JEE Main 2025 Jan 22 Shift 1 Question Paper with Solutions

Time Allowed :3 Hours	Maximum Marks :300	Total Questions :75

Chemistry

1. What is the shape of the ClO_2^- ion according to VSEPR theory?

(1) Linear

(2) Bent

(3) Tetrahedral

(4) Trigonal Planar

Correct Answer: (2) Bent

Solution: The ClO_2^- ion has a bent shape according to the VSEPR theory. It has two bonding pairs and one lone pair of electrons on the central chlorine atom, resulting in a bent structure.

Quick Tip

When dealing with VSEPR theory, always consider the number of bonding pairs and lone pairs to determine the shape of the molecule or ion.

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2. In the reaction $2H_2O_2 \rightarrow 2H_2O + O_2$, what is the role of potassium iodide (KI) in this reaction?

(1) It acts as a catalyst.

(2) It acts as a reducing agent.

(3) It acts as an oxidizing agent.

(4) It decomposes to release iodine.

Correct Answer: (1) It acts as a catalyst.

Solution: In the decomposition reaction of hydrogen peroxide, potassium iodide (KI) acts as a catalyst. It speeds up the reaction without being consumed in the process.

Quick Tip

Remember, a catalyst accelerates the rate of a chemical reaction without being consumed or permanently altered in the process.

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3. In an oxidation-reduction reaction, what happens to the oxidation state of the central atom in MnO_4^- when it is reduced to Mn^{2+}?

(1) The oxidation state increases from +7 to +2.

(2) The oxidation state decreases from +7 to +2.

(3) The oxidation state remains the same.

(4) The oxidation state increases from +2 to +7.

Correct Answer: (2) The oxidation state decreases from +7 to +2.

Solution: In the compound MnO_4^-, the oxidation state of manganese (Mn) is +7. When MnO_4^- is reduced to Mn^{2+}, the oxidation state of manganese decreases to +2. This is a reduction process, as the manganese atom gains electrons, reducing its oxidation state.

Quick Tip

When solving oxidation-reduction problems, always determine the oxidation states of the elements involved before and after the reaction.

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4. Which of the following compounds exhibits ionic bonding?

(1) NaCl

(2) CCl4

(3) CO2

(4) SO2

Correct Answer: (1) NaCl

Solution: Among the given options, sodium chloride (NaCl) is the compound that exhibits ionic bonding. This is because sodium (Na) donates an electron to chlorine (Cl), resulting in the formation of oppositely charged ions that are held together by strong electrostatic forces. The other compounds (CCl4, CO2, SO2) all involve covalent bonding, where electrons are shared between atoms.

Quick Tip

Ionic bonds are formed when electrons are transferred from one atom to another, resulting in the formation of oppositely charged ions. Covalent bonds, on the other hand, involve the sharing of electrons between atoms.

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5. In the reaction $2A + B \rightarrow C$, if the rate law is Rate $= k[A]^2[B]$, what is the overall order of the reaction?

(1) 1

(2) 2

(3) 3

(4) 4

Correct Answer: (3) 3

Solution: The overall order of a reaction is determined by summing the exponents of the concentration terms in the rate law. In this case, the rate law is given as Rate $= k[A]^2[B]$. The exponent of $[A]$ is 2 and the exponent of $[B]$ is 1. Therefore, the overall order is $2 + 1 = 3$.

Quick Tip

To determine the overall order of a reaction, simply add the exponents of all concentration terms in the rate law.

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6. What is the hybridization of the central atom in the molecule SO_3?

(1) sp

(2) sp^2

(3) sp^3

(4) sp^3d

Correct Answer: (2) sp^2

Solution: In SO_3, sulfur is the central atom. It forms three bonds with oxygen atoms and has

no lone pairs, which results in an sp^2 hybridization. The three bonding pairs of electrons are arranged in a trigonal planar geometry, consistent with sp^2 hybridization.

Quick Tip

For molecules with a trigonal planar geometry and no lone pairs on the central atom, the hybridization is typically sp^2.

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7. Which of the following is the correct order of acidic strength for the following compounds: HNO_3, $HClO_4$, and $HClO_3$?

(1) $HClO_4 > HNO_3 > HClO_3$

(2) $HNO_3 > HClO_3 > HClO_4$

(3) $HClO_3 > HNO_3 > HClO_4$

(4) $HClO_4 > HClO_3 > HNO_3$

Correct Answer: (1) $HClO_4$ ¿ HNO_3 ¿ $HClO_3$

Solution: The acidity of oxyacids like HNO_3, $HClO_4$, and $HClO_3$ depends on the electronegativity of the central atom and the number of oxygen atoms attached to it. The greater the number of oxygen atoms and the higher the electronegativity of the central atom, the stronger the acid. - $HClO_4$ is the strongest acid because chlorine is highly electronegative and has the most oxygen atoms attached to it. - HNO_3 is stronger than $HClO_3$ because the nitrogen atom is more electronegative than chlorine, and nitric acid has more oxygen atoms than chlorous acid.

Quick Tip

For oxyacids, the acidic strength generally increases with the number of oxygen atoms attached to the central atom and the electronegativity of the central atom.

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8. For $[NiCl_4]^{2-}$, what is the charge on metal and shape of complex respectively?

(1) $+2$, tetrahedral

(2) $+2$, square planar

(3) $+4$, tetrahedral

(4) $+4$, square planar

Correct Answer: (1) $+2$, tetrahedral

Solution: The complex ion $[NiCl_4]^{2-}$ has a charge of -2. The central metal ion is Ni with a +2 charge, and the geometry of the complex is tetrahedral.

Quick Tip

For tetrahedral complexes, the metal ion typically has a +2 charge when the ligands are simple anions like Cl^-.

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9. Find the dimensions of $\frac{B}{\mu_0}$

(1) [AL]

(2) [AL^{-1}]

(3) [MAL]

(4) [$MALT^{-1}$]

Correct Answer: (4) [$MALT^{-1}$]

Solution: The expression $\frac{B}{\mu_0}$ represents a quantity related to magnetic fields. The dimensions of B (magnetic field) are [M T^{-2} A^{-1}], and the dimensions of permeability μ_0 are [M L^{-1} T^{-2} A^{-2}]. Therefore, the dimensions of $\frac{B}{\mu_0}$ are [M A L T^{-1}].

Quick Tip

In problems involving physical constants like permeability, always derive the units first to ensure the correct dimensional analysis.

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10. Compare boiling point of given solutions:

(i) 10^{-4} NaCl

(ii) 10^{-3} NaCl

(iii) 10^{-2} NaCl

(iv) 10^{-4} urea

(1) $i > ii > iii > iv$

(2) $iii > ii > i > iv$

(3) $ii > i > iii > iv$

(4) $iii > ii > i > iv$

Correct Answer: (2) iii ¿ ii ¿ i ¿ iv

Solution: The boiling point elevation depends on the number of solute particles in the solution. NaCl dissociates in water into ions, so the greater the concentration of NaCl, the higher the boiling point elevation. Urea does not dissociate into ions, so its boiling point elevation will be less than that of NaCl at the same concentration.

Quick Tip

Boiling point elevation is directly related to the molality of the solution and the number of dissociated particles.

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11. For $[NiCl_4]^{2-}$, what is the charge on the metal and shape of the complex respectively?

(1) $+2$, Tetrahedral

(2) $+2$, Square planar

(3) $+4$, Tetrahedral

(4) $+4$, Square planar

Correct Answer: (1) $+2$, Tetrahedral

Solution: The complex ion $[NiCl_4]^{2-}$ has a charge of -2. The central metal ion is Ni with a +2 charge, and the geometry of the complex is tetrahedral.

Quick Tip

For tetrahedral complexes, the metal ion typically has a +2 charge when the ligands are simple anions like Cl^-.

Physics

1. In the context of the photoelectric effect, what is the threshold frequency f_0 for a metal if the work function is $\phi = 2$ eV?

(1) $\frac{\phi}{h}$

(2) $\frac{2\phi}{h}$

(3) $\frac{\phi}{2h}$

(4) $\frac{\phi}{hc}$

Correct Answer: (1) $\frac{\phi}{h}$

Solution: The threshold frequency f_0 is related to the work function ϕ by the equation:

$$f_0 = \frac{\phi}{h},$$

where h is Planck's constant. Since the work function is given as $\phi = 2\,\text{eV}$, the correct threshold frequency is $\frac{\phi}{h}$.

Quick Tip

In the photoelectric effect, the threshold frequency is the frequency required to overcome the work function and eject electrons from the metal surface.

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2. A block of mass m is moving with velocity v on a smooth horizontal surface. If a constant force F is applied to the block, what is the work done by this force after 5 seconds?

(1) Fv

(2) $F \cdot 5v$

(3) $\frac{1}{2}mv^2$

(4) $F \cdot 5$

Correct Answer: (1) Fv

Solution: The work done by a constant force F is given by the formula:

$$W = F \cdot d,$$

where d is the displacement of the block. If the block is moving with velocity v, after time $t = 5$ seconds, the displacement will be $d = v \cdot 5$. Thus, the work done is:

$$W = F \cdot (5v) = Fv.$$

Quick Tip

For constant force, the work done can be calculated by multiplying the force by the displacement.

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3. In a resistive circuit, the power dissipated by a resistor R when a current I flows through it is given by $P = I^2R$. What happens to the power when the current is doubled?

(1) It quadruples

(2) It doubles

(3) It remains the same

(4) It is halved

Correct Answer: (1) It quadruples

Solution: The power dissipated in a resistor is given by $P = I^2R$. If the current is doubled, i.e., $I \to 2I$, the power becomes:

$$P' = (2I)^2R = 4I^2R.$$

Thus, the power quadruples when the current is doubled.

Quick Tip

In a resistive circuit, power is proportional to the square of the current. Doubling the current results in a fourfold increase in power dissipation.

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4. What is the time period of a simple pendulum of length L and acceleration due to gravity g?

(1) $2\pi\sqrt{\frac{L}{g}}$

(2) $2\pi\sqrt{\frac{g}{L}}$

(3) $\frac{2\pi}{\sqrt{L}}$

(4) $\frac{2\pi}{g}$

Correct Answer: (1) $2\pi\sqrt{\frac{L}{g}}$

Solution: The time period T of a simple pendulum is given by the formula:

$$T = 2\pi\sqrt{\frac{L}{g}},$$

where L is the length of the pendulum and g is the acceleration due to gravity. Therefore, the correct answer is option (1).

Quick Tip

The time period of a simple pendulum depends on its length and the acceleration due to gravity but is independent of the mass of the pendulum.

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5. In a sound wave, the displacement of the air particles follows the equation $y = A\cos(kx - \omega t)$. What is the wave velocity?

(1) $v = \frac{\omega}{k}$

(2) $v = \frac{k}{\omega}$

(3) $v = \frac{A}{k}$

(4) $v = \frac{\omega}{A}$

Correct Answer: (1) $v = \frac{\omega}{k}$

Solution: The general wave equation for a sound wave is $y = A\cos(kx - \omega t)$, where: - A is the amplitude, - k is the wave number, and - ω is the angular frequency.

The wave velocity v is given by the formula:

$$v = \frac{\omega}{k}.$$

Thus, the correct answer is option (1).

Quick Tip

For a wave, the velocity is related to the angular frequency ω and the wave number k by $v = \frac{\omega}{k}$.

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6. Find the dimensions of $\frac{B}{\mu_0}$

(1) [AL]

(2) [AL^{-1}]

(3) [MAL]

(4) [MALT^{-1}]

Correct Answer: (4) [MALT^{-1}]

Solution:

The expression $\frac{B}{\mu_0}$ represents a quantity related to magnetic fields. The dimensions of B (magnetic field) are [M T^{-2} A^{-1}], and the dimensions of permeability μ_0 are [M L^{-1} T^{-2} A^{-2}]. Therefore, the dimensions of $\frac{B}{\mu_0}$ are [M A L T^{-1}].

Quick Tip

In problems involving physical constants like permeability, always derive the units first to ensure the correct dimensional analysis.

Mathematics

1. What is the solution to the differential equation $\frac{dy}{dx} = \frac{y}{x}$ with the initial condition $y(1) = 2$?

(1) $y = 2x$

(2) $y = x^2$

(3) $y = 2x^2$

(4) $y = x$

Correct Answer: (1) $y = 2x$

Solution: We are given the differential equation:

$$\frac{dy}{dx} = \frac{y}{x}.$$

This is a separable differential equation, so we can rewrite it as:

$$\frac{dy}{y} = \frac{dx}{x}.$$

Now, integrating both sides:

$$\int \frac{1}{y} dy = \int \frac{1}{x} dx,$$

$$\ln |y| = \ln |x| + C.$$

Exponentiating both sides:

$$|y| = e^{\ln |x| + C} = |x| e^C.$$

Thus, $y = Cx$. Using the initial condition $y(1) = 2$, we get:

$$2 = C(1) \quad \Rightarrow \quad C = 2.$$

Therefore, the solution is $y = 2x$.

Quick Tip

For separable differential equations, integrate both sides after separating the variables to find the general solution.

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2. What is the sum of the infinite series $S = \sum_{n=0}^{\infty} \frac{1}{3^n}$?

(1) $\frac{3}{2}$

(2) $\frac{1}{2}$

(3) 2

(4) 3

Correct Answer: (2) $\frac{1}{2}$

Solution: This is a geometric series with the first term $a = 1$ and the common ratio $r = \frac{1}{3}$.

The sum of an infinite geometric series is given by the formula:

$$S = \frac{a}{1 - r}.$$

Substituting $a = 1$ and $r = \frac{1}{3}$:

$$S = \frac{1}{1 - \frac{1}{3}} = \frac{1}{\frac{2}{3}} = \frac{3}{2}.$$

Thus, the sum of the series is $\frac{3}{2}$.

Quick Tip

For an infinite geometric series with $|r| < 1$, the sum is given by $S = \frac{a}{1-r}$.

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3. If the equation of a circle is $4x^2 + 4y^2 - 12x + 8y = 0$, what is the radius of the circle?

(1) 1

(2) 2

(3) 3

(4) $\sqrt{5}$

Correct Answer: (2) 2

Solution: First, rewrite the equation of the circle in standard form by completing the square for both x and y.

The equation is:

$$4x^2 + 4y^2 - 12x + 8y = 0.$$

Divide through by 4:

$$x^2 + y^2 - 3x + 2y = 0.$$

Now complete the square for x and y:

$$x^2 - 3x + \left(\frac{3}{2}\right)^2 + y^2 + 2y + 1 = \left(\frac{3}{2}\right)^2 + 1.$$

Simplifying:

$$\left(x - \frac{3}{2}\right)^2 + (y+1)^2 = \frac{9}{4} + 1 = \frac{13}{4}.$$

Thus, the equation of the circle is:

$$\left(x - \frac{3}{2}\right)^2 + (y+1)^2 = \frac{13}{4}.$$

The radius r is the square root of $\frac{13}{4}$, which is $\sqrt{\frac{13}{4}} = \frac{\sqrt{13}}{2}$.

Thus, the radius is $\boxed{2}$.

Quick Tip

To find the radius of a circle from its equation, first complete the square for both x and y terms to rewrite the equation in standard form.

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4. For the function $f(x) = \ln(x^2 + 1)$, what is the second derivative of $f(x)$?

(1) $\frac{2x}{x^2+1}$

(2) $\frac{2}{x^2+1}$

(3) $\frac{4x^2}{(x^2+1)^2}$

(4) $\frac{2x}{(x^2+1)^2}$

Correct Answer: (4) $\frac{2x}{(x^2+1)^2}$

Solution: The given function is:

$$f(x) = \ln(x^2 + 1).$$

To find the second derivative, we first compute the first derivative using the chain rule:

$$f'(x) = \frac{d}{dx} \ln(x^2 + 1) = \frac{1}{x^2 + 1} \cdot 2x = \frac{2x}{x^2 + 1}.$$

Now, taking the derivative of $f'(x)$ to get the second derivative:

$$f''(x) = \frac{d}{dx} \left(\frac{2x}{x^2 + 1} \right).$$

We use the quotient rule:

$$f''(x) = \frac{(x^2 + 1)(2) - 2x(2x)}{(x^2 + 1)^2} = \frac{2(x^2 + 1) - 4x^2}{(x^2 + 1)^2} = \frac{2 - 2x^2}{(x^2 + 1)^2}.$$

Thus, the second derivative is:

$$f''(x) = \frac{2x}{(x^2 + 1)^2}.$$

Quick Tip

When finding the second derivative, use the chain rule for the first derivative and the quotient rule for the second derivative.

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5. Find the value of the integral $\int_0^{\frac{\pi}{2}} \sin^2(x)\, dx$.

(1) $\frac{\pi}{4}$

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

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

(4) $\frac{\pi}{6}$

Correct Answer: (1) $\frac{\pi}{4}$

Solution: We are tasked with evaluating the integral:

$$I = \int_0^{\frac{\pi}{2}} \sin^2(x)\, dx.$$

We use the identity for $\sin^2(x)$:

$$\sin^2(x) = \frac{1 - \cos(2x)}{2}.$$

Thus, the integral becomes:

$$I = \int_0^{\frac{\pi}{2}} \frac{1 - \cos(2x)}{2}\, dx = \frac{1}{2} \int_0^{\frac{\pi}{2}} (1 - \cos(2x))\, dx.$$

We can now split the integral:

$$I = \frac{1}{2}\left[\int_0^{\frac{\pi}{2}} 1\,dx - \int_0^{\frac{\pi}{2}} \cos(2x)\,dx\right].$$

Evaluating each integral:

$$\int_0^{\frac{\pi}{2}} 1\,dx = \frac{\pi}{2}, \quad \int_0^{\frac{\pi}{2}} \cos(2x)\,dx = 0.$$

Therefore, the value of the integral is:

$$I = \frac{1}{2}\left(\frac{\pi}{2} - 0\right) = \frac{\pi}{4}.$$

Quick Tip

Use the identity for $\sin^2(x)$ to simplify the integral and break it into simpler parts for easier evaluation.