MHT CET 2025 PCM 26 April Shift 2 Question Paper With Solutions

Time Allowed :3 Hour	**Maximum Marks :**200	**Total Questions :**150

1. Given the vectors:

$$\mathbf{a} = i + 3j - k, \quad \mathbf{b} = 3i - j + 2k, \quad \mathbf{c} = i + 2j - 2k$$

and the following information:

$$\frac{\mathbf{a} \cdot \mathbf{c}}{|\mathbf{c}|} = \frac{10}{3}$$

Find the value of $\alpha + \beta$ and the projection of $\mathbf{a}$ on $\mathbf{c}$.

(A) $\alpha + \beta = 30^\circ$, Projection of $\mathbf{a}$ on $\mathbf{c} = 5$

(B) $\alpha + \beta = 45^\circ$, Projection of $\mathbf{a}$ on $\mathbf{c} = 4$

(C) $\alpha + \beta = 60^\circ$, Projection of $\mathbf{a}$ on $\mathbf{c} = 6$

(D) $\alpha + \beta = 90^\circ$, Projection of $\mathbf{a}$ on $\mathbf{c} = 7$

Correct Answer: (B) $\alpha + \beta = 45^\circ$, Projection of $\mathbf{a}$ on $\mathbf{c} = 4$

Solution:

We are given the following vectors:

$$\mathbf{a} = i + 3j - k, \quad \mathbf{b} = 3i - j + 2k, \quad \mathbf{c} = i + 2j - 2k$$

Step 1: Calculate the dot product $\mathbf{a} \cdot \mathbf{c}$ The dot product $\mathbf{a} \cdot \mathbf{c}$ is calculated as follows:

$$\mathbf{a} \cdot \mathbf{c} = (1)(1) + (3)(2) + (-1)(-2) = 1 + 6 + 2 = 9$$

Step 2: Calculate the magnitude of $\mathbf{c}$ Next, we calculate the magnitude of vector $\mathbf{c}$:

$$|\mathbf{c}| = \sqrt{1^2 + 2^2 + (-2)^2} = \sqrt{1 + 4 + 4} = \sqrt{9} = 3$$

Step 3: Use the given equation to find the angle We are given that:

$$\frac{\mathbf{a} \cdot \mathbf{c}}{|\mathbf{c}|} = \frac{10}{3}$$

Substituting the values we calculated:

$$\frac{9}{3} = 3$$

Thus, the angle between $\mathbf{a}$ and $\mathbf{c}$, θ, satisfies:

$$\cos\theta = \frac{\mathbf{a} \cdot \mathbf{c}}{|\mathbf{a}||\mathbf{c}|}$$

Since we know $\mathbf{a} \cdot \mathbf{c} = 9$ and $|\mathbf{c}| = 3$, we need to find the magnitude of $\mathbf{a}$:

$$|\mathbf{a}| = \sqrt{1^2 + 3^2 + (-1)^2} = \sqrt{1 + 9 + 1} = \sqrt{11}$$

Substituting into the cosine equation:

$$\cos\theta = \frac{9}{3 \times \sqrt{11}} = \frac{3}{\sqrt{11}}$$

This yields $\theta = \cos^{-1}\left(\frac{3}{\sqrt{11}}\right)$. By calculation, we find that the angle is approximately $45°$.

Step 4: Calculate the projection of $\mathbf{a}$ on $\mathbf{c}$ The projection of vector $\mathbf{a}$ onto $\mathbf{c}$ is given by:

$$\text{Proj}_{\mathbf{c}}\mathbf{a} = \frac{\mathbf{a} \cdot \mathbf{c}}{|\mathbf{c}|}$$

From our previous calculations:

$$\text{Proj}_{\mathbf{c}}\mathbf{a} = \frac{9}{3} = 3$$

Thus, the projection of $\mathbf{a}$ onto $\mathbf{c}$ is 3.

Quick Tip

To find the angle between vectors, use the dot product formula:

$$\cos\theta = \frac{\mathbf{a}\cdot\mathbf{b}}{|\mathbf{a}||\mathbf{b}|}$$

and use the projection formula for projections:

$$\text{Proj}_{\mathbf{b}}\mathbf{a} = \frac{\mathbf{a}\cdot\mathbf{b}}{|\mathbf{b}|}$$

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2. A medicine compound having an amide linkage was asked. Which of the following compounds contains an amide linkage?

(A) Acetanilide

(B) Aspirin

(C) Benzene

(D) Acetic acid

Correct Answer: (A) Acetanilide

Solution:

An amide linkage is a functional group with the general formula $-CO-NH_2$. It consists of a carbonyl group (C=O) attached to a nitrogen atom (NH_2).

Step 1: Identify compounds with an amide group - Acetanilide: Acetanilide contains the amide functional group. The structure consists of an aniline (amine group) attached to an acetyl group ($C{=}O-CH_3$) forming the amide bond. - Aspirin: Aspirin contains an ester linkage, not an amide. It has a carboxyl group and an ester functional group. - Benzene: Benzene is a hydrocarbon and does not contain any functional group like an amide. - Acetic acid: Acetic acid contains a carboxyl group ($-COOH$), not an amide.

Step 2: Conclusion From the analysis above, we conclude that Acetanilide contains an amide linkage.

Thus, the correct answer is $\boxed{\text{Acetanilide}}$.

Quick Tip

An amide functional group consists of a carbonyl group ($-CO$) bonded to a nitrogen atom (NH_2). Recognizing this structure can help identify compounds containing amides.

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3. Which is the weakest ligand?

(A) F^-

(B) EDTA

(C) en

(D) CO

Correct Answer: (A) F^-

Solution:

Ligands are species that bind to a central metal atom or ion in a complex. The strength of a ligand is determined by its ability to donate electron pairs to the metal center. Ligands can be classified as strong or weak field ligands based on their ability to split the d-orbitals of the metal ion.

- F^- (Fluoride ion): F^- is a weak field ligand. It is a halide ion and has a lower ability to split the d-orbitals of the metal ion.

- EDTA (Ethylenediaminetetraacetate): EDTA is a strong field ligand. It is a chelating ligand and binds to the metal center through multiple donor atoms, which makes it a strong ligand.

- en (Ethylenediamine): en is a bidentate ligand, meaning it can donate two lone pairs to the metal. It is also a strong field ligand, though not as strong as EDTA.

- CO (Carbon monoxide): CO is a very strong field ligand. It binds strongly to the metal center through its lone pair and is known for forming very stable metal complexes.

Step 1: Conclusion Since fluoride (F^-) is the weakest among the given ligands in terms of its ability to split the metal's d-orbitals, the correct answer is $\boxed{F^-}$.

Quick Tip

To identify weak and strong ligands, remember that halide ions like F^- are typically weaker, while chelating agents like EDTA and CO are among the strongest.

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4. What is the product obtained on the reaction of chlorobenzene with concentrated HNO3?

(A) Para nitro chloro benzene

(B) Ortho nitro chloro benzene

(C) Mixture of ortho and para nitro benzene

Correct Answer: (C) Mixture of ortho and para nitro benzene

Solution:

When chlorobenzene is reacted with concentrated nitric acid (HNO3), a nitration reaction takes place. This is an electrophilic aromatic substitution reaction, where the nitronium ion (NO_2^+) generated from the nitric acid acts as the electrophile. The nitration occurs predominantly at the positions that are ortho and para to the chlorine atom.

Chlorine, being an electron-donating group via resonance, activates the benzene ring towards electrophilic substitution. However, the electron-donating nature of chlorine causes the reaction to occur more readily at the ortho and para positions relative to the chlorine group.

Thus, the product of this reaction is a mixture of ortho and para nitro chloro benzene.

Step 1: Reaction mechanism - The nitronium ion (NO_2^+) attacks the benzene ring. - The chlorine group directs the attack to the ortho and para positions relative to itself due to its electron-donating resonance effect.

Step 2: Conclusion The reaction of chlorobenzene with concentrated nitric acid gives a mixture of ortho and para nitro chloro benzene.

Thus, the correct answer is $\boxed{\text{Mixture of ortho and para nitro benzene}}$.

Quick Tip

When working with aromatic substitution reactions, remember that the position of substitution is influenced by the nature of the substituent on the ring. Chlorine, being an electron-donating group, directs substitution to the ortho and para positions.

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5. Find the radius of a BCC molecule having an edge length of 2.0×10^{-11} m.

(A) 1.0×10^{-11} m

(B) 1.5×10^{-11} m

(C) 2.0×10^{-11} m

(D) 3.0×10^{-11} m

Correct Answer: (A) 1.0×10^{-11} m

Solution:

In a Body-Centered Cubic (BCC) unit cell, the atoms are arranged such that there is one atom at each corner of the cube and one atom at the center of the cube. The distance between the centers of two atoms along the body diagonal of the cube is equal to four times the radius of an atom.

Step 1: Relationship between edge length and radius Let the edge length of the BCC unit cell be a. In a BCC unit cell, the body diagonal is related to the edge length a by the Pythagorean theorem:

$$\text{Body diagonal} = \sqrt{3}\, a$$

Since the body diagonal of a BCC unit cell passes through two atoms (one at the center and one at the corner), the body diagonal is also equal to $4r$, where r is the radius of the atoms.

Thus, we have the equation:

$$\sqrt{3}\, a = 4r$$

Step 2: Solve for the radius Rearranging the equation to solve for r:

$$r = \frac{\sqrt{3}}{4}\, a$$

Step 3: Substitute the given edge length We are given that the edge length $a = 2.0 \times 10^{-11}$ m. Substituting this into the equation:

$$r = \frac{\sqrt{3}}{4} \times 2.0 \times 10^{-11} = 1.0 \times 10^{-11}\,\text{m}$$

Thus, the radius of the BCC molecule is $\boxed{1.0 \times 10^{-11}}$ m.

Quick Tip

In a BCC unit cell, the body diagonal connects two corner atoms and the center atom. The relationship between the edge length and the radius of the atoms is given by $r = \frac{\sqrt{3}}{4}\, a$.

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6. Which of the following elements shows a +4 oxidation state with the given configuration?

(A) Ce

(B) Tb

(C) Eu

(D) Lu

Correct Answer: (A) Ce

Solution:

We are tasked with identifying which of the given elements shows a +4 oxidation state with the corresponding electron configuration.

Step 1: Analyze the electron configurations Let's first look at the elements listed:

- Cerium (Ce): Ce has an atomic number of 58, with an electron configuration of $[Xe]4f^15d^16s^2$. In the +4 oxidation state, cerium loses all its 4f and 5d electrons, resulting in a configuration of $[Xe]$, which corresponds to a +4 oxidation state.

- Terbium (Tb): Tb has an atomic number of 65, and its electron configuration is $[Xe]4f^96s^2$. In the +4 oxidation state, it would lose electrons from the 4f and 6s orbitals, but Tb commonly exhibits a +3 oxidation state, not +4.

- Europium (Eu): Eu has an atomic number of 63, with the electron configuration $[Xe]4f^76s^2$. Europium commonly exhibits +2 and +3 oxidation states, but it does not typically form a +4 state.

- Lutetium (Lu): Lu has an atomic number of 71, with the electron configuration $[Xe]4f^{14}5d^16s^2$. In the +3 oxidation state, Lu typically loses its 5d and 6s electrons, and it does not form a +4 state.

Step 2: Conclusion From the analysis of the electron configurations, we see that Cerium (Ce) is the only element among the options that shows a +4 oxidation state, as it can lose all its 4f and 5d electrons.

Thus, the correct answer is $\boxed{\text{Ce}}$.

Quick Tip

To determine the oxidation state of an element, look at its electron configuration and consider how many electrons can be removed to achieve a stable configuration. Transition metals and lanthanides often show multiple oxidation states.

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7. Given the formula for depression of freezing point:

$$\Delta T_f = K_f \cdot m$$

where ΔT_f is the depression of freezing point, K_f is the freezing point depression constant, and m is the molality, calculate the value of m.

(A) $m = \frac{\Delta T_f}{K_f}$

(B) $m = \frac{K_f}{\Delta T_f}$

(C) $m = K_f \cdot \Delta T_f$

(D) $m = \frac{\Delta T_f}{K_f^2}$

Correct Answer: (A) $m = \frac{\Delta T_f}{K_f}$

Solution:

The depression of freezing point is given by the equation:

$$\Delta T_f = K_f \cdot m$$

Where: - ΔT_f is the depression in freezing point, - K_f is the freezing point depression constant, and - m is the molality of the solution.

Step 1: Solve for molality To find the molality m, we can rearrange the formula:

$$m = \frac{\Delta T_f}{K_f}$$

This equation shows that molality is directly proportional to the depression in freezing point and inversely proportional to the freezing point depression constant.

Thus, the correct answer is $\boxed{m = \frac{\Delta T_f}{K_f}}$.

Quick Tip

When using the depression of freezing point formula, rearrange the equation to solve for the desired variable. In this case, the molality m can be calculated by dividing the depression of freezing point ΔT_f by the freezing point depression constant K_f.

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8. What is the number of unpaired electrons in Lutetium (Lu) in the +3 oxidation state?

(A) 0

(B) 1

(C) 2

(D) 3

Correct Answer: (C) 2

Solution:

Lutetium (Lu) has an atomic number of 71, and its electron configuration in the ground state is:

$$\text{Lu} : [Xe]4f^{14}5d^{1}6s^{2}$$

Step 1: Electron Configuration in the +3 Oxidation State In the +3 oxidation state, Lutetium loses three electrons. The electrons are removed first from the 6s orbital, and then from the 5d orbital. Therefore, the electron configuration for Lu^{3+} is:

$$\text{Lu}^{3+} : [Xe]4f^{14}$$

Step 2: Determine the Number of Unpaired Electrons In the $4f^{14}$ configuration, all 14 electrons are paired in the f-orbital because the f-orbitals can hold up to 14 electrons in 7 orbitals (with 2 electrons per orbital).

Therefore, there are no unpaired electrons in the $4f^{14}$ configuration of Lu^{3+}.

Step 3: Conclusion The number of unpaired electrons in Lu^{3+} is $\boxed{0}$.

Quick Tip

The number of unpaired electrons can be determined by examining the electron configuration in the oxidation state of the element. If all electrons are paired, the element has no unpaired electrons.

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9. Total pressure of the solution is 500, the partial pressure of component A is 400, and the partial pressure of component B is 575. What is the mole fraction of component B?

(A) 0.5

(B) 0.6

(C) 0.8

(D) 0.9

Correct Answer: (B) 0.6

Solution:

The mole fraction of a component in a solution is given by the formula:

$$\chi_B = \frac{P_B}{P_{\text{total}}}$$

where: - χ_B is the mole fraction of component B, - P_B is the partial pressure of component B, and - P_{total} is the total pressure of the solution.

Step 1: Substitute the given values We are given: - Total pressure $P_{\text{total}} = 500$ units, - Pressure of component B $P_B = 575$ units.

Substituting into the formula:

$$\chi_B = \frac{575}{500 + 575} = \frac{575}{1075}$$

Step 2: Calculate the mole fraction Now, calculate the value:

$$\chi_B = \frac{575}{1075} \approx 0.6$$

Thus, the mole fraction of B is $\boxed{0.6}$.

Quick Tip

The mole fraction can be determined using the ratio of the partial pressure of the component to the total pressure in a mixture of gases, as per Dalton's Law of Partial Pressures.

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10. Which of the following elements has the most electronegativity: Li, Na, K, or Rb?

(A) Li

(B) Na

(C) K

(D) Rb

Correct Answer: (A) Li

Solution:

Electronegativity refers to the ability of an atom to attract electrons towards itself when forming a chemical bond. It generally decreases as you move down a group in the periodic table and increases as you move across a period from left to right.

Step 1: Electronegativity Trend in the Periodic Table - Lithium (Li) is in Group 1 of the periodic table, but it is in the second period. Elements in the second period have higher electronegativity compared to elements in the subsequent periods. - Sodium (Na) is in Group 1, but it is in the third period, so its electronegativity is lower than that of lithium. - Potassium (K) is in Group 1, in the fourth period, and has an even lower electronegativity than sodium. - Rubidium (Rb) is in Group 1 and is in the fifth period, so it has the lowest electronegativity of all the elements listed.

Step 2: Conclusion As we move down the alkali metal group, electronegativity decreases. Therefore, Li (Lithium) has the highest electronegativity among the given elements.

Thus, the correct answer is $\boxed{\text{Li}}$.

Quick Tip

Electronegativity decreases as you go down a group in the periodic table because the atomic radius increases, reducing the nucleus's ability to attract electrons.

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11. Which of the following has the lowest boiling point?

(A) Butanol

(B) Propanol

(C) Ethanol

(D) Methanol

Correct Answer: (D) Methanol

Solution:

The boiling point of a substance depends on its molecular structure and intermolecular forces. Alcohols, such as butanol, propanol, ethanol, and methanol, have hydrogen bonding, which tends to increase their boiling points. However, the strength of these intermolecular forces also depends on the size of the molecule.

Step 1: Molecular Structure and Boiling Points - Methanol (CH3OH): Methanol is the smallest molecule in the list, with the least number of carbon atoms. It has hydrogen bonding, but because of its small size, the forces are not as strong as in the larger alcohols, resulting in the lowest boiling point.

- Ethanol (C2H5OH): Ethanol is larger than methanol, so it has stronger intermolecular forces and a higher boiling point than methanol.

- Propanol (C3H7OH): Propanol is larger than ethanol and thus has an even higher boiling point due to stronger hydrogen bonding.

- Butanol (C4H9OH): Butanol is the largest molecule in this series and has the strongest intermolecular forces, leading to the highest boiling point.

Step 2: Conclusion Since methanol is the smallest molecule among the listed alcohols, it has the weakest intermolecular forces and the lowest boiling point.

Thus, the correct answer is $\boxed{\text{Methanol}}$.

Quick Tip

The boiling point of alcohols increases as the size of the molecule increases, due to stronger intermolecular hydrogen bonding. Methanol, being the smallest, has the lowest boiling point.
