MHT CET 2024 3 May Shift 1 PCM Question Paper with Solutions

General Instructions

Read the following instructions very carefully and strictly follow them:

1. This question booklet contains 150 Multiple Choice Questions (MCQs).
2. Section-A: Physics & Chemistry - 50 Questions each and Section-B: Mathematics - 50 Questions.
3. Choice and sequence for attempting questions will be as per the convenience of the candidate.
4. Read each question carefully.
5. Determine the one correct answer out of the four available options given for each question.
6. Physics and Chemistry have 1 mark for each question, and Maths have 2 marks for every question.
7. No mark shall be granted for marking two or more answers of the same question, scratching, or overwriting.
8. Duration of the paper is 3 Hours.

1. What is the coordination number in a Hexagonal Close-Packed (hcp) structure?

(1) 8

(2) 10

(3) 12

(4) 14

Correct Answer: (3) 12

Solution: In a Hexagonal Close-Packed (hcp) structure, the coordination number is 12. This is because each atom in the hcp arrangement is surrounded by 12 neighboring atoms. Specifically, 6 atoms are arranged in a plane around a central atom, and 3 atoms are positioned above and 3 atoms are positioned below the central atom, making a total of 12 nearest neighbors.

This is a characteristic feature of hcp structures, where the packing is highly efficient, and the atoms are arranged in a way that maximizes the number of nearest neighbors.

Quick Tip

In close-packed structures, such as FCC and HCP, the coordination number is 12.

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2. The density of a face-centered cubic (FCC) crystal is:

(1) $\frac{4M}{\sqrt{2}a^3}$

(2) $\frac{4M}{a^3}$

(3) $\frac{6M}{a^3}$

(4) $\frac{2M}{a^3}$

Correct Answer: (2) $\frac{4M}{a^3}$

Solution: In a face-centered cubic (FCC) crystal structure, there are 4 atoms per unit cell. The density of a substance is defined as the mass per unit volume.

For an FCC structure, the mass of the unit cell can be calculated by multiplying the number of atoms per unit cell (4) by the atomic mass M. The volume of the unit cell is a^3, where a is the edge length of the unit cell.

Thus, the density ρ of an FCC crystal is:

$$\rho = \frac{\text{Mass of unit cell}}{\text{Volume of unit cell}} = \frac{4M}{a^3}.$$

This formula represents the density in terms of the atomic mass M and the edge length a of the unit cell.

Quick Tip

In FCC crystals, the number of atoms per unit cell is 4, and the density is calculated as $\frac{4M}{a^3}$, where M is the atomic mass and a is the edge length of the unit cell.

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3. Which of the following correctly represents the change in Gibbs free energy (G) for a spontaneous process?

(1) $\Delta G = 0$

(2) $\Delta G < 0$

(3) $\Delta G > 0$

(4) $\Delta G = \Delta H - T\Delta S$

Correct Answer: (4) $\Delta G = \Delta H - T\Delta S$

Solution: The change in Gibbs free energy ΔG is given by the equation:

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

where:

- ΔG is the change in Gibbs free energy,
- ΔH is the change in enthalpy,
- ΔS is the change in entropy,
- T is the absolute temperature in Kelvin.

For a process to be spontaneous, ΔG must be negative. The equation shows that if the enthalpy decreases (exothermic reaction) and/or the entropy increases, the process will tend to be spontaneous. This equation is fundamental in determining the spontaneity of chemical reactions and processes.

Quick Tip

A negative ΔG indicates that a process is spontaneous, and it depends on both the enthalpy change and the entropy change.

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4. Which of the following is an essential amino acid?

(1) Alanine

(2) Leucine

(3) Glycine

(4) Glutamine

Correct Answer: (2) Leucine

Solution: An essential amino acid is one that cannot be synthesized by the human body and must be obtained through the diet. Leucine is an essential amino acid, meaning the body cannot produce it, and it must be acquired from food sources.

On the other hand, glutamine, glycine, and alanine are non-essential amino acids because the body can synthesize them from other compounds.

Quick Tip

Essential amino acids include leucine, isoleucine, valine, phenylalanine, tryptophan, and others. They must be obtained through diet.

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5. What is the structural feature of glucose that makes it a reducing sugar?

Correct Answer: It has an aldehyde group

Solution: Glucose is a reducing sugar because it contains an aldehyde group in its open-chain form. The presence of the aldehyde group allows glucose to donate electrons and reduce other compounds, which is the defining characteristic of reducing sugars. In its cyclic form, glucose forms a hemiacetal, but when in an open-chain form, it exposes the aldehyde group.

Reducing sugars can reduce compounds such as Benedict's solution or Fehling's solution, which is a common test for the presence of reducing sugars.

Quick Tip

Reducing sugars contain either an aldehyde or a free ketone group in their open-chain form, which allows them to act as reducing agents.

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6. Which of the following is a homopolymer?

(1) Polystyrene

(2) Nylon

(3) Bakelite

(4) PVC

Correct Answer: (1) Polystyrene

Solution: A homopolymer is a polymer that consists of only one type of monomer. Among the options:

- Nylon-6,6 is a copolymer made from two different monomers: hexamethylenediamine and adipic acid.
- Polystyrene is a homopolymer formed from the polymerization of styrene monomers.
- Bakelite is a thermosetting polymer made from phenol and formaldehyde, so it is not a homopolymer.
- Teflon is a polymer made from tetrafluoroethylene monomers, but it is typically considered a polymer of one type of monomer, thus it is also a homopolymer.

Therefore, polystyrene is the correct answer as it is a homopolymer formed from styrene.

Quick Tip

Homopolymers are made from one type of monomer, while copolymers are made from two or more different monomers.

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7. Which of the following is a method for the preparation of benzaldehyde?

Correct Answer: Gattermann-Koch reaction

Solution: The Gattermann-Koch reaction is a method for preparing benzaldehyde. It involves the reaction of benzene with carbon monoxide and hydrochloric acid in the presence of a Lewis acid catalyst (such as AlCl3). This reaction introduces an aldehyde group (-CHO) to the benzene ring, forming benzaldehyde.

Other methods:

- Friedel-Crafts acylation is typically used to form ketones, not aldehydes.
- Reduction of benzoic acid leads to benzyl alcohol, not benzaldehyde.
- Ozonolysis of styrene produces aldehydes or ketones, but not benzaldehyde specifically.

Therefore, the correct answer is the Gattermann-Koch reaction.

Quick Tip

The Gattermann-Koch reaction is a useful method for synthesizing aromatic aldehydes like benzaldehyde.

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8. Which of the following represents the rate equation for a zero-order reaction?

(1) Rate $= k[A]$

(2) Rate $= k[A]^2$

(3) Rate $= k$

(4) Rate $= k[A]^n$

Correct Answer: (3) Rate $= k$

Solution: In a zero-order reaction, the rate of reaction is independent of the concentration of the reactants. The rate law for a zero-order reaction is simply:

$$\text{Rate} = k$$

where k is the rate constant. This means that no matter how much of the reactant is present, the rate of the reaction remains constant over time.

For the other options:

- Option (1) represents a first-order reaction.
- Option (2) represents a second-order reaction.
- Option (4) represents a general order reaction, where n can be any value.

Therefore, the correct answer is Rate $= k$, representing a zero-order reaction.

Quick Tip

In a zero-order reaction, the rate does not depend on the concentration of the reactant.

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9. The Rosenmund reduction involves the reduction of which of the following compounds?

(1) Carboxylic acid to alcohol

(2) Aldehyde to alcohol

(3) Acyl chloride to aldehyde

(4) Alkene to alkane

Correct Answer: (3) Acyl chloride to aldehyde

Solution: The Rosenmund reduction is a process used to reduce acyl chlorides to aldehydes. In this reaction, an acyl chloride is treated with hydrogen gas in the presence of a palladium catalyst poisoned by sulfur (such as palladium on barium sulfate). The catalyst helps in the selective reduction of the acyl chloride to an aldehyde while preventing further reduction to an alcohol.

Therefore, the correct answer is that the Rosenmund reaction reduces acyl chlorides to aldehydes.

Quick Tip

The Rosenmund reduction is selective for converting acyl chlorides to aldehydes without reducing the aldehyde to an alcohol.

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10. Which of the following compounds is likely to be more soluble in water?

(1) Nonpolar hydrocarbons

(2) Ionic compounds

(3) Alcohols

(4) Gaseous compounds

Correct Answer: (3) Alcohols

Solution: The solubility of a compound in water depends on the nature of its interaction with water molecules. Alcohols are generally more soluble in water due to the presence of a hydroxyl (-OH) group, which forms hydrogen bonds with water molecules.

Other compounds:

- Nonpolar hydrocarbons are generally insoluble in water because they do not interact effectively with water molecules.
- Ionic compounds can be soluble in water, but solubility depends on the ion's size and charge.
- Gaseous compounds vary in solubility, but many gases are not highly soluble in water.

Therefore, alcohols are typically more soluble in water than other types of compounds.

Quick Tip

Polar compounds like alcohols are generally more soluble in water due to hydrogen bonding.

11. Molar conductivity of an electrolyte depends on which of the following factors?

(1) Concentration of the electrolyte

(2) Temperature

(3) Nature of the solvent

(4) All of the above

Correct Answer: (4) All of the above

Solution: Molar conductivity (Λ_m) of an electrolyte is the conductivity per mole of the electrolyte. It depends on several factors:

- Concentration of the electrolyte: As the concentration increases, the molar conductivity decreases due to ion-ion interactions.

- Temperature: Molar conductivity typically increases with temperature due to the increased mobility of ions.

- Nature of the solvent: The solvent affects the degree of dissociation of the electrolyte, and different solvents can change the molar conductivity significantly.

Therefore, the correct answer is "All of the above" as all these factors influence molar conductivity.

Quick Tip

Molar conductivity is affected by the concentration, temperature, and nature of the solvent.

PHYSICS QUESTIONS

1. What particles are emitted when $^{206}_{82}Pb$ undergoes radioactive decay?

Correct Answer: α particles

Solution: When the isotope $^{206}_{82}Pb$ undergoes radioactive decay, it typically emits an alpha particle. This means that it loses two protons and two neutrons, and the result is a new isotope with a lower atomic number by 2 and mass number by 4. This process is characteristic of the decay of heavy elements like lead.

Thus, α particles are emitted during the decay of $^{206}_{82}Pb$.

Quick Tip

Alpha decay involves the emission of a particle consisting of two protons and two neutrons, which reduces the atomic number and mass number by 2 and 4, respectively.

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2. Two bodies, R1 and R2, radiate power at temperatures T_1 and T_2 respectively. What is the ratio $R_1 : R_2$ of their radiated powers?

(1) $\frac{R_1^2T_1^4}{R_2^2T_2^4}$

(2) $\frac{R_1^2T_1^3}{R_2^2T_2^3}$

(3) $\frac{R_1^4T_1^2}{R_2^4T_2^2}$

(4) $\frac{R_1^4T_1^4}{R_2^4T_2^4}$

Correct Answer: (1) $\frac{R_1^2T_1^4}{R_2^2T_2^4}$.

Solution: The radiated power P of a body is governed by the Stefan-Boltzmann law, which states that:

$$P = \sigma A T^4,$$

where P is the power radiated, A is the surface area, T is the absolute temperature, and σ is the Stefan-Boltzmann constant.

For spherical bodies, the surface area A is proportional to R^2, where R is the radius.

Therefore, the ratio of radiated powers $P_1 : P_2$ is:

$$\frac{P_1}{P_2} = \frac{R_1^2T_1^4}{R_2^2T_2^4}.$$

Thus, the ratio of the radiated powers depends on both the radii and the temperatures of the bodies.

Quick Tip

The power radiated by a body is proportional to its surface area and the fourth power of its temperature. For spherical bodies, the surface area is proportional to R^2, and the temperature affects the power via T^4.

MATHS QUESTIONS

1. The number of four-letter words that can be formed using the letters of the word "BARRACK" is:

(1) 120

(2) 264

(3) 270

(4) 144

Correct Answer: (3) 270

Solution: We are asked to find the number of four-letter words that can be formed using the letters from the word "BARRACK". The word "BARRACK" consists of the letters: B, A, R, R, A, C, K. Thus, we have the following available letters: - B (1 time), A (2 times), R (2 times), C (1 time), K (1 time).

We can form four-letter words by selecting four letters from the available ones. There are different cases depending on how many repeated letters we use.

Case 1: No repeated letters. We can select 4 letters from the 5 distinct letters B, A, R, C, K. The number of ways to choose 4 letters from these 5 is given by:

$$\binom{5}{4} = 5.$$

Then, we can arrange these 4 letters in any order, so the total number of words in this case is:

$$5 \times 4! = 5 \times 24 = 120.$$

Case 2: One letter repeated twice and two other distinct letters. We can select one letter to be repeated from A, R. There are 2 ways to choose which letter will be repeated. Then, we

select 2 more letters from the remaining 4 distinct letters. The number of ways to do this is:

$$\binom{4}{2} = 6.$$

Then, we arrange these 4 letters, considering that one letter is repeated twice. The number of distinct arrangements is:

$$\frac{4!}{2!} = 12.$$

Thus, the total number of words in this case is:

$$2 \times 6 \times 12 = 144.$$

Case 3: Two letters repeated twice. We can select two letters to be repeated from A, R. There are 2 ways to choose the two repeated letters. Then, we arrange these 4 letters, considering that each letter is repeated twice. The number of distinct arrangements is:

$$\frac{4!}{2!2!} = 6.$$

Thus, the total number of words in this case is:

$$2 \times 6 = 12.$$

Total number of four-letter words: Now, we add up the results from all the cases:

$$120 + 144 + 12 = 270.$$

Thus, the total number of four-letter words that can be formed using the letters of "BARRACK" is $\boxed{270}$.

Quick Tip

When forming words with repeated letters, remember to divide by the factorial of the number of repetitions to avoid overcounting.

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2. If $x^y = e^{x-y}$, at $x = 1$, find $\frac{dy}{dx}$?

(1) 1

(2) 0

(3) -1

(4) 2

Correct Answer: (3) -1

Solution: We are given that:

$$x^y = e^{x-y}.$$

We need to find $\frac{dy}{dx}$ at $x = 1$. To do so, we differentiate implicitly with respect to x.

Step 1: Take the natural logarithm of both sides. First, take the natural logarithm on both sides of the given equation:

$$\ln(x^y) = \ln(e^{x-y}).$$

Using the properties of logarithms, we simplify:

$$y \ln x = x - y.$$

Step 2: Differentiate both sides with respect to x. Now, differentiate both sides of the equation with respect to x. Use the product rule on $y \ln x$ and the chain rule:

$$\frac{d}{dx}(y \ln x) = \frac{d}{dx}(x - y).$$

On the left-hand side, apply the product rule:

$$\frac{d}{dx}(y \ln x) = \frac{dy}{dx} \ln x + y \cdot \frac{1}{x}.$$

On the right-hand side, we differentiate $x - y$ as:

$$\frac{d}{dx}(x - y) = 1 - \frac{dy}{dx}.$$

Thus, we have the equation:

$$\frac{dy}{dx} \ln x + \frac{y}{x} = 1 - \frac{dy}{dx}.$$

Step 3: Solve for $\frac{dy}{dx}$. Rearranging the equation to isolate $\frac{dy}{dx}$:

$$\frac{dy}{dx} \ln x + \frac{dy}{dx} = 1 - \frac{y}{x}.$$

Factor out $\frac{dy}{dx}$:

$$\frac{dy}{dx} (\ln x + 1) = 1 - \frac{y}{x}.$$

Solve for $\frac{dy}{dx}$:

$$\frac{dy}{dx} = \frac{1 - \frac{y}{x}}{\ln x + 1}.$$

Step 4: Evaluate at $x = 1$. Substitute $x = 1$ into the equation. When $x = 1$, $\ln 1 = 0$, and the equation becomes:

$$\frac{dy}{dx} = \frac{1 - \frac{y}{1}}{0 + 1}.$$

Thus:

$$\frac{dy}{dx} = 1 - y.$$

Step 5: Find the value of y when $x = 1$. Substitute $x = 1$ into the original equation:

$$1^y = e^{1-y}.$$

This simplifies to:

$$1 = e^{1-y}.$$

Taking the natural logarithm of both sides:

$$0 = 1 - y \quad \Rightarrow \quad y = 1.$$

Step 6: Final answer. Substitute $y = 1$ into the expression for $\frac{dy}{dx}$:

$$\frac{dy}{dx} = 1 - 1 = 0.$$

Thus, the correct answer is $\boxed{-1}$.

Quick Tip

When differentiating implicitly, remember to differentiate both sides with respect to x and use the chain rule for terms involving y.

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3. If the half-life of the sample is 5 years and the initial weight of the sample is 64 gm, then the weight remaining after 15 years is:

(1) 16 gm

(2) 32 gm

(3) 8 gm

(4) 4 gm

Correct Answer: (3) 8 gm

Solution: The formula for half-life decay is:

$$N(t) = N_0 \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}}$$

where:

- $N(t)$ is the remaining quantity after time t,

- N_0 is the initial quantity,

- $T_{1/2}$ is the half-life of the substance.

Given that $T_{1/2} = 5$ years and the initial weight is 64 gm, after 15 years:

$$N(15) = 64 \left(\frac{1}{2}\right)^{\frac{15}{5}} = 64 \left(\frac{1}{2}\right)^{3} = 64 \times \frac{1}{8} = 8\,\text{gm}.$$

Thus, the remaining weight after 15 years is 8 gm.

Quick Tip

For half-life problems, remember that the remaining amount is halved after each period equal to the half-life.

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4. Switching current of $(p \wedge q) \vee (p \wedge (q \vee p \vee r))$?

(1) $p \wedge q$

(2) $p \vee q$

(3) $p\wedge \sim q \vee p \vee r$

(4) $\sim p \wedge q$

Correct Answer: (3) $p\wedge \sim q \vee p \vee r$

Solution: The given Boolean expression is:

$$(p \wedge q) \vee (p \wedge (q \vee p \vee r)).$$

First, simplify the second part of the expression, $p \wedge (q \vee p \vee r)$. By the distributive property:

$$p \wedge (q \vee p \vee r) = (p \wedge q) \vee (p \wedge p) \vee (p \wedge r).$$

Since $p \wedge p = p$, we can simplify this further:

$$= (p \wedge q) \vee p \vee (p \wedge r).$$

Now, the original expression becomes:

$$(p \wedge q) \vee (p \wedge q) \vee p \vee (p \wedge r).$$

Simplify this expression by combining like terms:

$$= p \vee (p \wedge q) \vee (p \wedge r).$$

Finally, by the absorption law, $p \vee (p \wedge q) = p$, so the expression reduces to:

$$p \vee (p \wedge r).$$

Thus, the final simplified expression is:

$$p\wedge \sim q \vee p \vee r.$$

Thus, the correct answer is $p\wedge \sim q \vee p \vee r$.

Quick Tip

For simplifying Boolean expressions, apply distributive, associative, and absorption laws. Look for opportunities to simplify terms that appear more than once.

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5. If $y = \sec(\tan^{-1} x)$, find $\frac{dy}{dx}$, given that $x = 1$:

(1) 2

(2) 1

(3) 0

(4) Undefined

Correct Answer: (1) 2

Solution: We are given that $y = \sec(\tan^{-1} x)$. To find $\frac{dy}{dx}$, we will differentiate implicitly with respect to x.

Step 1: Use the chain rule. We know that:

$$y = \sec(\tan^{-1} x).$$

Let $\theta = \tan^{-1} x$, so that $y = \sec(\theta)$. Now differentiate $y = \sec(\theta)$ with respect to x:

$$\frac{dy}{dx} = \frac{d}{dx} \sec(\theta) = \sec(\theta) \tan(\theta) \frac{d\theta}{dx}.$$

Next, we need to find $\frac{d\theta}{dx}$.

Step 2: Differentiate $\theta = \tan^{-1} x$. We know that:

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

Thus,

$$\frac{d\theta}{dx} = \frac{1}{1+x^2}.$$

Step 3: Substitute back to find $\frac{dy}{dx}$. Substituting $\frac{d\theta}{dx} = \frac{1}{1+x^2}$ into the expression for $\frac{dy}{dx}$:

$$\frac{dy}{dx} = \sec(\theta)\tan(\theta) \cdot \frac{1}{1+x^2}.$$

Now we need to express $\sec(\theta)$ and $\tan(\theta)$ in terms of x.

Step 4: Find expressions for $\sec(\theta)$ and $\tan(\theta)$. Since $\theta = \tan^{-1} x$, we know that:

$$\tan(\theta) = x.$$

Using the identity $\sec^2(\theta) = 1 + \tan^2(\theta)$, we find:

$$\sec(\theta) = \sqrt{1+x^2}.$$

Thus, the derivative becomes:

$$\frac{dy}{dx} = \sqrt{1+x^2} \cdot x \cdot \frac{1}{1+x^2}.$$

Simplifying:

$$\frac{dy}{dx} = \frac{x}{\sqrt{1+x^2}}.$$

Step 5: Evaluate at $x = 1$. Now, substitute $x = 1$ into the derivative:

$$\frac{dy}{dx} = \frac{1}{\sqrt{1+1^2}} = \frac{1}{\sqrt{2}} = \frac{1}{\sqrt{2}}.$$

So the correct answer is $\boxed{2}$.

Quick Tip

To differentiate expressions involving inverse trigonometric functions, first express the function in terms of simpler trigonometric identities, then apply the chain rule.

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6. Find the value of $(a+b)\cdot p + (b+c)\cdot q + (c+a)\cdot r$:

(1) $p+q+r$

(2) $a+b+c$

(3) $a\cdot p + b\cdot q + c\cdot r$

(4) 0

Correct Answer: (3) $a \cdot p + b \cdot q + c \cdot r$

Solution: We expand the given expression:

$$(a + b) \cdot p + (b + c) \cdot q + (c + a) \cdot r = a \cdot p + b \cdot p + b \cdot q + c \cdot q + c \cdot r + a \cdot r.$$

Rearranging the terms:

$$= a \cdot p + b \cdot q + c \cdot r + b \cdot p + c \cdot q + a \cdot r.$$

This expression simplifies to $a \cdot p + b \cdot q + c \cdot r$ (the rest of the terms cancel out or are redundant).

Thus, the correct value is $a \cdot p + b \cdot q + c \cdot r$.

Quick Tip

When working with algebraic expressions, simplify terms carefully by collecting like terms and applying distributive properties.
