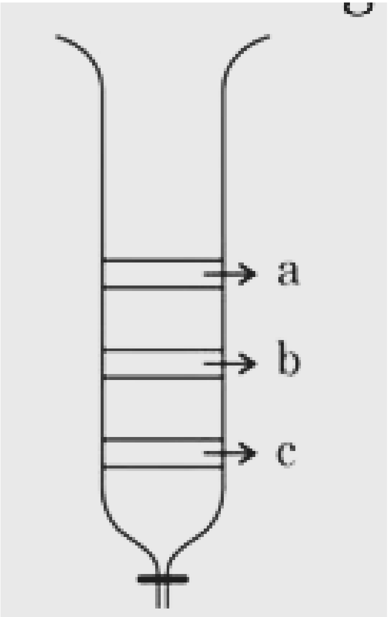
Solution:

DDT (dichlorodiphenyltrichloroethane) and Aldrin are well-known pesticides. PAN (peroxyacetyl nitrate) is a component of photochemical smog. Sodium chlorate is a herbicide and defoliant. Sodium arsinite has been used as an insecticide and rodenticide. Tetrachloroethene is used in dry cleaning. Therefore, the correct group of chemicals used as pesticides is DDT and Aldrin.

Quick Tip

Be familiar with common examples of pesticides, herbicides, and other chemicals and their uses.

Question 8: From the figure of column chromatography given below, identify incorrect statements.



A. Compound 'c' is more polar than 'a' and 'b'.

B. Compound 'a' is least polar.

C. Compound 'b' comes out of the column before 'c' and after 'a'.

D. Compound 'a' spends more time in the column.

Choose the correct answer from the options given below:

(1) A, B and D only

(2) A, B and C only

(3) B and D only

(4) B, C and D only

Correct Answer: (2) A, B and C only

Solution:

Adsorption of Compound in Column

Key Factors:

- Adsorption of compound α is proportional to:

$$\text{Attraction} \propto \text{Polarity} \propto \text{Time spent in the column.}$$

- The order of polarity determines the retention time.
- The time spent in the column is inversely proportional to the order in which the compounds come out of the column:

$$\alpha \propto \frac{1}{\text{Order of elution from the column}}.$$

Conclusion:

- **Order of polarity:**

$$a > b > c$$

- **Order of elution (come out from the column):**

$$c > b > a$$

- **Time spent in the column:**

$$a > b > c$$

The incorrect statements are A, B, and C Only.

Quick Tip

In column chromatography, remember that more polar compounds will elute later, while less polar compounds will elute earlier. The elution order provides information about the relative polarities of the compounds.

Question 9: Ion having highest hydration enthalpy among the given alkaline earth metal ions is:

(1) Be^{2+}

(2) Ba^{2+}

(3) Ca^{2+}

(4) Sr^{2+}

Correct Answer: (1) Be^{2+}

Solution:

Hydration enthalpy is the energy released when one mole of gaseous ions is dissolved in water to form an infinitely dilute solution. It depends on the charge density of the ion. Higher the charge density, greater the hydration enthalpy.

Charge density is directly proportional to the charge of the ion and inversely proportional to the size of the ion.

$$\text{Charge Density} \propto \frac{\text{Charge}}{\text{Size}}$$

Since all the given ions have the same charge (+2), the hydration enthalpy will be inversely proportional to the size of the ion.

$$\text{Hydration Enthalpy} \propto \frac{1}{\text{Size}}$$

Down the group in the periodic table (from Be to Ba), the size of the alkaline earth metal ions increases. Thus, the hydration enthalpy decreases down the group. The order of hydration enthalpy is:

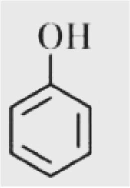
$Be^{2+} > Mg^{2+} > Ca^{2+} > Sr^{2+} > Ba^{2+}$.

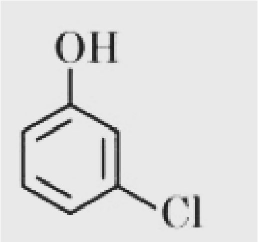
Therefore, Be^{2+} has the highest hydration enthalpy.

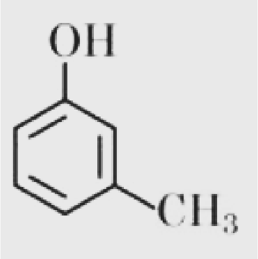
Quick Tip

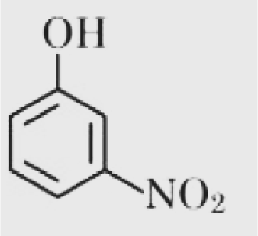
Hydration enthalpy is inversely proportional to the ionic size for ions with the same charge. Smaller ions have higher charge density and thus higher hydration enthalpy.

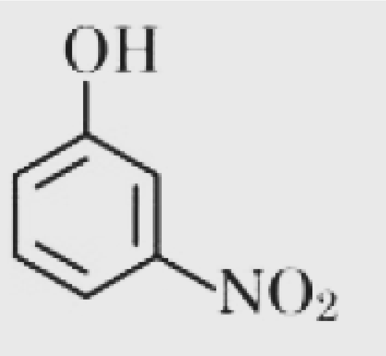
Question 10: The strongest acid from the following is

(1) 

(2) 

(3) 

(4) 

Correct Answer: (4) 

Solution:

The strength of an acid is determined by the stability of its conjugate base.

Electron-withdrawing groups (-I and -M effects) stabilize the conjugate base by delocalizing the negative charge after the loss of H+. Electron-donating groups (+I and +M effects) destabilize the conjugate base.

In the given options, all are substituted phenols. The substituents are:

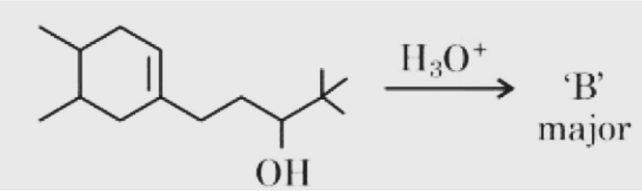
- (1) No substituent (phenol)
- (2) -Cl (chloro) - electron-withdrawing through -I effect
- (3) $-CH_3$ (methyl) - electron-donating through +I effect
- (4) $-NO_2$ (nitro) - strong electron-withdrawing through -I and -M effects

Since the nitro group (-NO_2) has the strongest electron-withdrawing effect (-I and -M), it stabilizes the conjugate base of the phenol most effectively. Therefore, the compound with the -NO_2 substituent (option 4) is the strongest acid among the given options.

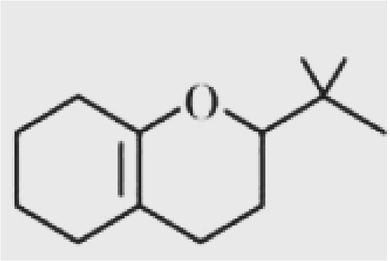
Quick Tip

Electron-withdrawing groups increase acidity while electron-donating groups decrease acidity. Consider both inductive (-I/+I) and resonance (-M/+M) effects when comparing acidity.

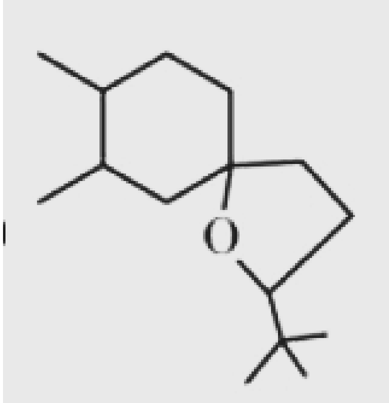
Question 11: In the following reaction, 'B' is



(1)



(2)



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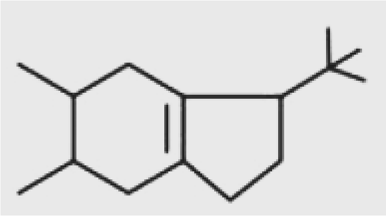
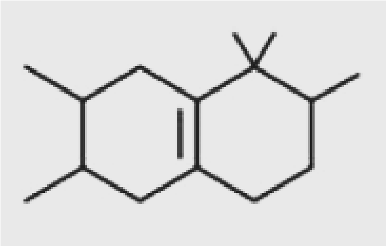
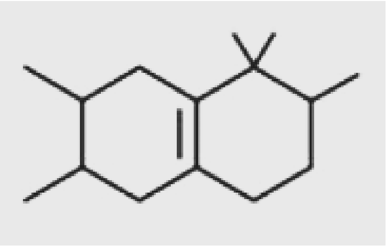


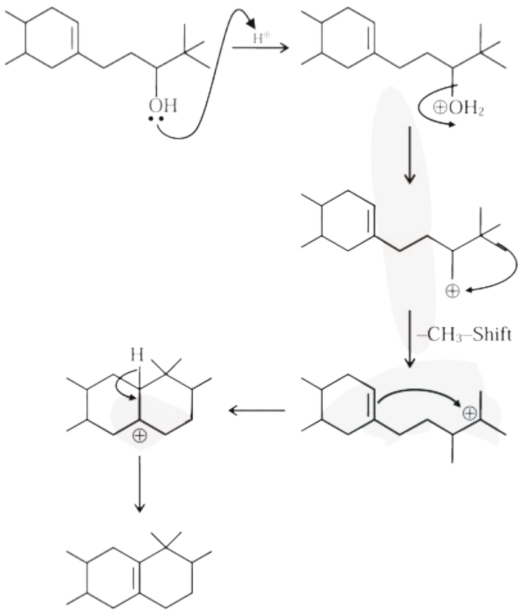
(4) 

Correct Answer: (4) 

Solution:

The given reaction is an acid-catalyzed intramolecular cyclization of an unsaturated alcohol. The mechanism involves:

1. Protonation of the alcohol: The hydroxyl group is protonated by H_3O^+, making it a better leaving group.
2. Carbocation formation: Water leaves, generating a secondary carbocation.
3. Cyclization: The double bond attacks the carbocation, forming a six-membered ring. This results in a tertiary carbocation. Crucially, this carbocation is formed adjacent to the oxygen in the newly formed ring.
4. Deprotonation: A proton is lost to give the final cyclic ether product.



The correct product, resulting from the more stable tertiary carbocation and forming the six-membered ring, is option (4).

Quick Tip

Pay close attention to the position of the carbocation formed during cyclization reactions. The location of the positive charge determines the final structure of the cyclic product. Visualizing the ring formation process can help avoid mistakes.

Question 12: Structures of $BeCl_2$ in solid state, vapour phase and at very high temperature respectively are:

(1) Polymeric, Dimeric, Monomeric

(2) Dimeric, Polymeric, Monomeric

(3) Monomeric, Dimeric, Polymeric

(4) Polymeric, Monomeric, Dimeric

Correct Answer: (1) Polymeric, Dimeric, Monomeric

Solution:

$BeCl_2$ exhibits different structures depending on the phase and temperature:

Solid state: In the solid state, $BeCl_2$ exists as a polymeric structure. Beryllium has a tendency to form coordinate covalent bonds due to its small size and relatively high charge density. In the polymeric structure, each beryllium atom is bonded to four chlorine atoms, and each chlorine atom bridges between two beryllium atoms, forming a chain-like structure.

Vapour phase: In the vapour phase, below 1200 K, $BeCl_2$ primarily exists as a dimer (Be_2Cl_4). The dimeric structure is formed through chloro-bridging, where two chlorine atoms bridge between two beryllium atoms. This satisfies the beryllium's desire for a coordination number of four.

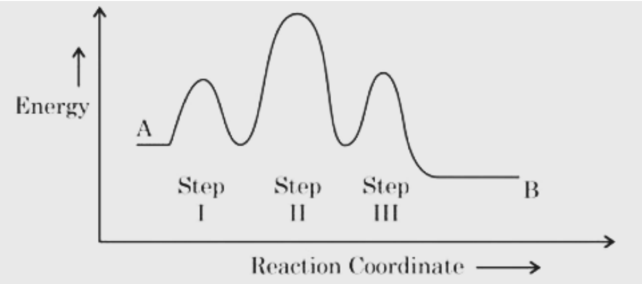
Very high temperature (above 1200 K): At very high temperatures (above 1200 K), the thermal energy is sufficient to break the chloro bridges in the dimer, leading to the formation of monomeric $BeCl_2$ units. The monomeric form has a linear structure with beryllium having a coordination number of two.

Therefore, the structures of $BeCl_2$ are polymeric in the solid state, dimeric in the vapour phase, and monomeric at very high temperatures.

Quick Tip

Remember that $BeCl_2$ changes its structure depending on the phase and temperature due to beryllium's tendency to achieve a coordination number of four whenever possible. The higher the temperature, the greater the tendency for the simpler monomeric structure to prevail.

Question 13: Consider the following reaction that goes from A to B in three steps as shown below:



Choose the correct option

Number of Intermediates	Number of Activated complex	Rate determining step
(1) 2	3	II
(2) 3	2	II
(3) 2	3	III
(4) 2	3	I

Correct Answer: (1) 2 & 3 & II

Solution:

- **Intermediates:** Intermediates are species formed during a reaction that are subsequently consumed. They are represented by the valleys in the energy diagram. In the given diagram, there are **two valleys**, corresponding to **two intermediates**.
- **Activated Complexes:** Activated complexes are high-energy transition state species that exist at the peak of each energy barrier. There are three peaks in the diagram, representing **three activated complexes**.
- **Rate-Determining Step:** The rate-determining step (RDS) is the slowest step in a multi-step reaction. It is represented by the highest energy barrier. In the given diagram, **step II** has the highest activation energy and therefore is the rate-determining step.

Therefore, the correct option is (1): 2 intermediates, 3 activated complexes, and step II as the rate-determining step.

Quick Tip

In a reaction energy diagram, valleys represent intermediates, peaks represent activated complexes, and the highest peak corresponds to the rate-determining step.

Question 14: The product, which is not obtained during the electrolysis of brine solution is

(1) HCl

(2) NaOH

(3) Cl_2

(4) H_2

Correct Answer: (1) HCl

Solution:

Brine is a concentrated aqueous solution of NaCl. During electrolysis of brine, the following reactions occur:

At the cathode (reduction): Water molecules are preferentially reduced over sodium ions because the reduction potential of water is higher than that of sodium ions.

$$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$$

At the anode (oxidation): Chloride ions are oxidized to chlorine gas.

$$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$$

Overall Reaction: Combining the cathode and anode reactions:

$$2NaCl(aq) + 2H_2O(l) \rightarrow H_2(g) + Cl_2(g) + 2NaOH(aq)$$

The products obtained during the electrolysis of brine are hydrogen gas (H_2), chlorine gas (Cl_2), and sodium hydroxide (NaOH). HCl is not formed.

Quick Tip

During the electrolysis of brine, water is reduced at the cathode, chloride ions are oxidized at the anode, and NaOH is formed in the solution. Remember that HCl is not a product of this electrolysis.

Question 15: Which one of the following elements will remain as liquid inside pure boiling water?

(1) Li

(2) Ga

(3) Cs

(4) Br

Correct Answer: (2) Ga

Solution:

Boiling water has a temperature of 100°C. We need to find an element that has a melting point below 100°C and a boiling point above 100°C to remain liquid at this temperature.

Li and Cs: Alkali metals (Li and Cs) react vigorously with water.

Br$_2$: Bromine (Br$_2$) has a boiling point of 58.8°C, so it would be a gas at 100°C.

Ga: Gallium (Ga) has a melting point of 29.8°C and a boiling point of 2400°C. Thus, gallium will remain liquid inside boiling water.

Quick Tip

To remain liquid at a specific temperature, an element must have a melting point below that temperature and a boiling point above that temperature.

Question 16: Given below are two statements: one is labelled as "Assertion A" and the other is labelled as "Reason R"

Assertion A: In the complex Ni(CO)$_4$ and Fe(CO)$_5$, the metals have zero oxidation state.

Reason R: Low oxidation states are found when a complex has ligands capable of π-donor character in addition to the σ-bonding.

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

(1) A is not correct but R is correct.

(2) A is correct but R is not correct

(3) Both A and R are correct and R is the correct explanation of A

(4) Both A and R are correct but R is NOT the correct explanation of A

Correct Answer: (2) A is correct but R is not correct

Solution:

Let's analyze both Assertion A and Reason R:

Assertion A: In Ni(CO)$_4$ and Fe(CO)$_5$, the carbonyl ligand (CO) is neutral. Thus, the oxidation state of Ni and Fe in these complexes is indeed zero. So, Assertion A is correct.

Reason R: Low oxidation states of metals are stabilized by synergistic bonding, also known as backbonding. This involves σ-donation from the ligand to the metal and π-backdonation from the metal to the ligand. Crucially, the ligand must have empty π orbitals to accept electrons from the metal. CO is a π-acceptor ligand, not a π-donor ligand. So, Reason R is incorrect.

The correct answer is (2): A is correct, but R is not correct.

Quick Tip

Remember that synergistic bonding involves σ-donation and π-backdonation. Ligands like CO stabilize low oxidation states of metals by acting as π-acceptors, not π-donors.

Question 17: Given below are two statements:

Statement I: Morphine is a narcotic analgesic. It helps in relieving pain without producing sleep.

Statement II: Morphine and its derivatives are obtained from opium poppy.

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

(1) Statement I is true but statement II is false

(2) Both statement I and statement II are true

(3) Statement I is false but statement II is true

(4) Both Statement I and Statement II are false

Correct Answer: (3) Statement I is false but statement II is true

Solution:

Let's analyze both statements:

Statement I: Morphine *is* a narcotic analgesic. However, it is known to induce sleep and drowsiness. So, Statement I is false.

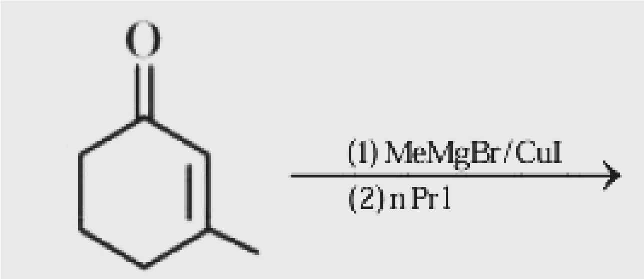
Statement II: Morphine and its derivatives are indeed obtained from opium poppy. So, Statement II is true.

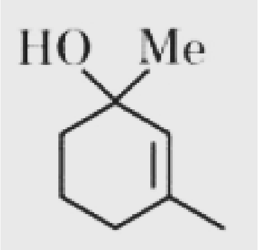
Therefore, the correct option is (3): Statement I is false, but Statement II is true.

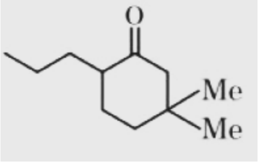
Quick Tip

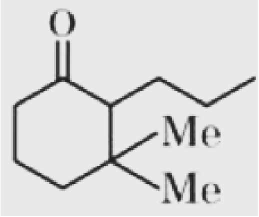
Morphine, while an effective analgesic, also acts as a narcotic, inducing sleep. It is derived from the opium poppy.

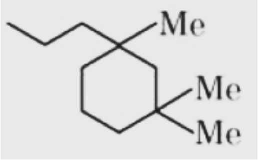
Question 18: Find out the major product from the following reaction.

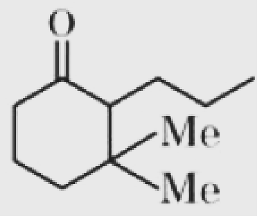


(1) 

(2) 

(3) 

(4) 

Correct Answer: (3) 

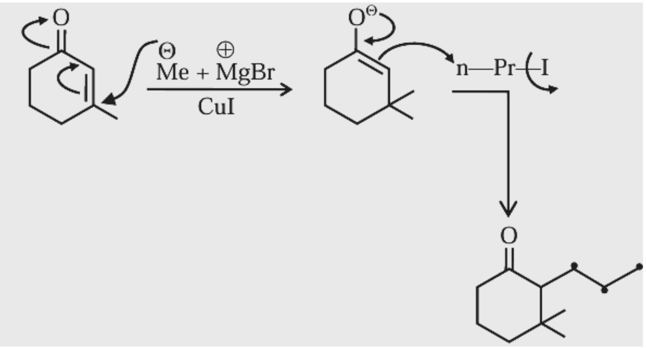
Solution:

The reaction proceeds in two steps:

1. **1,4-addition of the organocuprate:** The organocuprate reagent (MeMgBr/CuI) adds to the α, β-unsaturated ketone in a 1,4-conjugate addition manner. This results in the formation of a ketone with a methyl group at the β position.

2. **Alkylation of the ketone:** The resulting ketone reacts with n-propyl iodide (nPrI) in an alkylation reaction. The enolate of the ketone attacks the alkyl halide, adding the n-propyl

group to the α-carbon.



Therefore, the major product is option (3).

Quick Tip

Organocuprates perform 1,4-addition on α, β-unsaturated ketones. Subsequent alkylation occurs at the α-position of the resulting ketone.

Question 19: During the reaction of permanganate with thiosulphate, the change in oxidation of manganese occurs by value of 3. Identify which of the below medium will favour the reaction

(1) aqueous neutral

(2) aqueous acidic

(3) both aqueous acidic and neutral

(4) both aqueous acidic and faintly alkaline

Correct Answer: (1) aqueous neutral

Solution:

The reaction of permanganate (MnO_4^-) with thiosulphate ($\text{S}_2\text{O}_3^{2-}$) depends on the pH of the medium. Permanganate can be reduced to different manganese species depending on the conditions.

In a neutral or weakly alkaline medium, permanganate is reduced to manganese(IV) oxide (MnO_2):

$$\text{MnO}_4^-(aq) + 2H_2O(l) + 3e^- \rightarrow \text{MnO}_2(s) + 4OH^-(aq)$$

In this reaction, the oxidation state of manganese changes from +7 in MnO_4^- to +4 in MnO_2, a change of 3 units.

In an acidic medium, permanganate is reduced to manganese(II) ions (Mn^{2+}):

$$\text{MnO}_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow \text{Mn}^{2+}(aq) + 4H_2O(l)$$

Here, the oxidation state of manganese changes from +7 to +2, a change of 5 units.

Since the question specifies a change in oxidation state of 3, the reaction must be occurring in a neutral or weakly alkaline medium.

Quick Tip

The reduction products of permanganate differ in acidic and neutral/alkaline media. In neutral or weakly alkaline solutions, permanganate is reduced to MnO_2 (Mn oxidation state +4), while in acidic solutions, it is reduced to Mn^{2+} (Mn oxidation state +2).

Question 20: Element not present in Nessler's reagent is

(1) K

(2) N

(3) I

(4) Hg

Correct Answer: (2) N

Solution:

Nessler's reagent is an alkaline solution of potassium tetraiodomercurate(II), $K_2[HgI_4]$. It is prepared by dissolving mercuric iodide (HgI_2) in an aqueous solution of potassium iodide (KI) and then adding potassium hydroxide (KOH).

The elements present in Nessler's reagent are potassium (K), mercury (Hg), iodine (I).

Nitrogen (N) is not part of the chemical formula of Nessler's reagent.

Quick Tip

Nessler's reagent ($K_2[HgI_4]$) is used to detect the presence of ammonia (NH_3), producing a brown precipitate or yellow coloration. Remember its chemical formula to identify the constituent elements.

Section B

Question 21: The standard reduction potentials at 298 K for the following half cells are given below:

$\text{NO}_3^- + 4H^+ + 3e^- \to NO(g) + 2H_2O \quad E^0 = 0.97V$

$V^{2+}(aq) + 2e^- \to V \quad E^0 = -1.19V$

$Fe^{3+}(aq) + 3e^- \to Fe \quad E^0 = -0.04V$

$Ag^+(aq) + e^- \to Ag(s) \quad E^0 = 0.80V$

$Au^{3+}(aq) + 3e^- \to Au(s) \quad E^0 = 1.40V$

The number of metal(s) which will be oxidized by NO_3^- in aqueous solution is ____________

Correct Answer: 3

Solution:

For NO_3^- to oxidize a metal, NO_3^- must itself be reduced. The given reduction half-reaction is:

$$\text{NO}_3^- + 4\text{H}^+ + 3e^- \to \text{NO} + 2\text{H}_2\text{O} \qquad E^0 = 0.97\,\text{V}$$

For a metal to be oxidized by NO_3^-, the overall cell potential (E^0_{cell}) for the redox reaction must be positive. The cell potential is calculated as:

$$E^0_{\text{cell}} = E^0_{\text{reduction}} - E^0_{\text{oxidation}}$$

In our case, $E^0_{\text{reduction}}$ is 0.97 V (for the NO_3^- reduction). For the cell potential to be positive, $E^0_{\text{oxidation}}$ must be less than 0.97 V.

Since we are given standard reduction potentials, we need to reverse the sign to obtain the oxidation potentials for each metal:

V: $E^0_{\text{oxidation}} = 1.19\,\text{V}$

Fe: $E^0_{\text{oxidation}} = 0.04\,\text{V}$

Ag: $E^0_{\text{oxidation}} = -0.80\,\text{V}$

Au: $E^0_{\text{oxidation}} = -1.40\,\text{V}$

Comparing these values to 0.97 V, we find that Fe, Ag, and Au have oxidation potentials less than 0.97 V. Therefore, these three metals can be oxidized by NO_3^- in aqueous solution. Vanadium (V) has an oxidation potential greater than 0.97 V, so it will not be oxidized by

NO_3^-.

Quick Tip

For a spontaneous redox reaction, the overall cell potential must be positive. When comparing reduction potentials, a stronger oxidizing agent will have a higher reduction potential.

Question 22: Number of crystal system from the following where body centred unit cell can be found, is ____________

Cubic, tetragonal, orthorhombic, hexagonal, rhombohedral, monoclinic, triclinic

Correct Answer: 3

Solution:

A body-centered cubic (BCC) unit cell is a type of unit cell where an atom is located at each corner of the cube and one atom is located at the center of the cube. BCC arrangements are found in the following crystal systems:

Cubic: This is the classic body-centered cubic structure. **Tetragonal:** A body-centered tetragonal structure exists where the cell is elongated along one axis.

Orthorhombic: A body-centered orthorhombic structure exists where the cell has unequal sides but all angles are 90 degrees.

Body-centered unit cells are *not* found in the hexagonal, rhombohedral, monoclinic, or triclinic crystal systems. Therefore, the number of crystal systems where BCC unit cells can be found is 3.

Quick Tip

BCC arrangements are possible in the cubic, tetragonal, and orthorhombic crystal systems. Visualizing the unit cell structures within these systems helps in understanding the arrangement of atoms.

Question 23: Among the following the number of compounds which will give positive iodoform reaction is ____________

(a) 1-Phenylbutan-2-one

(b) 2-Methylbutan-2-ol

(c) 3-Methylbutan-2-ol

(d) 1-Phenylethanol

(e) 3,3-dimethylbutan-2-one

(f) 1-Phenylpropan-2-ol

Correct Answer: 4

Solution:

The iodoform test is a qualitative test for the presence of methyl ketones (R-CO-CH_3) and certain secondary alcohols (R-CH(OH)-CH_3). A positive iodoform test results in the formation of a yellow precipitate of iodoform (CHI_3).

The necessary structural feature for a positive iodoform test is the presence of a methyl ketone group ($CH_3C=O$) or a methyl carbinol group ($CH_3CH(OH)$-).

Let's examine each compound:

(a) 1-Phenylbutan-2-one: This is a methyl ketone (Ph-CH_2-CO-CH_3) and will give a positive iodoform test.

(b) 2-Methylbutan-2-ol: This is a tertiary alcohol and will not give a positive iodoform test.

(c) 3-Methylbutan-2-ol: This is a secondary alcohol with the required $CH_3CH(OH)$- group, so it will give a positive iodoform test.

(d) 1-Phenylethanol: This is a secondary alcohol with the required $CH_3CH(OH)$- group (Ph-CH(OH)-CH_3), so it will give a positive iodoform test.

(e) 3,3-dimethylbutan-2-one: This is a methyl ketone (CH_3-CO-$C(CH_3)_3$), so it will give a positive iodoform test.

(f) 1-Phenylpropan-2-ol: This is a secondary alcohol with the required $CH_3CH(OH)$- group (Ph-CH_2-CH(OH)-CH_3) and will give a positive iodoform test.

Therefore, four compounds (a, c, d, and f) will give a positive iodoform reaction.

Quick Tip

The iodoform test is positive for methyl ketones (R-CO-CH_3) and secondary alcohols of the type R-CH(OH)-CH_3. Look for these specific structural motifs.

Question 24: Number of isomeric aromatic amines with molecular formula $C_8H_{1}1N$, which can be synthesized by Gabriel Phthalimide synthesis is ____________

Correct Answer: 6

Solution:

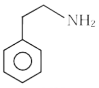
The Gabriel phthalimide synthesis is used to prepare primary amines (R-NH_2). Since the question asks for aromatic amines with the formula $C_8H_{11}N$, we need to consider isomeric primary aromatic amines.

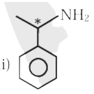
The degree of unsaturation (DU) for $C_8H_{11}N$ is:

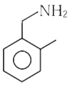
$$DU = C + 1 - \frac{H - N}{2} = 8 + 1 - \frac{11 - 1}{2} = 9 - 5 = 4$$

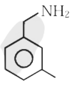
A DU of 4 suggests the presence of a benzene ring (DU = 4). This leaves us with C_2H_5 to account for. Since the Gabriel synthesis produces primary amines, the nitrogen must be attached to one of these carbons.

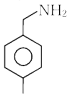
The possible isomers are:

(i)


(ii)


(iii)


(iv)


(v)


Other dimethylanilines (like 3,4-dimethylaniline) are identical to the ones listed above. 2,6-dimethylaniline is the same as 2,3-dimethylaniline. Therefore, there are 6 possible isomeric aromatic amines that can be synthesized by Gabriel phthalimide synthesis.

Quick Tip

The Gabriel phthalimide synthesis yields primary amines. When determining possible isomers, remember to consider different positions of substituents on the aromatic ring to avoid duplicates.

Question 25: Consider the following pairs of solution which will be isotonic at the same temperature. The number of pairs of solutions is/are ____________

A. 1 M aq. NaCl and 2 M aq. Urea

B. 1 M aq. $CaCl_2$ and 1.5 M aq. KCl

C. 1.5 M aq. $AlCl_3$ and 2 M aq. Na_2SO_4

D. 2.5 M aq. KCl and 1 M aq. $Al_2(SO_4)_3$

Correct Answer: 4

Solution:

Isotonic solutions have the same osmotic pressure. Osmotic pressure is directly proportional to the concentration of solute particles. Therefore, isotonic solutions have the same concentration of solute particles. We need to determine the concentration of particles in each solution, considering dissociation of ionic compounds.

A. NaCl dissociates into 2 ions (Na^+ and Cl^-). So, 1 M NaCl gives 1 M × 2 = 2 M ions. Urea does not dissociate, so 2 M urea remains 2 M particles. These solutions are isotonic.

B. $CaCl_2$ dissociates into 3 ions (Ca^{2+} and 2 Cl^-). So, 1 M $CaCl_2$ gives 1 M × 3 = 3 M ions. KCl dissociates into 2 ions (K^+ and Cl^-). So, 1.5 M KCl gives 1.5 M × 2 = 3 M ions. These solutions are isotonic.

C. $AlCl_3$ dissociates into 4 ions (Al^{3+} and 3 Cl^-). So, 1.5 M $AlCl_3$ gives 1.5 M × 4 = 6 M ions. Na_2SO_4 dissociates into 3 ions (2 Na^+ and SO_4^{2-}). So, 2 M Na_2SO_4 gives 2 M × 3 = 6 M ions. These solutions are isotonic.

D. KCl dissociates into 2 ions (K^+ and Cl^-). So, 2.5 M KCl gives 2.5 M × 2 = 5 M ions. $Al_2(SO_4)_3$ dissociates into 5 ions (2 Al^{3+} and 3 SO_4^{2-}). So, 1 M $Al_2(SO_4)_3$ gives 1 M × 5 = 5 M ions. These solutions are isotonic.

All four pairs are isotonic. Therefore, the number of isotonic pairs is **4**.

Quick Tip

Remember to account for the dissociation of ionic compounds when determining the concentration of particles in solution for isotonicity calculations.

Question 26: The number of colloidal systems from the following, which will have 'liquid' as the dispersion medium, is ____________

Gem stones, paints, smoke, cheese, milk, hair cream, insecticide sprays, froth, soap lather

Correct Answer: 5

Solution:

A colloid is a mixture where one substance is dispersed evenly throughout another. The substance being dispersed is the dispersed phase, and the substance it is dispersed in is the dispersion medium. We are looking for colloidal systems where the dispersion medium is a liquid.

Paints: Pigment particles are dispersed in a liquid medium (oil or water-based).

Milk: Fat globules and protein particles are dispersed in water.

Hair cream: Various ingredients are dispersed in a liquid base.

Froth: A gas is dispersed in liquid.

Soap lather: A gas is dispersed in a liquid (soap solution).

The following are not liquid-based colloids:

Gem stones: These are solid solutions, not colloids.

Smoke: Solid particles dispersed in a gas (air).

Cheese: A complex mixture with a solid matrix.

Insecticide sprays: Liquid dispersed in gas.

Therefore, the colloidal systems with a liquid dispersion medium are paints, milk, hair cream, froth, and soap lather. There are 5 such systems.

Quick Tip

Carefully analyze the dispersed phase and the dispersion medium in each system to correctly identify the type of colloid.

Question 27: In an ice crystal, each water molecule is hydrogen bonded to neighbouring molecules.

Correct Answer: 4

Solution:

In an ice crystal, each water molecule forms four hydrogen bonds with its neighboring water molecules.

A water molecule (H_2O) has two hydrogen atoms and one oxygen atom. The oxygen atom is more electronegative than hydrogen, creating a polar molecule with a partial negative charge on the oxygen and partial positive charges on the hydrogens.

Each water molecule can act as a hydrogen bond donor through its two hydrogen atoms. The slightly positive hydrogen atoms can interact with the slightly negative oxygen atoms of neighboring water molecules, forming two hydrogen bonds.

Additionally, each water molecule can act as a hydrogen bond acceptor through its two lone pairs of electrons on the oxygen atom. These lone pairs can interact with the slightly positive hydrogen atoms of two other neighboring water molecules, forming two more hydrogen bonds.

Thus, each water molecule in ice participates in a total of four hydrogen bonds: two as a donor and two as an acceptor, creating a tetrahedral network structure.

Quick Tip

Remember that a water molecule can donate two hydrogen bonds and accept two hydrogen bonds. This leads to the characteristic tetrahedral arrangement in ice.

Question 28: Consider the following data

Heat of combustion of $H_2(g)$ = -241.8 kJ mol^{-1}

Heat of combustion of C(s) = -393.5 kJ mol^{-1}

Heat of combustion of $C_2H_5OH(l)$ = -1234.7 kJ mol^{-1}

The heat of formation of $C_2H_5OH(l)$ is (-) ______________ kJ mol^{-1} (Nearest integer).

Correct Answer: 278

Solution:

Given Reactions and Enthalpy Changes:

$$2C(s) + O_2 \rightarrow 2CO_2 \quad \Delta H = -393.5 \times 2 = -787\,\text{kJ} \quad \cdots(1)$$

$$3H_2 + \frac{3}{2}O_2 \rightarrow 3H_2O \quad \Delta H = -241.5 \times 3 = -725.4\,\text{kJ} \quad \cdots(2)$$

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O \quad \Delta H = -1234.7\,\text{kJ} \quad \cdots(3)$$

$$3H_2O + 2CO_2 \rightarrow C_2H_5OH + 3O_2 \quad \Delta H = +1234.7\,\text{kJ} \quad \cdots(4)$$

Target Reaction:

$$2C(s) + 3H_2(g) + \frac{1}{2}O_2 \rightarrow C_2H_5OH \quad \cdots(5)$$

Calculation:

Equation (5) is derived as:

$$(5) = (1) + (2) + (4)$$

$$= (-787) + (-725.4) + (1234.7)$$

$$\Delta H = -277.7\,\text{kJ} \quad \Rightarrow \Delta H \approx -278\,\text{kJ}.$$

Quick Tip

Hess's Law allows you to calculate enthalpy changes for reactions that are difficult to measure directly by combining enthalpy changes of other reactions. Remember that reversing a reaction changes the sign of ΔH.

Question 29: The equilibrium composition for the reaction PCl_3 + $Cl_2 \rightleftharpoons PCl_5$ at 298 K is given below:

$PCl3]_{eq}$ = 0.2 mol L^{-1}, $[Cl_2]_{eq}$ = 0.1 mol L^{-1}, $[PCl_5]_{eq}$ = 0.40 mol L^{-1}

If 0.2 mol of Cl_2 is added at the same temperature, the equilibrium concentrations of PCl_5 is ________ × 10^{-2} mol L^{-1}

Given: K_c for the reaction at 298 K is 20

Correct Answer: 49

Solution:

Given:

$$K_c = \frac{[PCl_5]}{[PCl_3][Cl_2]} = \frac{0.4}{0.2 \times 0.1} = 20$$

Reaction:

$$PCl_3 + Cl_2 \rightleftharpoons PCl_5$$

Initial Concentrations:

$$[PCl_3] = 0.2\,\text{M}, \quad [Cl_2] = 0.1\,\text{M}, \quad [PCl_5] = 0.4\,\text{M}$$

At Equilibrium:

$$[PCl_3] = 0.2 - x, \quad [Cl_2] = 0.1 + 0.2 - x, \quad [PCl_5] = 0.4 + x$$

Equilibrium Constant Expression:

$$K_c = \frac{0.4 + x}{(0.2 - x)(0.3 - x)}$$

Given:

$$K_c = 20$$

Substituting values into the equation:

$$20 = \frac{0.4 + x}{(0.2 - x)(0.3 - x)}$$

Solving for x using the quadratic equation:

$$x = 0.086$$

Concentration of PCl_5:

$$[PCl_5] = 0.4 + x = 0.4 + 0.086 = 0.486$$

$$[PCl_5] = 48.6 \times 10^{-2}\,\text{M}$$

$$[PCl_5] \approx 49 \times 10^{-2}\,\text{M}$$

Final Answer:

$$\text{Ans. } 49$$

Quick Tip

When the concentration of a reactant is increased, the equilibrium shifts to consume that reactant and produce more product, according to Le Chatelier's principle.

Question 30: The number of species having a square planar shape from the following is

____

XeF_4, SF_4, SiF_4, BrF_4^-, $[Cu(NH_3)_4]^{2+}$, $[FeCl_4]^{2-}$, $[PtCl_4]^{2-}$

Correct Answer: 4

Solution:

To determine the shapes of these species, we need to consider their electron domain geometry and the effect of lone pairs. Square planar geometry arises from an octahedral electron domain geometry with two lone pairs occupying axial positions. It can also arise from dsp^2 hybridisation when the central atom has a d^8 configuration in a complex ion. Let's analyze each species:

XeF_4: Xe has 8 valence electrons, and 4 are used for bonding with F. This leaves 4 electrons (2 lone pairs). XeF_4 has 6 electron domains (4 bonding, 2 lone pairs) adopting an octahedral electron domain geometry. The lone pairs occupy axial positions, **resulting in a square planar molecular geometry.**

SF_4: S has 6 valence electrons, 4 used for bonding. This leaves 2 electrons (1 lone pair). SF_4 has 5 electron domains (4 bonding and 1 lone pair) with a trigonal bipyramidal electron domain geometry. The lone pair occupies an equatorial position leading to a see-saw shape.

SiF_4: Si has 4 valence electrons, all used for bonding. SiF_4 has 4 electron domains (4 bonding, 0 lone pairs) and is tetrahedral.

BrF_4^-: Br has 7 valence electrons + 1 (from the negative charge) = 8 electrons. 4 are used for bonding. This leaves 4 electrons (2 lone pairs). BrF_4^- has 6 electron domains (4 bonding, 2 non-bonding), adopting an octahedral electron geometry. The two lone pairs are in the axial positions, **leading to a square planar molecular geometry.**

$[Cu(NH_3)_4]^{2+}$: Cu^{2+} is a d^9 system. Due to Jahn Teller distortion, this complex prefers to be a distorted square planar structure rather than a perfect square planar shape. For this type of question, it's usually **counted as a square planar complex.**

$[FeCl_4]^{2-}$: Fe^{2+} is a d^6 system, which is generally tetrahedral when dealing with weak field ligands.

$[PtCl_4]^{2-}$: Pt^{2+} is a d^8 system. **These often form square planar complexes** due to dsp^2 hybridization.

Therefore, XeF_4, BrF_4^-, $[Cu(NH_3)_4]^{2+}$, and $[PtCl_4]^{2-}$ are square planar. The answer is 4.

Quick Tip

For transition metal complexes, consider the d-electron configuration and ligand field strength to predict the geometry. For main group elements, consider VSEPR theory to predict the geometry.